

TRANSPORTATION PLANNING GUIDELINES



NEW YORK CITY TRANSIT AUTHORITY DESIGN GUIDELINES

DIRECTORY

VOLUME I

1. TRANSPORTATION PLANNING AND ENVIRONMENTAL
2. STATION PLANNING
3. STRUCTURAL DESIGN

VOLUME II

1. CONSTRUCTION
2. SIGNALS AND COMMUNICATIONS

VOLUME III

1. HYDRAULICS, ELECTRIC DUCTS AND PLUMBING
2. TRACK AND CONTACT RAIL
3. EQUIPMENT

✓ VOLUME IV

1. POWER
2. NEW CAR ENGINEERING

VOLUME V

1. MATERIALS INSPECTION - 1

VOLUME VI

1. MATERIALS INSPECTION - 2

05164

TF
200
.N48
v.1-3

NEW YORK CITY TRANSIT AUTHORITY

David L. Yunich, Chairman and Chief Executive
Officer

MEMBERS OF THE BOARD

Lawrence R. Bailey

Leonard Braun

William L. Butcher

Donald H. Elliott

Justin N. Feldman

Harold L. Fisher

Mortimer J. Gleeson

Edwin G. Michaelian

Eben W. Pyne

Constantine Sidamon-Eristoff

NEW YORK CITY TRANSIT AUTHORITY

Daniel T. Scannell, Senior Executive Officer,
Operations Management

John T. O'Neill, Executive Officer, Construction
Administrative and Chief Engineer

Andrew T. O'Rourke, Executive Officer, Comptroller

Wilbur B. McLaren, Executive Officer, Labor Relations
and Personnel

Frederick D. Wilkinson, Jr., Executive Officer,
Passenger Services and
Public Information

Steven K. Kauffman, General Superintendent

John G. deRoos, General Counsel

Edward J. Babb, Secretary

ACKNOWLEDGEMENTS

We wish to acknowledge the following people for their contributions to the project, especially the working committee whose individual efforts enabled this project to be brought to a successful conclusion.

NYCTA Engineering Department

John T. O'Neill, Executive Officer, Construction
Administration and Chief Engineer
George Ziegler, Executive Deputy Chief Engineer
Bernard Adler, Deputy Chief Engineer
Salvatore Valenza, Deputy Chief Engineer
John Culhane, Deputy Chief Engineer

Division Engineers

Seymour Dornfeld, Signals and Communications
Leon Rossum, Civil Engineering and Architectural
Sol Rolnick, Equipment
Morris Loshinsky, Construction
Bertram Lane, Materials Inspection
Calvin Turin, Planning

Staff Division Engineers

Sverre A. Meberg, Contracts and Specifications
Frank T. Palotta, Program Management
Anthony Paolillo, Environmental
Richard J. Genova, Contract Management

NYCTA Power Department

John Mombach, Assistant General Superintendent, Power
John M. Hayes, Superintendent
Albert Somersille, Superintendent

NYCTA New Car Engineering Department

Hyman Feldman, Director
Lowell Tellerman, Division Engineer

COMMITTEE FOR THE ESTABLISHMENT OF

DESIGN STANDARDS

Director

Bernard Adler, Deputy Chief Engineer

Manager

Theodore Kaminski, Administrative Engineer

Coordination

Robert Cohen, Project Coordinator, Contract Management

Members of Committee

Noel Marks, Administrative Engineer, Civil Engineering
and Architectural

Jan Polivka, Administrative Engineer, Construction

Daniel Todes, Senior Mechanical Engineer, Equipment

Samuel Sturm, Senior Chemist, Material Inspection

Azmy Rafail, Electrical Engineer, Environmental

Muhammad Yusuff, Civil Engineer, Planning

Erwin Friedman, Assistant Electrical Engineer, Signals
and Communications

George Havriliak, Assistant Mechanical Engineer, New
Car Engineering

Vito Rabito, Administrative Engineer, Power

TRANSPORTATION PLANNING GUIDELINES



INTRODUCTION

INTRODUCTION

TRANSPORTATION PLANNING GUIDELINES

INTRODUCTION

The objectives of these guidelines is to provide insight into one of the complex, multi-disciplinary aspects of Urban Mass Transportation planning processes. The manual provides a great latitude to the planner to utilize his expertise judiciously and in a manner most beneficial to the community. It is neither a manual of rigid standards, nor does it provide easy solutions to the very complex challenging problems of our modern society.

DIVISION ENGINEER

CALVIN TURIN

AUTHORS

MOHAMED YUSUFF

JOHN T. DELANEY

MARTIN J. FRADUA

INDEX

INDEX

TRANSPORTATION PLANNING

INDEX

CHAPTER	PAGE
1. THE PLANNING PROCESS.	TP-1-1
2. TRANSPORTATION PLANNING TECHNIQUES.	TP-2-1
3. PLAN IMPLEMENTATION	TP-3-1
4. CONGESTION AND IT'S MITIGATION.	TP-4-1
5. OPERATIONAL CRITERIA.	TP-5-1
6. PRELIMINARY ENGINEERING	TP-5-1

Chapter 1

Page 1

Chapter 1

THE PLANNING PROCESS

TABLE OF CONTENTS

I	PLANNING PROCESS	TP-1-1
II	GOAL FORMULATION	TP-1-1
III	DECISIONS	TP-1-3
IV	SOCIAL VALUES	TP-1-4
V	PUBLIC OPINION	TP-1-4
VI	ACCESSIBILITY TO OPPORTUNITIES	TP-1-5
VII	LEVEL OF SERVICE	TP-1-5
VIII	INNOVATION	TP-1-7
IX	ALTERNATIVES	TP-1-8
X	ANALYSIS	TP-1-10
XI	EVALUATION OF ALTERNATIVES	TP-1-11
XII	BIBLIOGRAPHY	TP-1-13

Chapter 1

THE PLANNING PROCESS

I - PLANNING PROCESS

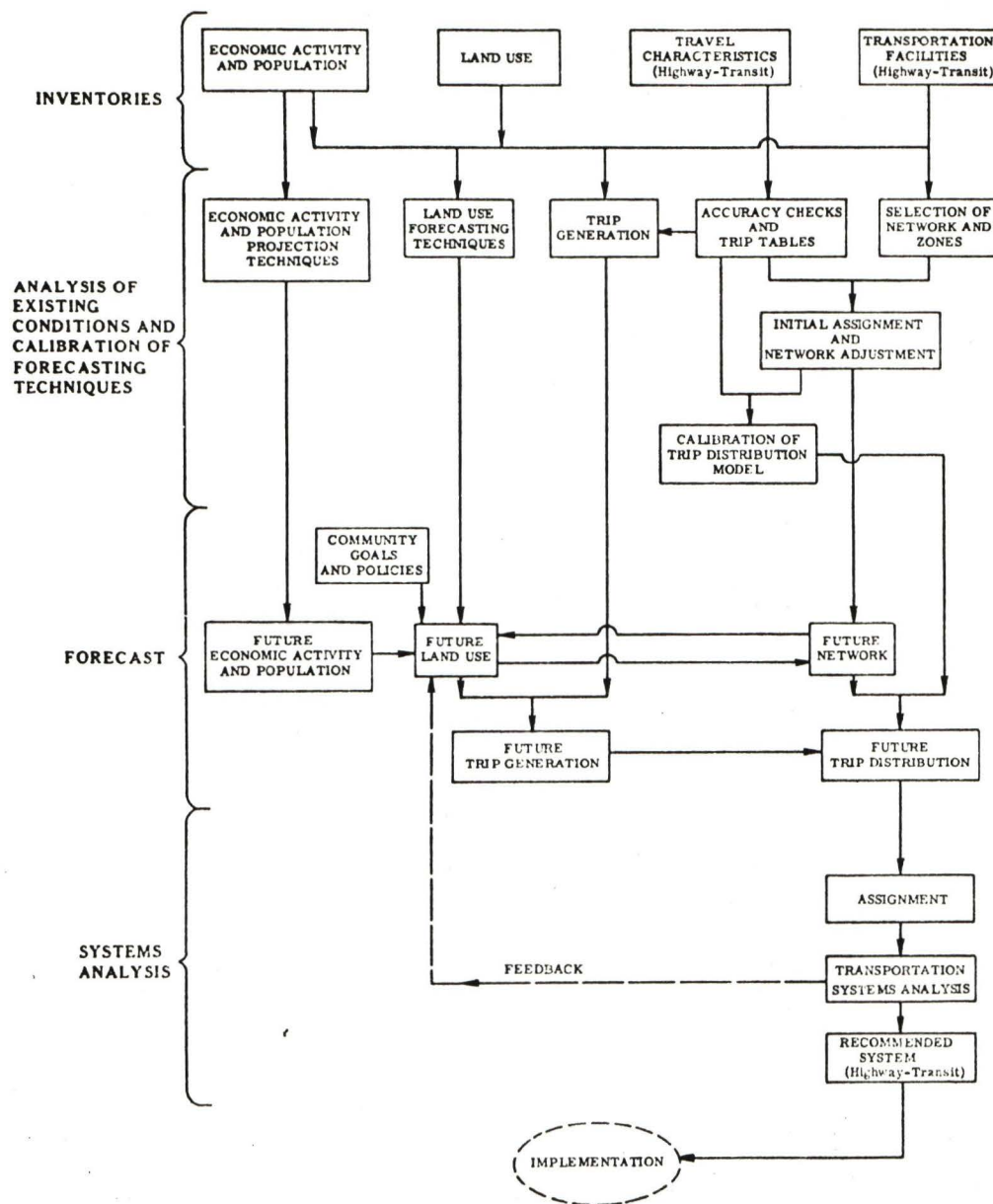
The planning process shown in Figure 1.01 is based on an iterative approach consisting of a series of steps. At the end of each step, the process is reviewed and modified, if necessary, based on new data and information.

The major steps of the planning process are:

1. to identify the objectives and requirements of the system.
2. to select criteria on which the objectives will be judged.
3. to forecast future land use, population, and requirements that will be placed on the system.
4. to develop models to characterize the functioning of the system and its interaction with its environment.
5. to devise alternative systems which have the potential of fulfilling the objectives and satisfying the requirements.
6. to analyze the performance of alternative systems and evaluate the potential consequences of each one.
7. to select the optimal system.
8. to develop complete design and specifications of the chosen system.¹

II - GOAL FORMULATION

The future goal of a transportation system is furthering the growth of social development and making available the resources and opportunities of the city to all its citizens.



Activity Relationships, Urban Transportation Planning Process

Figure 1.01

(Source: Defining Transportation Requirements)

The formulation of goals requires the choice between similar and conflicting interests and levels of values. All considerations (social, legal, aesthetic, political, economic, technical, and environmental) are weighed, evaluated and reconciled with respect to society's needs.²

The planner bases the goals of a transportation system on the opinions and attitudes of the community and the dictates of the politicians. These goals are usually generalizations which must be converted into specific objectives if the planning process is to function effectively.

The goals also serve as a measure of the effectiveness of the planning process.

III - DECISIONS

The criteria for formulating decisions is based on economic return and the responsiveness of the solution to social values. The first decision is: Should funds be spent on a transportation system or should they be spent elsewhere? After reaching the initial decision, then it must be decided by how much, in what way, and when. To answer "how much" requires an understanding of the nature of community gain. Therefore, the decision problem in mass transit cannot be separated from the other problems of the community.

The decision-maker should attempt to determine and evaluate the range of the benefits and drawbacks of alternative decisions on each of the affected communities, rather than engage in a social accounting for some generalized community.

The best design for a transportation system is one that yields the highest social return on the investment, and that reconciles most effectively the conflicting interests of the individuals and various groups in the community affected by the project.

In addition to the more conventional criteria (comfort, convenience, frequency of service, etc.) in the evaluation of a transportation system, the following factors will influence decisions concerning urban transportation: accessibility to opportunities, environmental effects, long-term impact on land use and level of service.

IV - SOCIAL VALUES

The description of the significant aspects of society's condition, progress or retrogression, is known as "social accounting." Social accounting identifies the social problems and furnishes effective solutions designed to resolve them, the ultimate purpose of which is the satisfaction of society's goals through the direction of public policies.

To function effectively, social accounting must use scientific method, follow the rules of logic and employ the appropriate scale of measurement. Its objectives are changes in social indicators which are classified as either benefits or costs.

The following procedures should be used to identify the improvements that have a high priority in a social accounting system:

1. "Analyze the need for major social programs (health, education, law enforcement, welfare, etc.) for improved transportation systems."³
2. Analyze urgent concerns (poverty, racism, law enforcement, education, etc.) of urban areas to determine what contribution various types of transportation systems would contribute to the solution.³
3. Analyze and identify specific social functions (mass transit for low-income groups, better transportation to jobs, etc.) that could be improved by better mass transportation systems.³

V - PUBLIC OPINION

Public opinion provides guidelines for the planning of the transportation system by relating the needs of the citizens and the goals of the system.

Planners are interested in the relationships between the facilities and the people who use them. The individual's perceptions and attitudes make an important

contribution to the evaluation and design of the system.

The process by which individuals evaluate transportation facilities, form opinions about them, and make decisions about where, when and how to travel and where to work and live is given in Figure 1.02. It is apparent from the Figure that both opinions and travel behavior are the results of the processing of information by the individual. Since behavior is constrained by the nature of the system, opinions provide an alternate source of information of value to the planner, but one that is rarely used to its full potential.

Planning decisions could probably be made more effective by greater inclusion of the opinions of citizens, as well as their behavior, as informational inputs to the transportation planning process. However, it is difficult to involve all segments of the population in the decision-making process because of the lack of established channels for these people to make a meaningful input to this process.

VI - ACCESSIBILITY TO OPPORTUNITIES

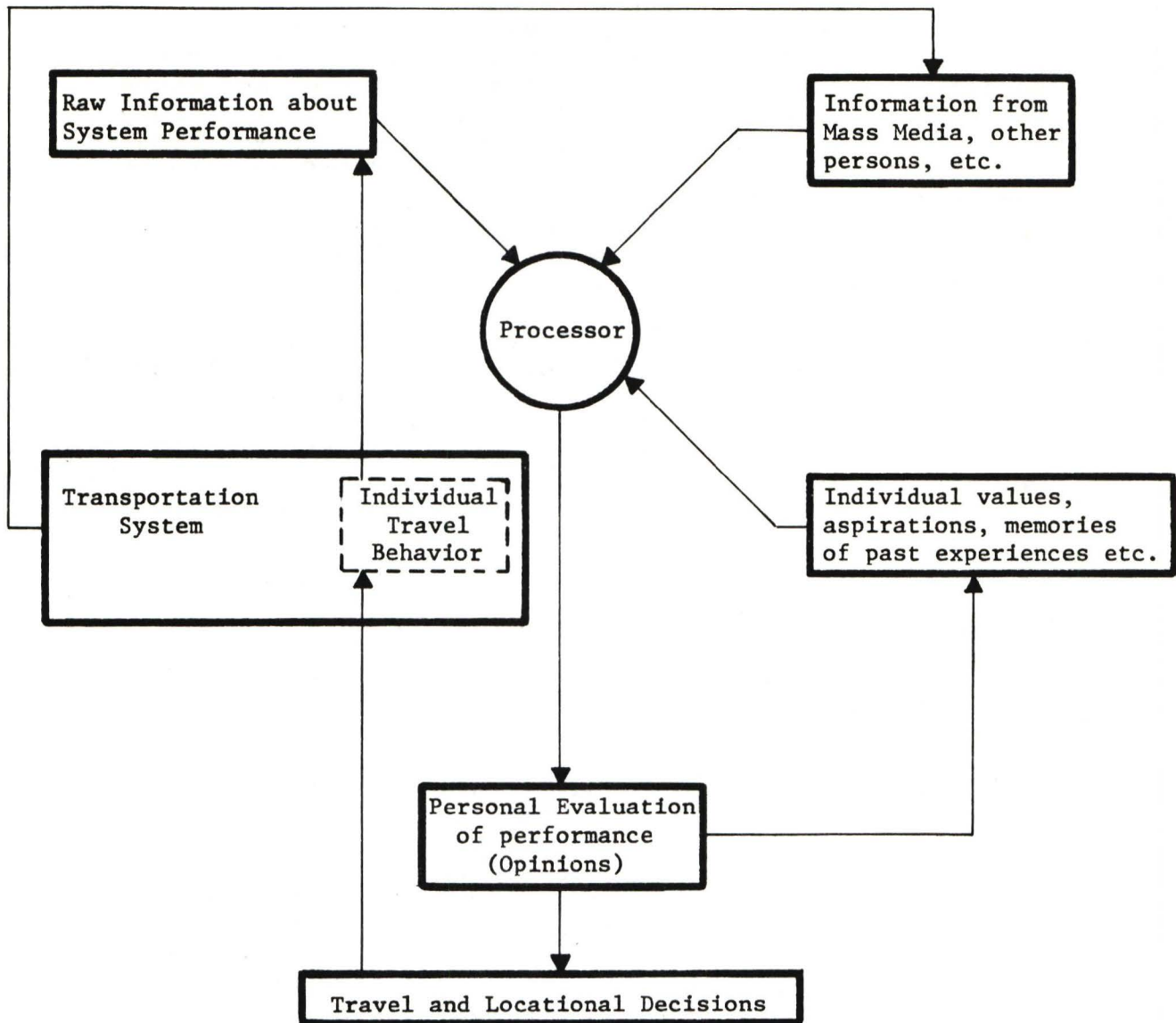
Transportation improves economic development of a region by making the region geographically accessible. Economic development is the primary objective for large-scale investment in transportation except in urban areas where the objective is to make available the assets and opportunities of the city to all its citizens.

In urban areas, many people are denied access to the services and facilities (employment, education, housing, medical care, recreation, etc.) of the city because of poor public transportation or lack of an automobile. Therefore, accessibility to opportunities should play a major role in the evaluation of a transportation system's performance.

VII - LEVEL OF SERVICE

The level of service should define:

1. the efficiency of the transportation system.



Personal Evaluation Process for Transportation System Performance

Figure 1.02

(Source: Defining Transportation Requirement)

2. the influence of the system on the community; favorable or unfavorable.
3. the support of the programs of society by the system.

The level of service consists of two main categories that describe the quality of service; direct and indirect. The direct category describes system capability (cost, time, safety, comfort) with its principal impact on the surrounding environment. The indirect category is composed of physical and psychological effects.

The level of service is composed of several elements such as purpose, quantity, direct and indirect effects, and resources consumed. The relative importance of each element, which is a measurable quantity relative to an established standard, will vary with the user and circumstances.

The decision-maker should use the relationship between level of service and performance of the transportation system in allocating funds and in compromising constraints and requirements.

Comparison of alternative systems should be made on the basis of impact on demand, the environment, and the activities which require the services.

"The level of service measurement must provide an accurate, usable representation of the performance of the system so that the decision-maker, the activity-user, and the system-designer have the same view of the required performance."³

VIII - INNOVATION

The transportation system must be aware of changing conditions and react quickly to them, if the system is to continue to serve adequately the community's requirements. To react to these changes may require innovative ideas involving uncertainties arising from construction, performance, compatibility with existing transportation systems, and public opinion.

Due to the financial and political risks involved, the level of innovation in urban mass transportation systems has been relatively low.

To increase the level of innovation, it will be necessary to test the innovation under actual conditions on a small-scale before incorporating it into the transportation system.

IX - ALTERNATIVES

The planner must make the decision-makers aware of the alternatives and their effects on the community.

Many of the alternatives are severely limited due to the planning methodology and institutional setting in which they are conducted. The institutional setting usually stresses a single method and precludes innovation.

"To broaden the spectrum of transportation alternatives that can be analyzed and evaluated for potential implementation in urban communities, the following principles should be observed:

1. Transportation planning and investment studies should not be tied to any single mode but should be conducted within an institutional setting that encourages the comprehensive analysis of several modes.
2. The potential of various forms of transportation - pedestrian, automobile, transit, and multimodal systems - to provide a broader range of integrated services, should be more systematically analyzed. Particular attention should be given to the interface among the several components of urban transportation systems and between urban and inter-city systems.
3. A mixed strategy should be employed in which short-run improvements, based on available technology and practices, are instituted within a framework of more comprehensive and longer run programs that might include unconventional technology.
4. In view of the very rapid rate of technological and social change,

preference should be given to improvements that can be introduced incrementally so as to avoid "locking in" the future with massive fixed investments.

5. Systems engineering studies that explore the potentials of new technologies should be made an integral part of the urban transportation planning process so as not to base transportation plans on, or continue to encourage the adoption of, outdated or obsolete technologies.
6. Transportation systems analysis techniques should be developed and adopted that allow for a rapid screening of a wide range of candidate systems in terms of both level of service and community impact. These overview techniques should not rely on massive accumulations of data but should serve to suggest the most effective directions for subsequent, more intensive data collection and analyses.
7. Research should be encouraged in formal design and search techniques, including systems optimization and mathematical programming models. Both community impact criteria and transportation service objectives should be made an explicit part of the model system.
8. Because land use is part of the system, any selection of alternatives should include those that vary land use arrangements, as well as transportation facilities."²

X - ANALYSIS

The following guidelines, based upon social goals rather than economic return, should be established for analysis of transportation requirements.

1. "Transportation is not an end in itself.
2. Transportation is a part (subsystem) of society's activities.
3. Transportation developments should be derived from the requirements of society's social and economic activities rather than from its potential for growth.
4. Whether the investment of public funds will produce a net increase or decrease in the community's economic resources must be established.
5. Transportation analysis should permit an evaluation by decision-makers, whose priorities for solving social problems will vary with time in accordance with the public interest.
6. Performance requirements and a practical strategy for their achievement must be established before transportation system design and long range planning is undertaken."³

The following set of guidelines for the analysis of a mass transportation system are based upon the preceding section:

1. Mass transportation studies should be directed towards transportation needs, instead of some other objective to fulfill the economic goals.
2. The desired level of service, the quantity, and, or time usage, and the social and economic livelihoods must be determined.

3. The requirements of a mass transportation system must be determined through the analysis of mass transportation goals before the most effective solution to the system can be designed.
4. The results of investing public or private funds in mass transportation should be determined.
5. Identify and evaluate alternative systems that fulfill the requisites:
 - a) with the resources allocated
 - b) within the constraints imposed
 - c) within the desired timetable
6. The decision-maker should review the alternative solutions and their consequences before making the final decision.

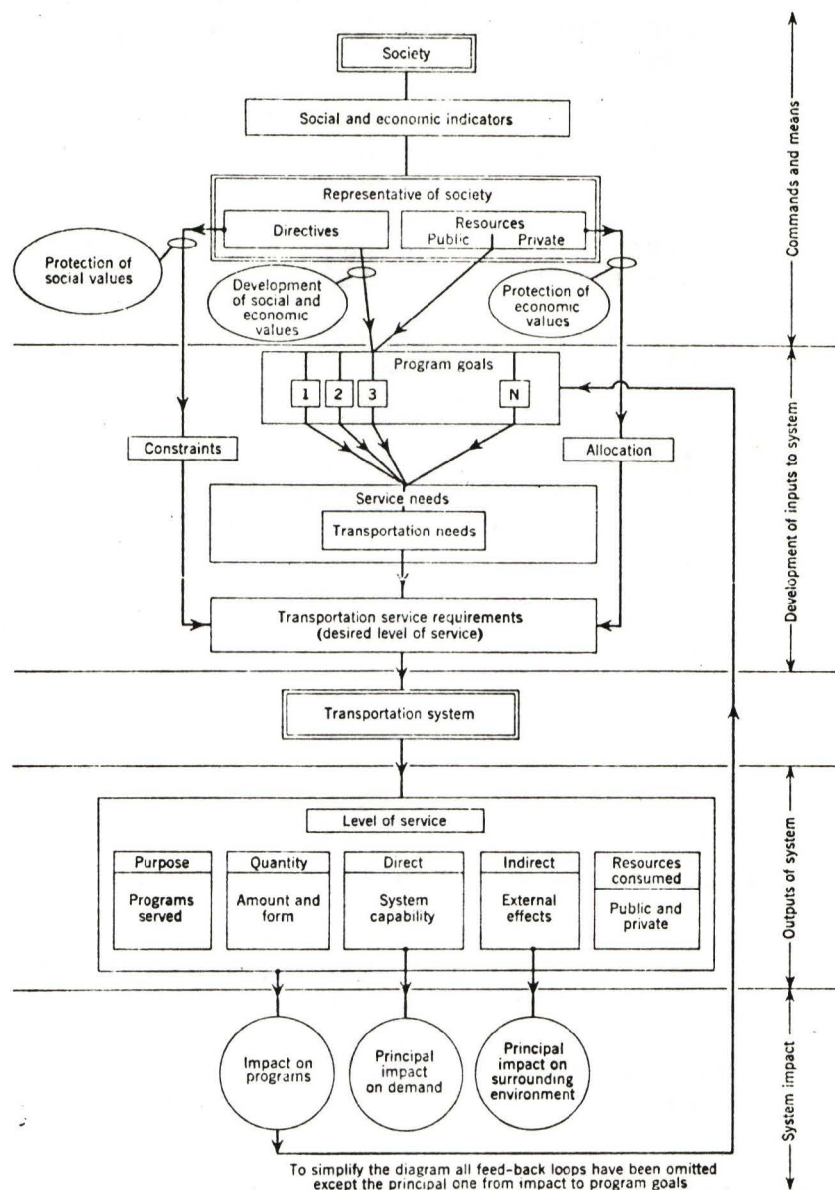
The flow diagram in Figure 1.03 depicts how the desires and values of society lead to the construction and operation of transportation systems.³

XI - EVALUATION OF ALTERNATIVES

A method must be established to inform the decision-maker of the benefits of each alternative in relation to the goals of the program. Existing methodology is suitable when similar low cost proposals are considered, but cannot be used for high investment multimodal proposals.

The decision-maker must realize that certain assumptions were made and considerations ignored in the analysis of the alternatives.

The following factors should be employed in the evaluation of each proposal: benefit cost ratio, land use, environmental, political, social, and economic impact.



Basic Flow Diagram

Figure 1.03

Source: Access to Airports

XII -BIBLIOGRAPHY

1. Transportation Engineering Conference. "Defining Transportation Requirements", New York, American Society of Mechanical Engineers, 1968.
2. Organization for Economic Co-operation and Development, "The Urban Transportation Planning Process", Paris, 1971.
3. Baker, F. Robert, and Raymond M. Wilmotte, "Technology and Decisions in Airport Access", New York, American Society of Civil Engineers, 1970.
4. Institute for Training in Municipal Administration, "Local Planning Administration", International City Manager's Association, Chicago, 1959.

Chapter 2

Chapter 2

Chapter 2

TRANSPORTATION PLANNING TECHNIQUES

TABLE OF CONTENTS

I	PLANNING PROCESS	TP-2-1
II	DATA COLLECTION	TP-2-1
III	ORIGIN AND DESTINATION STUDIES	TP-2-4
	Methods of Obtaining O & D Data	TP-2-4
IV	TRIP GENERATION	TP-2-7
V	PARAMETERS	TP-2-8
	Land Use Parameters	TP-2-8
	Population Parameters.	TP-2-9
	Economic Parameters.	TP-2-10
VI	TRIP DISTRIBUTION	TP-2-10
	Trip Distribution Models	TP-2-10
	Fratar Model	TP-2-10
	Gravity Model.	TP-2-11
	Intervening Opportunity Model.	TP-2-12
	Competing Opportunity Models	TP-2-13
	Comparison of Models	TP-2-14
	Modal Split.	TP-2-16
	General Rules for Establishing Zone Boundaries.	TP-2-19
VII	TRIP ASSIGNMENT.	TP-2-19
	Assignment Process	TP-2-19
	Computer-Oriented Analysis Techniques	TP-2-21
VIII	SOCIAL IMPACT OF URBAN MASS TRANSIT.	TP-2-26
IX	CONCLUSION	TP-2-28
	Evaluation of Models and Procedures	TP-2-28
X	BIBLIOGRAPHY	TP-2-31

2000

1000

500

250

125

62.5

31.25

15.625

7.8125

3.90625

1.953125

0.9765625

0.48828125

0.244140625

0.1220703125

0.06103515625

0.030517578125

0.0152587890625

0.00762939453125

0.003814697265625

0.0019073486328125

Chapter 2

TRANSPORTATION PLANNING TECHNIQUES

I - PLANNING PROCESS

The process of planning is to take many random observations, interpret them by consistent logical methods, foresee the needs and desires of a particular population and implement them into a feasible scheme.

These are the basic four steps to complete a system. The planner is to decide which observations are recordable and also indicative. Methods of analysis must be proposed. The assumptions in these methods must be weighed in order to obtain the best and most reasonably correct answer from the accumulated data. He must project these usable data to determine the best of the proposed alternatives.

II - DATA COLLECTION

Data collection is a vital phase of planning. It gives the planner facts to:

1. know what exists
2. project future needs
3. establish public relations values that indicate a careful job and can become public record.

Data files describe the city. In general, the data files should consist of:

1. land use
2. population by residence
3. employment by locations

Existing data once obtained must project future trends of population and of land use. In forecasting land use, the planner may encounter a region or metropolitan area and decide where people should live, where factories and shipping areas are to be built and

where to locate parks, cemeteries, etc. This could be an undeveloped area or even one that has been established for some time and now is zoned. The planner may also run into an area unzoned and must forecast growth not only in amount but also in location.

In general, "transportation plans are prepared for a single expanded city; whether the city reaches that size, two or three years sooner or later, is unimportant, since administrators can accelerate the pace of transportation construction to suit actual growth rates."¹¹

The planner provides two stages to the development of data. Stage one is an office planning scheme. The planner accumulates:

1. maps
2. aerial photographs
3. census data
4. previous studies made of the area.⁷

This information is checked for validity, completeness, currentness and usefulness.

The planner proceeds to stage two by checking the data and adding new data that may have been omitted. This stage is primarily field work and includes:

1. obtaining support of local government officials.
2. proposed urban renewal projects.
3. suburban development.
4. private housing starts.
5. industrial and commercial development.⁷

Any impending project can have critical effects on proposed transit developments and should be analyzed for its effects.

Published sources of data include:

A. Census Data:

1. head count - population forecasting
2. size of family - growth pattern, children - school trips
3. family income levels - number of cars
4. older citizens - mass transit requirements
5. level of education - work characteristics
6. housing facilities - renters/owners, density
7. density patterns of a city - route location
8. fiscal data - employment projection
9. journey to work statistics

B. Economic Data Sources:

1. Statistical Services of the United States Government Executive Office of President, Bureau of Budget.
2. Directory of Federal Statistics of Metropolitan Areas, Advisory Commission on Intergovernmental Relations. Oct. 1962.

Both documents provide the methods of Federal data collection processing and presentation and describe in topical form principal social and economic statistical programs of various Federal agencies.

3. Bureau of Labor Statistics - indicates national and state trends in employment estimates.

4. State Employment Agencies - employers must report quarterly, number of employees, their total taxable wages; gives a good employment count.

New methods of obtaining data including customary means should be developed. In one study the use of aerial photography was such a source. The aerial photograph provided a dwelling unit count and floor area ratio count. These are excellent indicators of trip generation and density. A check of non-residential floor area from fire insurance atlas, census figures and field counts of mail-boxes and utility meters showed a close correlation of data collected by these check methods and the inexpensive, quick aerial photography method. Twelve (12%) per cent errors were indicated for low density areas.¹⁰ The limitations of methods too, should be developed. This aerial method yields high errors for higher density zones giving poorer results.

III - ORIGIN AND DESTINATION STUDIES

To determine hourly, daily and seasonal trends of traffic flows, a sampling procedure using traffic counts is required. These counts establish flow maps which can determine route and station locations.

"Land use is the most important single factor in establishing zones for origin and destination studies."⁷ Separate O & D zones should account for one land use or a combination of land uses with the same traffic generating capacity. The surveys can determine social-economic causes, trip frequency, route and purpose of the trip-maker.

Origin and destination returns for large samples can only be coded for tabulation by the computer into a limited number of columns and group classifications. Therefore, limit the size of the questionnaire.

Methods of Obtaining O & D Data

1. Home interview - techniques in which sampling is drawn from the complete urban universe of dwelling units. Current lists should be drawn up from city directories, utility company records, city assessor's tax records, and a field listing of dwelling units.

A rule of thumb, indicating required degree of sampling per population of area is as follows:¹²

Size of Sample of Dwelling Unit	(D.U.)	:	Population of Area
1 in 5	D.U. or (20%)	:	less than 50,000
1 in 8	" (12.5%)	:	50,000 to 150,000
1 in 10	" (10%)	:	150,000 to 300,000
1 in 15	" (6.67%)	:	300,000 to 500,000
1 in 20	" (5%)	:	500,000 to 1,000,000
1 in 25	" (4%)	:	More than 1,000,000

Selective interviews of groups of employees at specific buildings are good techniques.

The home interview provides the most comprehensive method of obtaining travel characteristics within a study area. Personal interviews, from random sampling, obtain travel characteristics for all members of the household by all modes of transportation. This direct information requires a large task force and, in general, is costly and time consuming, although it provides superior information when correctly executed.

2. Postcard-questionnaires field distributed to ridership. 20% return required for usable data. Questions should be kept to a minimum and be simple and direct. Well publicized advertisements aid proper distribution and completeness of this survey.

The disadvantages of post-card survey are:

- (a) the required brevity of the questionnaire may not meet objectives
- (b) answers difficult to verify
- (c) it is impossible to ensure random distribution of the answers
- (d) biased sample since the majority of those answering are regular transit users
- (e) the absence of contact limits the motivation to reply.

3. Telephone pre-survey information required. Call in evening - weekdays, after most home trips have been completed. In order to assure the validity of the sample and the representativity of the information, it is essential that possession of a telephone in the home be a common characteristic of all the social levels being surveyed.

The advantages of Telephone interview are:

- (a) a more elaborate questionnaire that would cover all transit modes
- (b) the interviewer, when required, could clarify the questions
- (c) it is economical. Interviewer can contact more people in a shorter period of time and since no travel by personnel is required, a smaller staff could be employed
- (d) it is efficient. Quality control easier and better coordination possible because the interviewers could be grouped in a central location
- (e) random distribution of sample possible

Requirements for a valid telephone survey:

- (a) random distribution of sample in time and space
- (b) compatibility of sample size with the objectives of the survey
- (c) proper choice of period
- (d) abundant publicity
- (e) capable personnel
- (f) verification of record

4. On-Street Interview - people may be willing enough to be questioned but may not give the interviewer enough time to complete the questionnaire.

Refer "Urban Mass Transportation Travel Surveys" by U. S. Department of Transportation for survey design, techniques, and survey details.

IV - TRIP GENERATION

The transit planner is faced with two problems in the realization of a new system or the extension of the existing one.

1. What number of people would use the system now?
2. What number of people would use the system in the future?

Determination of who are the users of the system is of prime importance. Without a sufficient number of people a particular service can become under utilized due to either poor location (accessibility), excessive fares or change in makeup of the ridership. A process of trip generations must be established based upon present travel patterns and a determination of future demand based upon:

1. population characteristics
2. economic characteristics
3. land use characteristics

The purpose of Trip Generation is to describe trips starting or ending in a particular zone in an area in relation to the characteristics of land use, social and economic characteristics to estimate the demand in trips per day. Some common methods employed are:

1. Trip ends to land use and economic characteristics (Regression Analysis)
2. Trip ends to land area (Land Area Trip Rate Analysis)

3. Trip ends to social and economic characteristics (Cross-Classification Analysis)¹

To relate the characteristics of population, economics and land use, first develop parameters that can be recorded and analyzed into useful information. General parameters relate population, economy and land use to trip production.

V- PARAMETERS

1. LAND USE PARAMETERS:

Land Use relationship with trip generation is based upon measurable quantities of an activity in areal zones of residential, commercial or industrial sites. Each activity requires transportation to and from sites. Intensity of use can be determined from floor area ratio of buildings, be it a commercial zone or floor area per unit land area for the residential zone. Location of each site with accessibility to other sites is time and distance dependent in their relationship with each other and affects the desirability or attractive force of the site to generate trips. Land use patterns determine the activity, intensity and location of sites. Commercial uses are located in the CBD with high activity and high intensity. Industrial uses are located near major arterial and rail routes while residential uses outlying the CBD have low intensity.

A field theory of movement, relating land use and work trips can be mathematically set.

$$V_{P_i Q_j} = \frac{\frac{Q_j}{R_{ij}} P_i}{\sum_{j=1}^m \left(\frac{Q_j}{R_{ij}} \right)} \quad (i=1, 2, \dots, n)$$

$V_{P_i Q_j}$ = number of one-way trips from zone i to j.

P_i = number of workers living in zone i.

Q_j = number of jobs available in zone j.

R_{ij} = straight line distance between centers i and j assuming no physical barriers.¹⁰

Similarly, shopping trip field theory can be set up with the following assumptions:

1. Every household makes a certain number of shopping trips per day.
2. The number of retail employees at each shopping center provides a measure of relative attractiveness of each center.
3. Straight line distance between center of residence and a shopping center is proper measure of separation.

$$M_{H_i S_j} = \frac{(E_j / R_{ij}) H_i}{\sum_{j=1}^m \left(\frac{E_j}{R_{ij}} \right)}$$

$M_{H_i S_j}$ = number of one-way shopping trips from i to j .

H_i = number of households in zone i .

E_j = number of retail employees in zone j .

R_{ij} = straight line distance from i to j .¹⁰

2. POPULATION PARAMETERS:

- (a) Population patterns usually show high concentrations near CBD with decreasing density with distance from the CBD.²
- (b) Relative importance of seven household factors ranked in order of importance are:
 1. family size
 2. car ownership
 3. income
 4. stage in family life cycle
 5. occupation of head of household
 6. density of neighborhood

7. distance from CBD.¹

3. ECONOMIC PARAMETERS:

- (a) vehicle ownership
- (b) family income
- (c) employment

"In general, families in the higher income range are often multi-car families which result in increased mobility. Low-income families, on the other hand, often own no cars and must rely on public transportation."¹

As residential density increases, fewer trips per family are generated. High-rise apartments have shops, grocery and drug stores within the building or nearby in walking distance. Thus, this higher density will generate fewer trips than the spaced suburban areas which require additional trips to get required services and goods. The greatest percentage of travel is from or to home in the urban area. Therefore, total travel can be estimated using household characteristics which provide an accurate control check for estimates of trips by purpose. In addition, these trips can be used as control checks of trips estimated to non-residential land.¹

VI - TRIP DISTRIBUTION

Trip Distribution Models

Once the number of trips generated from an area are established, procedures for trip distribution of these numbers to other areas or zones must be used. Four useful distribution procedures have been set down. These are models that reflect the trips that can occur from one zone to another zone.

A. FRATAR MODEL

The procedure where, " ... the distribution of trips from one zone is in proportion to the present movements out of the zone modified by the growth factor of the zone to which trips are attracted."⁴

$$T_{ij}^{(p,q)} = t_{ij}^{(p,q)} \cdot G_i^{(p)} \cdot G_j^{(q)} \cdot \frac{L_i^{(p)} + L_j^{(q)}}{2}$$

where:

$L_i^{(p)}$ = Location factor

$$L_i^{(p)} = \frac{t_i^{(p)}}{\sum_{j=1}^n t_{ij}^{(p,q)} \cdot G_j^{(p)}}$$

$T_{ij}^{(p,q)}$ = future year trips from zone i to zone j with a purpose p at zone i and a purpose q at zone j.

$t_i^{(p)}$ = base year trip ends at zone i for purpose p.

$t_{ij}^{(p,q)}$ = base year trips between zone i and zone j with a purpose p at zone i and a purpose q at zone j.

$G_i^{(p)}$ = growth factor for zone i, purpose p.

B. GRAVITY MODEL

Gravity Model parallels Newton's gravitational law and "..... is based on the assumption that all trips starting from a given zone are attracted by the various traffic generators and that this attraction is in direct proportion to the size of the generator and in inverse proportion to the spatial separation between the areas."⁴

$$T_{ij} = \frac{P_i A_j F_{ij} K_{ij}}{\sum_{j=1}^n A_j F_{ij} K_{ij}}$$

where

T_{ij} = trips produced in zone i and attracted to zone j.

P_i = trips produced in zone i.

A_j = trips attracted to zone j.

F_{ij} = empirically derived travel time factors (one factor for each 1-minute increment of travel time) that are a function of the spatial separation between the zones and express the average areawide effect of spatial separation on trip interchange.

K_{ij} = specific zone-to-zone adjustment factor to allow for the incorporation of the effect on travel patterns of defined social or economic linkages not otherwise accounted for in the gravity model formulation.

C. INTERVENING OPPORTUNITY MODEL

"... utilizes a probability concept which in essence requires that a trip remain as short as possible, lengthening only as it fails to find an acceptable destination at a lesser distance. An equal areawide probability of acceptance for any origin is defined for all destinations in a given category. In operation, the first opportunity considered is the one closest to the origin and has the stated areawide probability of acceptance; however, the actual probability is decreased by the fact that the trip being distributed has a chance of already being accepted the first opportunity."⁴

$$T_{ij} = O_i (e^{-LD} - e^{-L(D+D_j)})$$

where

T_{ij} = trips originating in zone i with destination in zone j.

O_i = trip origins in zone i.

D = trip destination considered before zone j.

D_j = trip destinations in zone j.

L = measure of probability that a random destination will satisfy the needs of a particular trip; it is an empirically derived function describing the rate of trip decay with increasing trip destinations and increasing length of trip.

e = base of natural logarithms (2.71828)

D. COMPETING OPPORTUNITY MODELS

"...opportunities or destinations compete for trips within equal travel time, travel distance, or travel cost bands as measured from zone or origin. Within a given band, every opportunity has an equal probability of acceptance. The probability that trips will distribute to a certain zone is the product of two independent probabilities. The first, called the "probability of satisfaction," reflects the chances that a trip will be of a particular length and is a function of the opportunities at a greater distance than the time band under consideration. The determination of the specific destination within this trip length is quantified by a "probability of attraction" related to the available opportunities which fall within the area up to and including the time band considered."⁴

$$T_{ij} = O_i P_{aj} P_{sj}$$

where

T_{ij} = trips produced in zone i and attracted to zone j

O_i = trip origins in zone i

P_{aj} = probability of attraction

P_{aj} = destination available in zone j divided by the sum of destinations available in the time bands up to and including band m

$$= \frac{D_d}{\sum_{k=0}^m D_k}$$

P_{sj} = probability of satisfaction

P_{sj} = $1 - (\text{Sum of destination available in time bands up to and including band m divided by the sum of total destination in study area})$

$$P_{sj} = 1 - \frac{\sum_{K=0}^m D_K}{\sum_{K=0}^n D_K}$$

where

K = any time band

m = time band into which zone j falls

D_K = destination available in time band k

n = last time band as measured from origin
zone i

D_j = destination available in zone j

Comparison of Models

Comparison of Gravity Model and Intervening Opportunity Model

Studies of the gravity model have proved to be slightly more accurate in base year simulation and forecasting. "Considering all factors, the gravity and the intervening opportunity models proved of about equal reliability and utility."⁴

Gravity Model Advantages and Disadvantages

Advantages:

1. accounts for competition of trips between different land uses.
2. sensitive to changes in travel time between zones.
3. easy to operate in any urban area.
4. relatively inexpensive, requiring little travel inventory information.
5. recognizes trip purpose as affecting zonal interchange.

Disadvantages:

1. attempts to apply simple physical law of Newton's

gravitational equation to relate to social behavior.

2. average travel pattern cannot be applied to all zones within the urban area since there is considerable variation in social and economic characteristics of zonal populations.
3. trip lengths do not remain constant; therefore, exponent of distance is not constant from place to place, or time to time.
4. the changing nature of distance between zones with time of day makes questionable the use of a single value of travel time, regardless of the transportation facilities available.
5. as the distance between zonal centroids decreases to zero, the number of trips predicted between two zones becomes infinitely large.
6. the model tends to show only approximate agreement with field data when the zones and cumulative traffic volumes are small.
7. the gravity model requires a considerable manipulation of proportionality factors in order to produce results comparable to observed traffic patterns.²

Opportunity Model

Advantages:

1. basic assumption that a trip prefers to be as short as possible is closer to basic reasons for internal travel than the assumptions underlying the gravity model.
2. is computationally convenient.
3. is independent of zonal or regional boundaries.
4. requires no special adjustment to fit models to observed data.
5. has increased accuracy and reliability of predicted interzonal volumes over similar gravity model results.

Disadvantages:

1. loss of simplicity, and ease of application by inexperienced personnel.

2. cost inherent with obtaining necessary input data.
3. does not explicitly recognize trip purpose.
4. difficulty in determining "L" factor.²

Modal Split

Establishing the distribution of trips from generating areas leads to the following question. How do people travel from these points to other points? It is of great importance to the planner to know if transit or automobile usage is the prime mode of travel, or even some combination of both. "Thus far, it has been shown that transit usage varies with and is dependent upon the characteristics of the trip, the tripmaker, and the transportation system. A model to estimate transit usage should, therefore, contain measures of each characteristic mentioned."⁵ Future travel demand determinations should indicate the demand for public transportation and the demand for private transportation.

The Modal Split Model can estimate the proportion of future intercity travel demand for both public and private travel.⁶

The variables of the general models include:

1. characteristics of the trip maker; it can depend on auto ownership, residential density, income, workers per household, distance from CBD and employment density.
2. characteristics of the transportation system, involving travel time, travel cost, parking cost, excess travel time, accessibility.
3. characteristics of trip; dependent on number of trip purposes used, length of trip, time of day, and orientation of CBD.

Two general types of models to express the Modal Split are:

1. Trip End Model - allocates a portion of total trip person origins and destinations to the alternate modes of transportation prior to trip distribution.⁶
 - a. Accessibility Index: measures ease by which ac-

tivity within a planning area can be reached from a particular zone on a specific transportation system.

$$Q_i = \sum_{j=1}^n (A_j F_{ij})$$

where

Q_i = accessibility index for zone i to all other zones (auto or transit)

A_j = attractions in zone j

F_{ij} = travel time friction factor

$F_{ij} = 1 / (\text{door to door travel time})^b$

F_{ij} is a measure of impedance for travel from zone i to zone j on the particular transportation system being considered.

b = an exponent which varies with trip purpose and travel time range.

n = number of zones.⁵

Door-to-Door Travel Time for Highway Network includes:

1. Walk time at origin
2. Unpark time at origin
3. Driving time
4. Park time at destination
5. Walk time at destination

Door-to=Door Travel Time for Transit Network includes:

1. Walk time at the origin
2. Wait time at the origin
3. Time spent in transit vehicle
4. Transfer time between transit vehicles
5. Walk time at destination⁵

2. Trip Interchange Model - allocates portion of given trip movements resulting from trip distribution to the alternate transportation modes.⁶

- a. Travel Time Ratio: ratio of door-to-door travel time by public transit divided by door-to-door travel time by private auto.
- b. Relative Travel Costs: ratio of the out-of-pocket travel cost via transit to the travel cost via auto.

$$\text{Travel cost ratio} = \frac{X_1 \cdot X_5}{(X_2 + X_3 + 0.5 X_4)}$$

where

X_1 = transit fare

X_2 = cost of gasoline

X_3 = cost of oil change

X_4 = parking cost

X_5 = average car occupancy

- c. Economic Status of Trip Maker: the ability to own and maintain auto; dependent on family income.

- d. Relative Travel Service: indicator of comfort, smoothness of ride, arrival and departure times, etc.⁵

$$\text{Travel service ratio} = \frac{X_6 + X_7 + X_8 + X_9}{X_{10} + X_{11}}$$

where

X_6 = transfer time between transit vehicle

X_7 = time spent awaiting for transit vehicle

X_8 = walking time to transit vehicle

X_9 = walking time from transit vehicle

X_{10} = parking delay at destination

X_{11} = walking time from parking place to destination

General Rules for establishing Zone Boundaries :

Incorrect setting of zone boundaries without consideration to land use will result in erroneous evaluation of the data because different classes of land use produce different levels of trip generation.⁷

1. CBD should constitute a single zone. If CBD is large enough, subdivision into separate zones may be permitted; but peripheral zones should not be included in CBD zones or CBD zone divisions.
2. Establish origins and destinations with land uses of similar traffic generating capacities.
3. Care to be taken in determination of which major streets to become zone dividers. (shoestring development - identical community on either side of road - poor zone division; include the two parts as one zone.)
4. Street zone divider permissible when areal extent perpendicular to highway large enough to warrant subdivision.
5. Street zone divider when dissimilar land use bounded on either side.
6. Street zone divider useable when there is barrier to future development.
7. Block splitting only to separate commercial from residential areas from each other when they inter-face mid-block.
8. Coordinate zone with census tract zones.

VII - TRIP ASSIGNMENT

Assignment Process

The planner who has determined the distribution of the generated trip volume is interested in the assignment of these trips to the many possible routes available between any two zones. The assignment process is used to determine future network and vehicle or person volumes.

This procedure provides:

1. Volume of vehicles or persons expected to use each link of network.
2. Data indicating quality of service.
3. Data evaluating location of facilities.
4. Data showing economic feasibility.

Before going into the general methods, the matter of capacity restraint should be established. Capacity restraint indicates a relationship between travel time and volume. When traffic on a highway is at capacity, speeds decrease and it takes much longer to travel between two points than it would in off-peak hours. This holds true in transit facilities also. Travel resistance should consider all factors chosen by a user in determining his route.

Capacity Restraint Formula: $V_i = e^{(R_i - 1)} V_0$

where

V_i = travel time on a link for a given pass

e = 2.7182

R_i = ratio of averaged assigned volumes to capacity

V_0 = original travel time of link.⁸

There are two general assignment methods:

1. All-or-Nothing Assignment: "process in which the total number of trips between two zones are assigned entirely to path or route with minimum travel resistance."²
2. Diversion Assignment: "process of assigning the total number of trips between two zones to at least two paths or routes, according to the relative travel resistance of the paths or routes."²

Each of these programs can be modified with capacity restraint factors to better describe an actual network.

The operation of the first method is to:

1. Load proposed system
2. Determine how loaded network acts
3. Compare the system with other systems for social and economic goals.⁸

Network performance is based on average travel time per unit distance, cost per unit movement and density flow per system link. This process lends itself to digital techniques.

Diversion curves are used in the second method. They relate travel resistance and usage between two routes. Diversion curves that may be developed are:²

1. Travel time saved
2. Distance saved
3. Travel time ratio
4. Distance ratio
5. Travel time and distance saved
6. Distance and speed ratio
7. Cost ratio
8. Cost per minute saved

For mass transit, travel time saved is significant in user usage in choice of a mode of mass transit (bus, train, ferry, etc.) The distance saved is less significant in choice of mass transit. Travel patterns during peak hours vary greatly from those in off-hours. Choice of mass transit is dependent on spatial separation of stations, number of required transfers, headway, comfort, surface traffic conditions and rider fare.

Computer Oriented Analytic Techniques

The Urban Mass Transportation Administration (UMTA) of the United States Department of Transportation is presently developing multi-modal transportation planning techniques in order for local government to make sound decisions regarding the investment of resources in transit-facilities and for UMTA to properly evaluate requests for capital grants.⁹

At present, a package of fourteen (14) computer programs, called the UMTA Transportation Planning System (UTPS), designed explicitly to aid in the long-range planning of a multi-modal Urban Transportation System is available. These programs assist in the analysis of urban mass transportation supply and demand as well as their interaction, and furnish aggregate and detailed estimates of the system's level of service, ridership, and costs.

The fourteen programs are grouped under three analytical categories, viz.: Network Analysis, Demand Forecasting, and System Evaluation. A brief description of the programs is as follows:

NETWORK ANALYSIS PROGRAM

PROGRAM	INPUT	OUTPUT
UNET	Transit Network	Link data, Line data
		Check network coding, detailed transit line reports by mode (estimate fleet size and operating costs), transit line summary, transit company summary.
UPATH	Transit Path Finder	UNET, mode to mode fare matrix, fare link data
		Description of shortest paths between all selected modes, zone to zone fare matrix.
UPSUM	Minimum Path Summary	UPATH
		Up to 12 impedance matrices (number of transfers, travel time by mode, waiting time required for each zone to zone trip) and frequency distribution for each output matrix. Single or merged.
UFMTR	TRIP TABLE/ Skim Trees Formatter	Trip Tables
		Selected portions of matrices, number of trips leaving, entering and remaining in each zone.
UDZFS	Dist. to zone fare	Dist. to zone fare matrix
		Zone to zone fare matrix.
UTLD	Trip Length Distribution	Impedance matrix (fare), trip matrix (Trip Tables)
		Plot of interzonal trips paying a given fare

DEMAND FORECASTING PROGRAMS

PROGRAM		INPUT	OUTPUT
UMODE	Mode Choice	Modal split formulae, diversion curve, land use transportation system characteristics, (interzonal data), person trip matrix	Trip matrices up to nine modal components, provides comparison forecasted trip matrices with observed trip matrices.
UDATR	Data Reduction	Land use and transportation system level of service	Formulates and calibrates multiple regression mode split models.
UREGRE	Regression	Raw data or UDATR output and regression model specifications	Calculates linear multiple regression parameters, and goodness of fit estimates, residual analysis.
UMCON	Matrix Conversion	Trip tables, skim trees, impedance matrices, etc.	Copies, modifies and merges matrices.
UFMTR	See Network Analysis Program		
UMNIP	Matrix Manipulation		Arithmetic combinations of two or more matrices.

TP-2-24

PASSENGER LOADING PROGRAMS

PROGRAM	INPUT	OUTPUT
ULOAD Passenger Loading	UNET, UPATH, UMODE	Mode to mode transfer summary, non-transit link volumes, total number of trips assigned, file of loaded links and transit legs.
UPRAS Assignment	ULOAD, UNET	Summary reports of ridership, passenger volumes for each line or link, peak loads, pass.miles, pass. hours, revised headways, performance of each route and systems.
USTOS Station to station volumes	UPATH, Inter-zonal trip matrix, transit modes	Passenger flows between selected stations, access and egress station for each zone to zone trip. Useful for station design and revenue forecasting.

VIII- SOCIAL IMPACT OF URBAN MASS TRANSIT

Comprehensive planning is necessary in any design development. Project undertaking requires vast expenditures, and society is at the limits of its natural resources. "Comprehensive transportation planning is the study of present transportation patterns in relation to present population, economy, and land use; the design of alternate transportation networks and facilities; the evaluation of alternates; and the selection of a transportation plan with proposals for its implementation, scheduling, and financing."⁵

Once several alternative plans are developed, the selection of the best scheme may not be the most economical. Value judgements are required to weigh the intangible benefits or debits. Usually, a procedure is implemented which gives these intangible factors some assignable cash value equivalent. Good basis for sound judgement in making decisions should include the following requirements:

1. economic performance - direct monetary benefits and cost
2. total time required by users of the system - a measure of service
3. comfort and convenience - measure of service
4. safety
5. aesthetic - appearance of system to user and to community as a whole
6. public welfare:
 - a. reduce unemployment
 - b. support cultural and athletic events
 - c. raise general standard of living
 - d. service to senior citizens.⁵

Federal agencies establish certain planning requirements for its funded projects. The three "C's" of urban transportation planning are:⁵

- A. Continuity - update forecasts, inventories and plan of completed project

B. Comprehensiveness - includes the following:

- a. economic development affected
- b. population studies
- c. inventory
- d. travel patterns
- e. traffic engineering features
- f. zoning ordinances and building codes
- g. financial resources
- h. social and community effects

C. Cooperation - by all local governments by written agreement

An important note on the urban transportation picture is in 1962 letter to the President of the United States by the Administrator of Housing and Home Finance Agency. It states, "Mass transportation must be viewed as a public service and often cannot be a profit-making enterprise. While mass transportation is provided on a more or less limited scale in hundreds of localities, it is generally not possible to support a large scale investment program from the fare box. But the price to the community and to the Nation of inadequate mass transportation can be uneconomic uses of land and higher than necessary costs of public facilities, excessive travel and increasingly aggravated congestion at peak hours."⁵

Public policy should demand sound investments with strong regard to benefits:

1. reduce aggregate costs of transportation
2. provide transit to non-driver
3. provide transit for low-income families
4. provide good transportation so personal travel is easy and convenient
5. reduce street congestion
6. revitalize economic growth of C.B.D.
7. create higher real estate values
8. reduce air pollution
9. promote desirable land use patterns and development⁵

IX - CONCLUSION

Evaluation of Models and Procedures:

The techniques set forth in this chapter are early and simplistic attempts to model the urban environment that are still used by many state and federal governmental agencies, as well as by many large consulting firms.

All these models have several basic shortcomings. Most important, they are specific to the time and place they are used for. Each new situation in which they are used requires different parameter values for the functions which fit them to the observed data. They are based on a structure of trip-making and travel habits which may include other determinant factors besides time and cost, or measures of attraction, or simple ratios of these.

The models are initially calibrated on a historical record of a given number of years. If they are calibrated for a data period of say ten years, they suppress or smooth out much short-term variability. If they are static or calibrated over a short period, then longer-term projections may become less valid. Changing technology, the irregularity of changes, and inadequate dates could make even a 1980 prediction based on 1970's structured relationships of little use.

All these models using fitted parameters are forms of linear regression techniques. They use one or more multipliers in the equations to calibrate or adjust the results to fit known data, and then use these same multipliers (fitted parameters) to predict the future. Yet a strong relationship may exist between two elements even if the regression analysis does not reveal it; and conversely, statistical relationships do not necessarily imply cause and effect patterns.

The trip generation models use as input present patterns of trip generation, and future population, economic, and land use characteristics. There is no input on availability of transportation or level of transportation services in any mode. Vehicle ownership is taken as a given fact. Thus there is an implicit assumption that the transportation system has no influence on trip generation rates.

Time and cost - even where time includes waiting and transferring time - do not subsume all the variables involved in choice of route, or destination, or mode, or even of whether to make a trip. Other factors, including sociological, psychological, and physical factors - for example, peer-group standards, fear of crime, expectation of seats versus standing, etc., may play an important role. Higher income groups may go further to shop because a nearer shopping area is frequented by lower income groups; auto drivers may choose a toll parkway over an interstate highway because it is more pleasing to drive there; a potential passenger may drive rather than take the bus because there are no seats available on the bus. Expected conditions may be more important in the decision process than average observed conditions: the expectation of congestion even 25% of the time may lead a driver to choose another highway route all the time; maximum expected headway may be a more critical factor than half the scheduled headway.

An example of the kind of problems this can lead to is the subway trip assignment model that Traffic Research Corporation developed for the Queens-Long Island Demonstration Project. The model was consistently assigning too many passengers to the Queens IND line (E & F) and almost no one to the Jamaica BMT line (J) for CBD-bound trips, due to the much faster trip time on the E and F lines. The cordon count predicted by the model exceeded the capacity of the line. Fitted parameters were not helping. But when a factor was added to the model to reflect the availability of seats at 168 Street, the problem was solved and the correlation became excellent.

The UTPS programs are only adaptations of the above approaches to mass transit planning, and as such bear the same limitations. For instance, the ULOAD program "assigns trips to elements of the transportation system using the shortest (weighted) time paths.."

Zone size is another critical problem in these models. Zone boundaries are commonly drawn according to census or political boundaries, and are typically large, non-homogenous in many ways, and comprise a wide range of available transportation opportunities in each zone. But each zone has only one centroid, and therefore reflects an average of varying conditions which reduces the ability of the model to accurately represent the trip-maker's reaction to the choices confronting him. For example, the Traffic Research Corporation modal split model for the Queens-Long Island Demonstration Project used in one case postal zones, in another Tri-State O & D survey

zones. Different regression coefficients were required for each set of zones, and both contained many zones with significantly different transportation characteristics for one or more modes of transportation in the same zone. The population in the zones varied by as much as an order of magnitude of 5.

Zone boundaries and network coding should be carefully reviewed on a zone-by-zone and link-by-link basis to make sure they accurately reflect real conditions and that average values are realistic.

It is important to keep the above limitations in mind when making use of these models, or when reviewing consultant's work that has relied on such models. While the results of such work, including the UTPS programs, can be useful tools or aids in analyzing potential future demand for transportation, it is essential that the results of the models not be taken as absolute. Information should always be obtained and reviewed as to the types of data and model relationships used. Other factors that may affect the results but that may not have been in the model should be carefully analyzed for their possible impact. Where possible, they should be included in the model.

In order to broaden the perspective of review, it might be worthwhile to consider establishing a policy that would have Surface and Rapid Transit Transportation Schedule or Planning Staffs review such network link-values and zone-values that are input to the model.

X - BIBLIOGRAPHY

1. U.S. Dept. of Transportation/Federal Highway Administration/Bureau of Public Roads, "Guidelines for Trips Generation Analysis", June, 1967.
2. Brian V. Martin, "Principles and Techniques of Predicting Future Demand for Urban Area Transportation", M.I.T. Report No. 3, 1961.
3. Frederick W. Memmott III, "Home Interview Survey and Data Collection Procedures", Highway Research Record No. 41, National Research Council, Washington, D.C., 1963.
4. Kevin E. Heanue & Clyde E. Pyers, "A Comparative Evaluation of Trip Distribution Procedures", Highway Research Record No. 114, Urban Planning Division, U. S. Bureau of Public Roads.
5. Wolfgang S. Homburg, "Urban Mass Transit Planning", Institute of Transportation and Traffic Engineering, University of California, 1967.
6. Martin J. Feital, "Modal Split", U.S. Department of Commerce, Bureau of Public Roads, Office of Planning, December, 1966.
7. L. W. Kerr, "Determination of O & D Zones by means of Land Use Data", Highway Research Board Bulletin #347, National Research Council, Washington, D.C., 1962.
8. David K. Withford, "Traffic Assignment", Highway Research Record No. 6, Highway Research Board, 1963.
9. UTPS Newsletter, July, 1972.
10. Samuel M. Hodfield, "An Evaluation of Land-Use and Dwelling - Unit Data Derived from Aerial Photography", Highway Research Board Bulletin #347, National Research Council, Washington, D.C., 1962.
11. Roger L. Creighton, Urban Transportation Planning, University of Illinois Press, 1970.

12. Department of Commerce, Bureau of Public Roads, "Manual of Procedures for Home Interview Traffic Study", reprint 1957.
13. Mary McLean, Local Planning Administration, the International City Managers Association, 3rd Edition, 1959.
14. Clerk Henderson, "Manhattan Passenger Distribution Project: Effectiveness of Midtown Manhattan System Alternatives", Stanford Research Institute, June, 1972.
15. Highway Research Board, "Use of Census Data in Urban Transportation Process", Highway Research Board Special Report No. 121, July, 1970.
16. ASME, "Defining Transportation Requirements", Papers and discussions of 1968 Transportation Engineering Conference, October, 1968.
17. Robert T. Howe, "A Critical Analysis of An Origin - Destination Survey", Highway Research Record No. 41, National Research Council, Washington, D.C., 1963.
18. Montreal Urban Community Transit Commission, "Survey Method", June, 1972.
19. U. S. Government Printing Office, "Urban Mass Transportation Travel Surveys", August, 1972.

Chapter 3

8-10-10

Chapter 3

PLAN IMPLEMENTATION TABLE OF CONTENTS

I	PLAN IMPLEMENTATION	TP-3-1
II	FINANCIAL ASPECT	TP-3-2
III	LOCAL GOVERNMENTAL ROLE	TP-3-2
IV	GOVERNMENTAL APPROVAL	TP-3-4
V	FEDERAL AND STATE RESPONSE	TP-3-6
VI	EFFECTS OF NATIONAL POLICY ON PLAN IMPLEMENTATION	TP-3-8
VII	PROTECTION OF THE ENVIRONMENT	TP-3-10
VIII	RIGHT OF WAY	TP-3-13
IX	CONSULTANT SERVICES AND CONTRACTS	TP-3-14
	Define the Problems	TP-3-14
	Select Consultant	TP-3-14
	Fee	TP-3-15
	Contract Requirements Established	TP-3-15
X	PROBLEMS AND PLANNERS	TP-3-16
XI	CONCLUSION	TP-3-17
XII	BIBLIOGRAPHY	TP-3-18

Chapter 3

PLAN IMPLEMENTATION

I - PLAN IMPLEMENTATION

The development of feasible and economic plans is not enough to justify their construction and management. The adoption of these plans by the general community, through its respected governmental leaders, is required. Until implemented by governmental or citizen action, the plan has little value. Governmental action either administratively or legislatively must be engaged to make the planning function pay off. It should not be concluded here that the planner at this point of project visualization has achieved his end and can place this project into the hands of others. If this is the attitude he shows, the planner might surely find his work relegated to the shelf. "Transportation planning can only be an effective tool of government if its implementation is assured. Planning that is not implemented is useless, regardless of the skill with which it was performed. Proper administrative organization of the planning function is one way to see that plans are carried out as municipal policy."¹

The planner must engage in two activities; he must develop plans, and he must follow through with their effectuation. He must pursue all official steps to execute the plans into operation by presentation to all branches of government; this includes the legislative, executive and judicial areas. Furthermore, this may require the selling of the plans to the community directly. Such involvement is not established only by the technical competence of the planner but also in his understanding of the social and political implications that the proposed plan may engender.

One important point the planner should regard is: "The decisions actually made by members of society which determine the pattern of values realized will be determined by institutional structure, that is, rules of law, governmental organizational arrangements, private organizational arrangements, and public and private policies, together with information available to and utilized by decision makers which indicates probable consequence of alternative decisions."² "Once the plan is completed it is adopted by the planning agency. The agency usually presents the plan to the governing body and attempts to have the plan adopted."³

Depending on the type of local government, the enabling action to accept plans may produce difficulties or areas that must be examined before approval. New York City, like many other local governments, sets requirements that these plans must not only be technically feasible, but the priorities established and the funds available for the plan execution to proceed.

II - FINANCIAL ASPECT

Funding may be obtained by the local government by bonds when it has the power to do so. Funds can be obtained by taxes from the general city revenues. A composite of bonding, taxes, and city collectable fees can go into a general city fund to be divided among the governmental agencies which service the city. This is capital budgeting which is "a body of techniques for deciding the desirability of proposed investment expenditures."⁴

"Capital programming is a form of financial planning. In preparing a capital improvement program the planner goes to each department of the municipality and determines the nature and cost of all proposed projects which cannot be financed out of current revenues. He then establishes priorities for these projects, determines how they can be financed and schedules their implementation. In essence the capital program is a means of coordinating governmental investments."⁵

III - LOCAL GOVERNMENTAL ROLE

The Transit Authority submits all projects for the budget year, with their estimated costs to the City Planning Commission which draws up the New York City draft budget for all city agencies. This capital budget is an authorized list of capital projects giving cost and time necessary for project completion. The method of financing is also included. The City Planning Department's draft capital budget is submitted to the Budget Director who then drafts the Mayor's budget. This Mayor's budget is finally acted on by the Board of Estimate following public hearings held jointly by the City Council and Board of Estimate. Budget cuts and changes are performed here and the budget is returned to the Mayor for final approval. If he vetoes it, the budget can receive final approval at the Board of Estimate by over-riding vote.

The intricacies and procedures in this City's government will not be included in this report. The planner should be familiar in detail with his city's governmental structure, so that his resources and capabilities can be channeled and utilized to the fullest capacity to move the project from the drawing board to the field. The principles of plan implementation should be understood and developed by the planner in his daily work. The interaction of political power, community action, and ideals of proper planning become embroiled and the end product will not be recognized by the planner as the project he first envisioned. The relationship of government and the planning agency is a direct and strong influence on planning concepts and its implementation. Sometimes this relationship has adverse effects.

A city government may not have the willingness to support mass transit. There may be no local framework to obtain transit funds. There may be no organization to develop the plan nor a planning agency. Other problems include the difficulties of obtaining the right-of-way and the question of whether the system should be self-supporting or dependent on local funds.

The mass transit rider is interested in better and more frequent rides. The increase in cost may not be feasible when the financial officers allocate funds to the different city agencies to maintain other essential services. Usually this question involves a political solution to determine the equilibrium point to balance transit improvements and spiraling costs. The additional service requires an additional labor force which can be bought only at a high wage price. Productivity decreases as experienced men retire early, leaving inexperienced men to maintain the services.⁶ The transit planner's project may not achieve finality due to the poor timing of concurring events. The wise planner should realize the temperment of the times and the political implications when advancing his project. Good timing may be the required impetus in implementing the proposal.

Procedure for the Preparation of Route and General Plan Document:

Approval of the Route and General Plan is initiated by the Chairman of the Authority through a resolution submitted to the Board of Estimate for their approval and the approval of the Mayor of the City of New York.

Required by law is a certified copy of a resolution, adopted by the Authority and signed by the secretary of the Authority, on determining and establishing rapid transit-routes, and the general plans of construction for such rapid transit railroads. The resolution shall include a statement of the route which is provided, and such general plans adopted showing the general mode of operation and such details as to the manner of construction as may be necessary to show the extent to which any street, avenue, or other public place is to be encroached upon and the property thereon affected.

Also in accordance with the provisions of the Rapid Transit Law, a communication for the consent and approval of the Board of Estimate and of the Mayor is submitted by the Authority, signed by the Chairman of the Authority and its Members and countersigned by the Chief Engineer of the Authority. This communication contains the estimates of the cost of construction and equipment, time for completion and beginning of operation and the prospective results of operation over a term of ten years from the estimated date of beginning operation of said rapid transit railroad.

IV - GOVERNMENTAL APPROVAL

The importance of governmental approval of the proposed project, although evident, bears enough weight to be mentioned. It gives the project a degree of finality, it establishes certain rights to the concerned parties, it places liabilities and obligations on these parties and becomes part of the public record for future use. The approval limits the scope of the project and protects it from random changes that can be detrimental. Those who oppose the project after its inception now must seek recourse through similar channels in order to amend, alter or prohibit the project. No one can unilaterally affect the project, without just cause, that has received approval by the public process of government already.

Unlike other localities, New York is not left with a choice between highways or more public modes of transport. The need for mass transportation is not denied by the decision making officials in New York City. "Manhattan's densely developed central business district - accessible only by river crossings and congested with traffic - heightens the need for mass transit as the basic method of passenger transport."⁶

The basic problems have been in the areas of funding and of obtaining the required right-of-way. Both are within the realm of the city financial managers and law bodies. Previously the attitude of the public officials and public was that the subway system should and would be a self supporting one. Transit records indicate the major source of revenue is from the passengers. This thinking continued the concept that increasing the fare would sustain the operating costs of the system. It has been noted that with each city fare increase, the number of riders has decreased. Although the decrease in ridership was not as much as was anticipated (percent decrease in ridership approximately equal to 1/3 times percent of fare increase), the designated fare permitted the incoming yearly revenue to increase to meet the higher operating costs. But the loss of ridership due to a fare increase caused certain social and economic side effects.⁶

1. decreased mobility curtails effectiveness of the CBD as the hub of vitality.
2. with respect to New York City as the headquarters center of the nation, the decrease in centralization becomes damaging. New and old businesses would no longer be attracted to the CBD.
3. retail decline.
4. labor cost increases.
5. increased auto use - increased congestion, pollution, etc.

The decline of ridership is not attributed to the fare increase alone. The life-style has changed the passenger characteristics. Some other causes leading to the passenger decline are:

1. increase in post-war use of auto.
2. exodus of middle class families to the suburbs.
3. reduction of work week from six days to five days.

4. increase in home TV use.⁶
5. decreasing level of transit service.

V - FEDERAL AND STATE RESPONSE

Public officials noting that decline in ridership is not beneficial for the general good and welfare of the city are searching the federal and state arenas for financial aid in subsidizing the subway system. Within the city there are not enough funds to service and rebuild the transit system as required and at the same time maintain other city functions of fire, police, parks, schools and hospitals. Regarding this local planning and Federal Government, Senator Abraham Ribicoff has stated: "For the crisis of our cities is the crises of the modern United States. Seventy percent of all Americans now live in or close to the cities. The number grows each year. So the fate of the city and the future of our country are one and the same thing."³

It has been stated regarding federal aid, "The growing fiscal problems of cities and states throughout the nation have made it increasingly evident that the Federal Government is the only one capable of raising the revenue needed to solve these problems."⁶

The Urban Mass Transportation Act of 1964 states as its purpose to improve mass transit including its facilities, methods and equipment. Encouragement in planning for economic and urban development is emphasized. Finance of state and local governments for transportation systems is established. Also the Act creates a partnership that permits local government through Federal assistance to satisfy its mass transit requirements. The main goals of the Transportation Act are both long range and short range. Long range goals are to improve urban life with respect to social costs and benefits and for safety of travelers. The short range ones include:

1. mobility of non-drivers - "transportation disadvantaged" - young, aged, handicapped, poor, unemployed.
2. relief of traffic congestion.
3. improving quality of urban environment.

State intervention into the planning process and its implementation is desirable. The urban area is one that is extended beyond the city's actual boundaries. "New York City, for example, contains some 352 square miles, but the total urbanized area included in the metropolitan city is nearly four times as large."⁷ The approach to the transportation problem must be attacked from a regional picture. A local solution will not be feasible since part of the problem is caused outside the urban city rather than only internally. With the result of families moving to the suburbs, poorer families replaced the ranks of those who have fled. These poorer families offer little in taxes and the cost of government increases due to their dependence on public service.⁷ The fleeing families continue to retain their city jobs but contribute little to the city other than using city services, congesting trains and streets, and reducing the city dweller's job market. "The effectiveness of regional regulation can be greatly increased through the use of extraterritorial powers. Where a zoning code, subdivision control ordinance and official map are designated to achieve the objectives of a comprehensive regional plan, and enforced for the whole urban area, there is real hope for meeting the problem of providing for future transportation needs."¹ In essence the Metropolitan Transportation Authority (MTA) was designed "...to develop a regional formula for all mass transit systems in this region, subways, commuter railroads, and buses."⁶

Without federal or state aid the city would be left with alternatives that would not be desirable to city residents. Possible alternatives for funding are:

1. increase charge on motorist with a transfer of revenue to mass transit.
2. raise taxes.
3. the imposition of specific transit charge.⁶

"Transportation is the life blood of a metropolis. The economic viability of our City and region is dependent upon the ability to provide a mobile work force and to be able to transport it expeditiously at moderate fares."⁶ City leaders have begun to realize that the detrimental effects of fare increase adversely effect the CBD and also the boroughs.

VI - EFFECTS OF NATIONAL POLICY ON PLAN IMPLEMENTATION

The Urban Mass Transportation Assistance Act of 1970 has made available funds to public agencies for eligible projects for use in the mass transit areas. Funding for acquisition, construction, reconstruction, or improvement of facilities and equipment is permitted while repair maintenance and operating costs are not. The federal grant covers up to but not more than two-thirds of the project cost. The Urban Mass Transportation Administration (UMTA) determines the net project cost, and is assured that local matching funds of one-third cost are available prior to project completion.

Traditional approaches to decision making and plan implementation involve economic, technical and political factors. The inception of the National Environmental Policy Act of 1969 has included an environmental concept to decision making. An analysis of all environmental impacts must be made, including the effect of not doing the project at all. A benefit-cost study must be determined, but based on social, environmental, political and economic factors, all being equal weights.⁸ Comprehensive planning is necessary as resources and capital are limited.

The preliminary application for federal grants consists of a letter (original and 5 copies) addressed to the Urban Mass Transportation Administration, Department of Transportation, Washington, D.C. 20590, and signed by an authorized representative of the public agency, which:

1. Describes in as much detail as is currently available the capital facilities or equipment for which the grant is desired.
2. Describes the transportation system in which the facilities or equipment will be used.
3. Describes the benefits to be derived from the facilities or equipment and relates these benefits to the transportation program for the urban area.
4. Estimates the total cost of the project.
5. Estimates what portion of the total cost of the project can be financed

from revenues, identifies the source of the revenues, and indicates how such financing will be arranged.

6. Estimates what portion of the total cost of the project cannot be reasonably financed from revenues and indicates how the local share of this amount (at least $1/3$ or $1/2$) will be secured.
7. Describes efforts made to obtain private revenue financing and any State or local actions which have been taken to provide financial or other assistance in the solution of urban mass transportation problems.
8. Describes the status of (a) comprehensive planning for the development of the urban area, and (b) transportation planning undertaken to provide the basic framework of the urban mass transportation system and highway network for the area; and list the area-wide, subregional and local agencies responsible for comprehensive and transportation planning, and the State and metropolitan or regional clearinghouses notified of the application. (Refer to Urban Mass Transportation Planning Requirements Guide.)
9. Describes the program which exists or is being developed for a unified or officially coordinated urban mass transportation system for the urban area. (Refer to Urban Mass Transportation Planning Requirements Guide.)
10. Describes the arrangements which exist or will be made to insure satisfactory continuing public control over the operation or use of the facilities or equipment, whether publicly or privately operated.
11. Indicates whether or not the project will:
 - a. Adversely affect employees of the

transportation system to be assisted or of other transportation systems in the urban area, and identifies the systems and labor unions involved.

- b. Result in the relocation of families, individuals, business concerns, or non-profit organizations.

- 12. Includes a Draft Environmental Statement containing the information outlined hereafter under the heading "Protection of the Environment."

The preliminary application should be supported by any engineering, planning, or financial reports which have been prepared and are pertinent to the project. It should also be supported by an opinion of counsel clearly showing that the applicant is a public body authorized by law to carry out the described project in the manner contemplated.

As a part of the project budget, the applicant must provide a table that shows the actual disbursements of Federal funds required, by year, to complete the project using the Federal fiscal year of project approval as the base year. The approved project budget will include a table of maximum UMTA funds that can be disbursed each fiscal year during the life of the project.⁹

UMTA requires public hearings before the submission of final application. Public notice in a local newspaper, thirty days prior to the hearing is a requirement. This will enable the private citizen to inspect the application for its analysis of impact and the transportation development program. Information is to include project location, estimated cost and financial method, number of displaced families requiring relocation, all adverse environment effects, a comprehensive plan including land use, significant social, economic, and environmental issues.

VII - PROTECTION OF THE ENVIRONMENT

The National Environmental Policy Act of 1969 and the Urban Mass Transportation Assistance Act of 1970 require full consideration of the impact which a Federally-assisted project may have on the environment. Therefore,

the applicant will submit data and analysis of any environmental impacts which the proposed project may have. This environmental analysis should be initially submitted at the time of preliminary application and updated, if necessary, to form a part of the final application.

1. A description of the proposed project and its impact on the environment, including any maps, drawings, plans or photographs that may help in understanding the impacts involved.
2. Discussion of any unavoidable adverse environmental effects of the project as proposed and a description of the steps that have been or will be taken to minimize these effects.
3. Identification of possible alternatives to a project, or any portion of the project to eliminate that adverse impact. Description of each alternative should include an assessment of the financial costs and the resulting environmental benefits.
4. A comparative analysis of the short-term and local impact on the environment and the long-term environmental consequences.
5. Identification of any irreversible and irretrievable environmental impacts or commitments of resources. This statement should include an analysis of the likelihood of adverse environmental impacts which would be caused by future increments to the proposed project.
6. A discussion of problems and objections raised by Federal, State or local entities, and citizens and the disposition of the issues involved. This may be added after the public hearing and local review process, in the final text of the required submission.⁹

Capital grant facilities are likely to have environmental impacts of the following kinds:

1. effects on the amount of land required to be devoted to transportation and related purposes in the future; effects on population growth and dispersal within the area.
2. increases or decreases in the traffic or congestion levels on streets and highways.
3. diversion or disruption of established communities; division of an existing use (e.g., cutting off residential areas from recreation or shopping areas), or disrupting orderly, planned development.
4. aesthetic or visual effects, especially on areas of unique interest or scenic beauty.
5. displacement of people or businesses.
6. changes in the ambient noise level.
7. changes in the level or distribution of air pollution.
8. destruction or derogation of parks, recreational areas or historic sites.
9. disturbing the ecological balance of animal or natural resources.
10. probability of altering or contaminating public resources, (e.g., public water supply source, treatment facility or distribution system) either during construction or in actual operation.
11. physical disruption during construction.⁹

Citizen complains can institute legal action into halting the proposed project construction. "Credible environmental-impact statements are required; the courts will readily detect any lesser effort."¹⁰ Agencies have been striving to meet the letter of the law by preparing regulations, impact statements and

complying with court decisions. But too little has been done to comply with the spirit of the law by furthering the art and science of environmental planning."10

VIII - RIGHT OF WAY

A major aspect facing the transit planner is obtaining the right-of-way to implement the desired project. The acquisition of property can be through purchase, condemnation, gift, dedication or devise. "In the United States the general rule is that land and other property which is acquired out of public revenues can be lawfully acquired only if it is for a public use."5

The city acquires various lots and buildings. When they become city owned and are not used by the city services or are not readily saleable to interested third parties the city loses tax revenue. The non-use of such buildings or lots is also detrimental to the surrounding community and cannot be readily measured in monetary amounts. These sites are usually offered to city departments who can assemble lots for possible projects, in such a way the Transit Authority can take possession of a lot, in fee absolute, in part as required, or by easement. This process saves the city money in that the parcel will not be developed by a private individual only to be condemned or altered for transit construction later at high cost to the city. The basic concept is that in this instance the Transit Authority must have some ideas or proposals of possible route alignment in the area of the parcel in question. The TA has the obligation to develop new routes; with the general route and alignment plan the acquiring of city property becomes expensive but not as much as the holding of the property in an untaxed unused state. The development of new routes has not only provided better transit but increased property values, development, and employment opportunities.

The acquiring of parcels for transit uses is through the Site Selection Board which deems the suitability of property use for the city agency. It is a governmental check which prevents any city department from randomly condemning buildings through the city's police powers before the proposed projects are finalized or even funded. The nine member board approves the site and implements transfer of title to the city agency if the city is already in possession. This is through the Board of Estimate. When the property is privately-owned the Cor-

poration Counsel is directed by the Board of Estimate to institute condemnation procedures against the property. Usually only an easement is desired but this insures legal possession can be obtained by the city.

IX - CONSULTANT SERVICES AND CONTRACTS

The municipal use of consultants is an area of interest and concern to planning departments. They have been retained under contract to engage in their specialized service to complete the development of proposed plan. The supervision of the consultant falls to the planning agency which prepares guidelines stating requirements of service.

The Association of Consultant Management Engineers, ACME, outlines the use of consultants in planning development.¹¹ They recommend that the agency define the problem at hand before approaching consulting services and do the following:

Define the Problem:

1. Collect and analyze facts needed to define or describe the problem which requires the solution.
2. Analyze conditions which have created and sustained the problem.
3. Determine the conditions for its solution and the end results which should be achieved by solution
 - a. Why does it have to be solved?
 - b. When does it have to be solved?
 - c. What is to be gained by the solution?
 - d. What does the solution cost?
 - e. What limitations are there on solution?

Select Consultant:

1. Client (planning agency) should determine nature and general scope of project prior to contracting consultants.

2. Credentials of various consultants should be submitted with respect to the project.
3. Preliminary discussions held with each qualified consultant; each then asked to submit proposal.
4. Check in depth consultants references.
5. Study proposals.
6. Final selections - negotiations.

Fee:

1. Discussion of fee requirements.

Contract Requirements Established:

1. Services to be furnished the city.
2. Scope of services furnished by the professional and his subordinates.
3. Fee schedule - with established maximum limits.
4. Method of payment (10% retained to completion).
5. Term of agreement and completion of work.
6. Specifics as to schedule, scope, and extent of written and oral reports from consultant.
7. Original documents to be property of city.
8. Non-assignment of agreement.
9. Identification of individuals in firm responsible for contract and termination clause in event of death or incapacity or that of specified employees.
10. Professional liability insurance.
11. City construction budget of figures of construction is contemplated.

12. Designation of person responsible for city supervision of the agreement.
13. Right of supervision to approve specialists, consultants who might be retained by consultant for some special purpose.

X - PROBLEMS AND PLANNERS

The external effects of outside governmental agencies, special interest groups, citizen action, and politics cause the planner to alter or even dispose of his project. Part of the problem is explained quite clearly in Levin and Abend's book, *Bureaucrats in Collision: Case Studies in Area Transportation Planning*, which relates the nature of the planner.

1. Planner considers himself civilized believer in reason and compromise.
2. He is awed when confronted with blind certainty and violent opposition.
3. He is unskilled at infighting except with professional colleagues.
4. The art of planning is fuzzily defined.
5. Planning is subject to encroachment by other professionals.
6. Planning agencies usually service operations rather than a center of political power.
7. Planner optimist about future, his current project and the possibility of educating the uneducable.
8. Planner's dilemma to reconcile professional and agency loyalties.
9. Newly hired planner regarded as instrument rather than senior contributor to policy.

"The recent tendency to thrust the planner and the planning agency into a (theoretically) cooperative and

de facto competitive relationship with other agencies has not been wholly successful. Early return from this friendly confrontation, which pits the planning agency against powerful so-called cooperating agencies clad in ideological plate armor, indicate that the planning agency tends to be very much the junior, accommodating partner."¹²

The planner, in carrying out a public relations program, ". . . is cautioned that he should undertake no public programs which are not approved by the mayor and the city council, since these officials are the responsible political officials who must answer to the voters."⁵ Another advisable point to follow is that "Nothing will destroy public confidence in the planning agency more quickly than the making of decisions based on political considerations. Political decisions should be left to the elected officials."⁵

XI - CONCLUSION

In summary, urban transportation planning should ideally be set up as a governmental body in which all urban transportation is dealt with on a regional basis. Each function of mass transit administration should be clearly defined and organized into a unit responsible for it alone, and each headed by a single responsible director. The interdependency of transportation functions and urban redevelopment should be recognized and headed by an administrative authority.

XII - BIBLIOGRAPHY

1. Thomas J. Seburn, "Urban Transportation Administration", Bureau of Highway Traffic, Yale University, 1959.
2. Lynton K. Caldwell, Ed., "Research on Policy and Administration in Environmental Quality Programs", Institute of Public Administration, Indiana University, 1967.
3. David C. Ranney, Planning and Politics in the Metropolis, Charles E. Merrill Publishing Co., 1969.
4. James C. T. Mao, "Efficiency in Public Urban Renewal Expenditures through Capital Budgeting", University of California, 1965.
5. Donald H. Webster, Urban Planning and Municipal Public Policy, Harper and Brothers, New York, 1958.
6. Citizens Budget Commission, Inc., "Financing Transit in New York City", February, 1971.
7. Wilfred Owen, The Metropolitan Transportation Problem, The Brookings Institution, Washington, D.C., 1956.
8. Joseph Newel, Jr., "The National Environmental Policy Act of 1969 and the Engineering Curriculum", ASCE, "Civil Engineering", March, 1973.
9. U. S. Department of Transportation, Urban Mass Transportation Administration, Washington, D.C., "Capital Grants for Urban Mass Transportation", June, 1972.
10. Wm. K. Johnson, "Environmental Litigation: Lessons from the Courts", ASCE, "Civil Engineering", January, 1972.
11. Management Information Service, "Municipal Use of Consultants", International City Manager's Association, Washington, D.C., April, 1968.

12. Melvin R. Levin, Bureaucrats in Collision: Case Studies in Area Transportation Planning, MIT Press, 1971.
13. Wallace S. Sayre, Governing New York City, Russell Sage Foundation, 1960.

Chapter **4**

Page 10

Chapter 4

CONGESTION AND ITS MITIGATION

TABLE OF CONTENTS

I	CONGESTION	TP-4-1
II	STAIRS AND ESCALATORS	TP-4-1
III	PLATFORM ENTRANCES	TP-4-7
IV	STATION ENTER/EXIT FACILITIES	TP-4-7
V	OBSTRUCTIONS	TP-4-7
VI	TOKEN BOOTHS	TP-4-8
VII	SIGNAGE	TP-4-9
VIII	PASSAGEWAYS AND CORRIDORS	TP-4-10
IX	LEVEL OF SERVICE	TP-4-10
X	BIBLIOGRAPHY	TP-4-15

Chapter 4

CONGESTION AND ITS MITIGATION

I - CONGESTION

Congestion in transportation facilities is inevitable, but it could be made bearable by careful consideration of all causes of congestion, while designing for new facilities. Promoting staggered work hours for reducing congestion rather than change in design of existing subway stations or their elements is more feasible and less expensive.

II - STAIRS AND ESCALATORS

1. Inadequate capacity: Capacity of a stairway or escalator varies to some extent according to the size of the crowd, time of the day and position in an arriving crowd of people. It would be highly expensive to provide for stairs or escalators for ideal situation where no congestion exists.

Design should be based on:

- a) 20 minute peak or less.
- b) waiting time, time spent waiting in a queue to board the stairway or escalator, of up to 15 seconds may be considered normal, in heavily used stations with limited space.
- c) use of faster escalators. Increase in escalator speed (say 90 fpm to 120 fpm) does not increase the capacity by the same proportion because of constant pressure of heavy traffic volumes, frequent queuing, and momentary hesitation to step on a fast moving escalator.
- d) walking on escalators produces little gain in escalator capacity but shortens pedestrian trip times for those who choose to walk.

2. Location: The location of a stairway or escalator should be compatible with the direction of pedestrian flow. Abrupt change in direction contributes to congestion promoted by slow speed required in making that change in direction.

Lack of sufficient distance between the edge of the station platform and the first tread of escalator or stairway causes congestion. Greater walking distance between the stairway or escalator and the edge of platform allow for bypassing slower moving people without causing a chain reaction of congestion by spacing people in roughly single file lines as they head for a stairway. If sufficient distance is not maintained wider than required, stairway or escalator should be provided.

To keep the platform clear of the queues and to provide queuing areas for people boarding an escalator or stairway, locate these facilities in recessed areas.

Proper location of stairways and escalators will channelize pedestrian flows and lessen confrontation with reverse flow.

Stairs and escalators located on island platforms cause congestion as circulation must occur in restricted areas around these facilities. If it is intended to provide a center loading island platform, this platform should be made wider. Stairs and escalators located at the ends of an island platform cause little movement restriction. Side platforms should be preferred to island platforms.

Advantages of side platforms:

- a) unobstructed movement of passengers by placing staircases and escalators in recessed areas.
- b) minimal effects of reverse flow because of common direction of flow of most passengers.
- c) elimination of columns from platforms possible due to shorter span.
- d) straight line track approach

to the station, savings in construction costs (no diversion of tracks required to allow for island platform).

- e) a mezzanine is not a requirement, although it provides better circulation, economic operation, and surveillance.

Advantages of island platforms:

- a) ease of across-the-platform transfers.
- b) best suited where more than two tracks are served by a station, and for terminal stations.
- c) width of the island platform can be smaller than the width of two side platforms, an advantage where severe R.O.W. limitations exist.
- d) ease of maintenance.

3. Reverse Flow: The capacity of a stairway may be sufficient for unidirectional flow, but reverse flow will lead to congestion if not considered in determining the width of stairway. The effects of reverse flow are more pronounced during rush hours and should be considered.

Providing escalators for up and stairways for down directions will eliminate the problems of reverse flow. Poor configuration adds to the problem.

4. Entrance Configurations: Some entrance configurations restrict movement along platforms as shown in Figure 4.01. Reservoir space should be provided in proportion to the number of people to be accommodated.

5. Queuing Space: The volume of people who are queuing at a particular stairway or escalator determine the queuing space. Queuing space may be determined using queuing level of service standards.

6. Direct Connections: Direct connections from

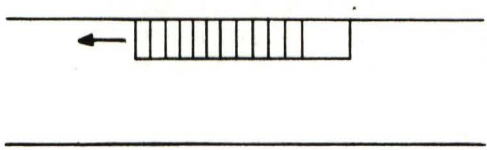
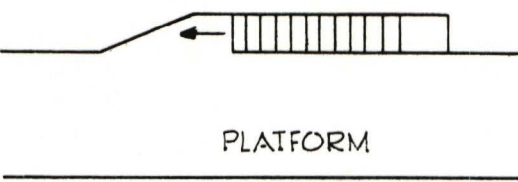
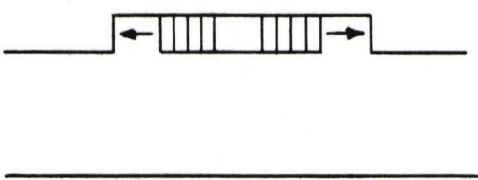
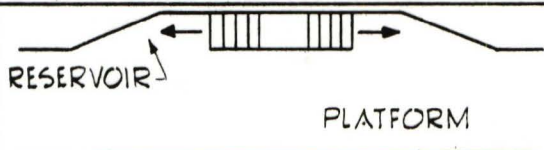
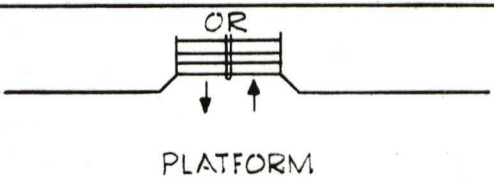
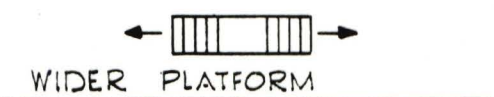
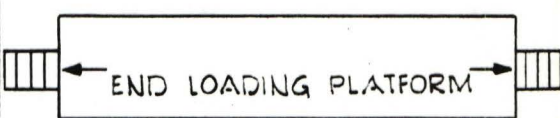
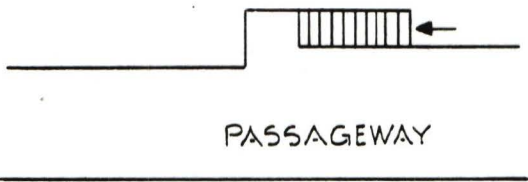
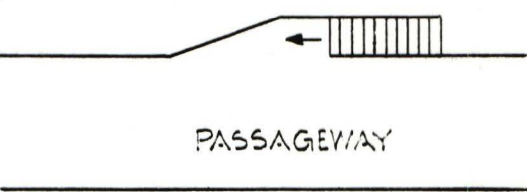
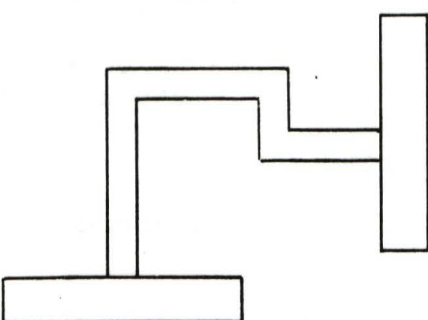
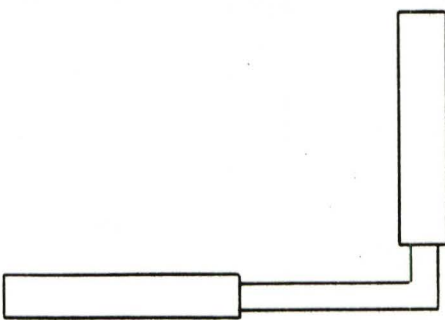
TYPE	UNDESIRABLE E	DESIRABLE
SIDE PLATFORM		 PLATFORM
		 RESERVOIR PLATFORM  OR PLATFORM
ISLAND PLATFORM	 NARROW ISLAND PLATFORM	 WIDER PLATFORM OR  END LOADING PLATFORM
PASSAGEWAY	 PASSAGEWAY	 PASSAGEWAY
		

FIGURE 4.01

station to major employment or shopping centers, to alleviate potential major congested areas on stairways or escalators, and sidewalks, should be considered.

7. Design Criteria: Design criteria not covered above is:

- a) the nominal or design capacity for an escalator is 80% of the manufacturer's theoretical capacity for a 90 fpm escalator speed and 75% for a 120 fpm escalator speed.
- b) maximum riser height of $6\frac{1}{2}$ " and a rounded nosing flush with the riser should be provided for stairs for comfort and convenience and to increase efficiency of traffic. Time mean speed is higher with riser height of 6" than with riser height of $6\frac{1}{2}$ ". Pedestrian stair speeds are shown in Table 4.01.
- c) the width of traffic lane on a stairway or escalator should be 30 inches.
- d) on stairways where reverse flow volumes occur frequently, a reverse flow lane should be provided.
- e) stairways and escalators should be well lighted.
- f) stairways and escalators should be readily visible and identifiable.
- g) stairways and escalators should be designed for safety, security, convenience, continuity, system coherence and attractiveness.

PEDESTRIAN STAIR SPEEDS¹
Horizontal Time-Mean-Speeds
(Feet Per Minute)

	DOWN DIRECTION		UP DIRECTION	
	(1)	(2)	(1)	(2)
Age-29 or under				
Males	163	183	110	120
Females	117	132	106	110
Group Average	149	160	108	115
Age-30 to 50				
Males	136	160	101	116
Females	100	128	94	107
Group Average	127	153	99	114
Age-Over 50				
Males	112	118	85	81
Females	93	111	77	89
Group Average	108	117	83	83
Average-all ages, sexes	132	152	100	113

- (1) Indoor stair, 7-inch riser, 11.25-inch tread, 32-degree angle
(2) Outdoor stair, 6-inch riser, 12.0-inch tread, 27-degree angle

TABLE 4.01

(Source: Pedestrian Planning and Design, Fruin)

III - PLATFORM ENTRANCES

Similarity of platform entrance locations along a subway line promote congestion by clustering people close to entrances. More evenly loaded subway trains on any one particular line would result by alternating entrance positions along the line. Care must be taken to identify major enter/exit stations along the line while alternating entrance locations.

For practical purposes only four basic entrance locations may be considered. These locations are at both ends, 1/3 point, 1/4 point, and at the center. The center loading arrangement has the flexibility of movement along the longitudinal axis up to a point 120 ft. to 150 ft. from the ends of the station. In alternating platform entrance locations the variations in locations should be at least one car length or 75 ft. to create the desired effect.

IV - STATION ENTER/EXIT FACILITIES

Providing more than one enter/exit facility, if enough demand exists, would relieve congestion. Part-time operation of additional enter/exit facilities may be considered if full time use of the facility is expected in future.

Location of enter/exit facilities on sidewalks restricts sidewalk space and creates congestion at sidewalk level and on stairs. Off street enter/exit locations are preferred.

The entrance to the mezzanine should be direct, avoiding unnecessary turn which could cause confusion and congestion.

V - OBSTRUCTIONS

Columns located close to the platform edge interfere with passengers boarding or exiting cars, resulting in congestion. Columns on platforms should be avoided; if not, they should be located at least 5 ft. from the edge of platform.

Benches should be located away from entrance points as there is a tendency for people to cluster

around benches.

Vending machines restrict available circulation space, and hinder surveillance operations. Their interference could be lessened by placing them in recessed areas in the mezzanines and adopting a policy not to have any vending machines on platforms.

Token and change machines should be located as near major flow routes as necessary to ensure high usage but shall have minimum undesirable effects on flow.

VI - TOKEN BOOTHS

Token booths should be located such that the queues generated do not interfere with various flow routes present, or diminish the effective width of key movement channels. Token booths, if grouped, should be located such that one queue does not obscure the view of another, and joining one queue should not necessitate passing through another. Pedestrian waiting in areas surrounding the token booth should be discouraged.

Reservoirs, groups of people who have accumulated in an area because of some limitation in flow capacity beyond that area, that occur in service areas interfere with servicing and movement. Service areas should be so designed that reservoirs occur prior to service areas rather than in them. This could be accomplished by making the capacity of the entrance to the service area equal to the capacity of its exit.²

When streams intersect and merge in a service area, a great deal of personal interference results. Therefore the confluence of streams entering the station should occur prior to the service area rather than in it.²

If more than one token booth is provided in a service area, and if symmetrical usage cannot occur naturally, information should be provided to ensure that similar facilities will be equally used.

VII - SIGNAGE

Moving people who suddenly stop in the middle of a heavy stream, obviously looking for information, create congestion. The system coherence of station elements is an important aspect of the design. Incoherent station design increases the need for explanatory signing which further confuses the pedestrian with multiple visual inputs and lessens individual sign effectiveness.

It is vital that all signs be read easily and understood quickly. This demands the consistent use of a distinctive type face throughout the entire system.

Research has shown that the most "appropriate" type face for this purpose is a regular sans serif. Of the various weights of sans serif available, Standard Medium has been found to offer the easiest legibility from any angle, whether the passenger is standing, walking or riding.

The specific size type to be used will vary according to the three basic sign categories:

1. for Station Identification, Exit and Transfer signs, the largest type face, X height 9"
2. for Direction signs, X height 4 1/4"
3. for Information Signs, X height 1 3/8"

(X height has been used as a point of reference and represents the height of upper case X in the Standard Medium alphabet.)

The placement of all signs should be controlled so that there is no conflict in the information offered for proper direction. The basic sign distribution is vital and should include:

1. Street Level: station name, direction, color-coded line identification discs.
2. Maps: system map, neighborhood map, "How to get there" map.

3. Direction signs, branching traffic flow to track levels and exit.
4. Direction sign branching traffic to left and right.
5. Exit/Transfer sign.
6. Train information signs: direction, discs and schedules relating to trains passing on that track.
7. Station Identification.
8. Station Identification on the columns (abbreviated.)

VIII - PASSAGEWAYS AND CORRIDORS

Insufficient width of passageways or corridors leads to severe congestion. The width of passageways or corridors may be obtained using level of service standards for walkways.¹

Machines, located in passageways or corridors, and the group of people around them cause considerable decrease in the effective width of the passageway which diminishes the flow capacity and gives rise to high level inter-personal interference. Therefore, allowance should be made for the physical separation between the pedestrian and the stationery objects or walls.

Peak periods of 20 minutes or less should be used in designing the passageway. The effects of platoons should be considered when applying level of service standards.

IX - LEVEL OF SERVICE

The level of service concept is used for determining the maximum capacity ratings for pedestrian space. The method takes into account physical and psychological discomfort and circulation such as the freedom to choose walking speed, and the ability to overtake and pass slower pedestrians. Level of service standards

for walkways, stairways, and queuing spaces are given in Tables 4.02 through 4.04. For transportation facilities the design should be based on level of service B or C¹.

LEVEL OF SERVICE STANDARDS FOR WALKWAYS

Level of Service Category	Avg. Area S.F. Per Person	Avg. Flow Vol. (PFM)*	Circu- lation	Places of Occurrence
A	35 or greater	7 or less	Unre- strict- ed	Plazas, Mezzanines
B	25 - 35	7 - 10	Slight- ly Re- strict- ed	Transport- ation Terminals
C	15 - 25	10 - 15	Re- strict- ed	Transport- ation Terminals
D	10 - 15	15 - 20	Severe- ly Re- strict- ed	Not Recom- mended
E	5 - 10	20 - 25	Severe- ly Re- strict- ed	Not Recom- mended
F	5 or less	Variable up to 25	Severe- ly Re- strict- ed	Not Recom- mended

* Persons per ft. width of walkway per minute.

TABLE 4.02

(Source: Pedestrian Planning and Design, Fruin)

LEVEL OF SERVICE STANDARDS FOR STAIRWAYS

<u>Level of Service Category</u>	<u>Avg. Area S.F. Per Person</u>	<u>Avg. Flow Vol. (PFM)*</u>	<u>Circulation</u>	<u>Places of Occurrence</u>
A	20 or greater	5 or less	Unrestricted	Plazas, Mezzanines
B	15 - 20	5 - 7	Slightly Restricted	Transportation Terminals
C	10 - 15	7 - 10	Restricted	Transportation Terminals
D	7 - 10	10 - 13	Severely Restricted	Not Recommended
E	4 - 7	13 - 17	Severely Restricted	Not Recommended
F	4 or less	Variable up to 17	Severely Restricted	Not Recommended

* Pedestrians per ft. width of stairway per minute.

TABLE 4.03

(Source: Pedestrian Planning and Design, Fruin)

LEVEL OF SERVICE STANDARDS FOR QUEUING SPACES

<u>Level of Service Category</u>	<u>Avg. Area S.F. Per Person</u>	<u>Inter-Person Spacing, Ft.</u>	<u>Circulation</u>	<u>Places of Occurrence</u>
A	13 or more	4 or more	Unrestricted	Concourse
B	10 - 13	3-1/2 - 4	Slightly Restricted	Platforms, Concourse
C	7 - 10	3 - 3-1/2	Restricted	Ticket areas, Lobbies
D	3 - 7	2 - 3	Severely Restricted	Escalators
E	2 - 3	2 or less	Not Possible	Not Recommended
F	Less than 2	-	Not Possible	Not Recommended

TABLE 4.04

Source: Pedestrian Planning and Design, Fruin

X - BIBLIOGRAPHY

1. John F. Fruin, "Pedestrian Planning and Design.
2. I. B. Stilitz, "The Role of Static Pedestrian Groups in Crowded Spaces", Ergonomics, November, 1969.
3. City University of New York, "Congestion".
4. New York City Transit Authority, "Graphic Standards Manual".

Chapter **5**

1000

Chapter 5

OPERATIONAL CRITERIA

TABLE OF CONTENTS

I	CAPACITY	TP-5-1
II	SPEED LIMIT	TP-5-6
III	HEADWAY	TP-5-7
	Theoretical Headway with	
	No Station Stop	TP-5-9
	Theoretical Headway with	
	Station Stop	TP-5-13
	Practical Minimum Headway	
	Considerations	TP-5-16
	Practical Minimum Headway	
	and Maximum Capacity	TP-5-17
	Practical Headway in a	
	Practical System	TP-5-22
IV	ADHESION	TP-5-22
V	BRAKING DISTANCE	TP-5-24
	System Response Time	TP-5-28
	Effects of Grades	TP-5-28
VI	ACCELERATION	TP-5-31
	Passenger Comfort	TP-5-31
	Traction Motor	TP-5-31
	Power Demand and Consumption	TP-5-34
VII	RESISTANCE	TP-5-39
	Curve Resistance	TP-5-39
	Grade Resistance	TP-5-39
	Train Resistance	TP-5-40
VIII	SPEED-DISTANCE AND TIME- DISTANCE CURVES	TP-5-42
IX	SUPER-ELEVATION	TP-5-46
	Balanced Super-Elevation	TP-5-47
	Unbalanced Super-Elevation	TP-5-47
	Relationship between Balanced and Unbalanced Super-Elevation	TP-5-48

X	MAINTENANCE FACILITIES	TP-5-49
	Requirements	TP-5-56
	Inspection	TP-5-56
	Renovation	TP-5-56
	Exterior Car Cleaning	TP-5-56
	Wheel Truing	TP-5-56
	Overhaul Programs	TP-5-56
	Detrucking	TP-5-57
	Wheels	TP-5-57
	Motors	TP-5-57
	Air Conditioning Equipment and Air Compressors	TP-5-57
	Miscellaneous	TP-5-57
XI	POWER SUPPLY	TP-5-58
	Power for Train Operation	TP-5-58
	Power Demand	TP-5-60
	Power Cost for Train Operation	TP-5-60
	Power for New Lines	TP-5-60
	Substations	TP-5-62
	Auxiliary Electrical Systems	TP-5-65
XII	BIBLIOGRAPHY	TP-5-68

Chapter 5

OPERATIONAL CRITERIA

1- CAPACITY

In rapid transit operation, provision is made for maximum capacity operation during the hours when the heaviest volume of people must be moved at optimum speeds. As the rush hour load tapers off and fewer trains are required to provide service, it is possible to run high speed service with the schedule speeds limited only by the car equipment capabilities, the physical restrictions of the right of way, and the number and duration of station stops.

System capacity is not solely a function of train speed, but a complex function of speed, train length, braking distance, rate of acceleration and deceleration, system reaction time, station dwell time, and the percent tolerance which must be allowed for each function in practical situations.

Maximum capacities occur at speeds considered moderate, and as train speeds exceed this critical moderate speed, capacity decreases.

Train capacity is a parabolic function between time and speed. Optimum capacity occurs at approximately 90 seconds headway, when station dwell time is considered.

The following conclusions are based on analysis of a theoretical system and are valid in a practical system:

1. for any given train length, capacity increases as headway decreases.
2. for any given train length, the critical velocity yielding minimum headway also yields maximum capacity.
3. as velocity increases past the critical value, capacity decreases.
4. at any given speed, capacity increases as train length increases.
5. at any given fixed capacity requirement, velocity increases and headway increases as train length increases.

In optimizing capacity, the problem is to maximize it with a given amount of equipment. The alternatives are:

1. provide many short, slow trains.
2. provide few long, fast trains.

Capacity is defined as the number of people per unit time moved past a fixed point. Dividing the number of passengers per train by the headway in seconds gives us the capacity in units of passengers per second. A more convenient form of capacity is given by

$$C_p = \frac{3600 P_T}{h} \quad (1)$$

where:

C_p = capacity, passengers per hour.

P_T = number of passengers per train.

h = headway in seconds.

Capacity can also be expressed in trains per hour per track, rather than number of passengers per hour.

$$C_T = \frac{3600}{h} \quad (2)$$

Multiplying C_T by the train length, L , in feet, gives capacity in train-feet per hour, C'_T ; a useful figure for comparison purposes.

$$C'_T = \frac{3600L}{h} \quad (3)$$

From (1) and (3), we can establish the following relationship between capacities:

$$C_p = \frac{3600L}{h} \times \frac{P_T}{L} \quad (4)$$

$$C_p = \frac{P_T}{L} C'_T$$

$$C_p = 2.813 C'_T \text{ (for R-44 Car) } \quad (5)$$

If we define $C_p(s)$ as capacity of seated passengers per hour, then:

$$C_p(s) = \frac{P(s)}{L} \times C'_T$$

$$C_p(s) = 0.987 C'_T \text{ (for R-44) } \dots (6)$$

Where:

$P(s)$ = number of seated passengers per train.

(5) and (6) are based on an 8(75') car train, allocating a 1.5' x 2.0' elliptical area for each standing person. For varying passenger density and different types of cars, the appropriate figures should be obtained from Table 5.01. Table 5.02 lists the standing room available in various car series.

Variations in flow within the peak-hour have definite effects on the operating characteristics of a line, and thus influence the capacity which can be obtained in practice. Variations in flow are expressed in terms of the Peak-Hour Factor, which is the ratio of the volumes occurring during the peak-hour to the maximum rate of flow during a given time period, within the peak-hour. These ratios are determined by dividing the peak-hour volumes by three times the peak 20 minute volumes. The maximum value the peak-hour factor can take is 1.0.

Peak-hour factors should be applied in determining the capacities of lines.

$$C_{pL} = PHF \times C_T \times P_T$$

Where:

C_{pL} = Capacity of the line,
passengers/hour/track

PHF = Peak-hour factor

CAR AND TRAIN LOADING

NO. OF PASSENGERS PER CAR										
CAR TYPE	CRUSH	P R A C T I C A L (1.6 S.F. /person approx.)			R E A S O N A B L E * (2.36 S.F. /person)			D E S I R A B L E (3 S.F. /person)		
		STAND	SEAT	TOTAL	STAND	SEAT	TOTAL	STAND	SEAT	TOTAL
R-44 A	350	200	72	272	135	72	207	109	72	181
R-44 B	350	204	76	280	139	76	215	113	76	189
R-42	300	174	46	220	111	46	157	91	46	137
R-40 A/C	300	174	46	220	118	46	164	97	46	143
R-38	300	170	50	220	120	50	170	99	50	149
R-16 **	300	166	54	220	116	54	170	103	54	157

NO. OF PASSENGERS PER TRAIN,

R-44	2800	2208	1096	592	1688	1480
R-42	3000	2200	1110	460	1570	1370
R-40 A/C	3000	2200	1180	460	1640	1430
R-38	3000	2200	1200	500	1700	1490
R-16 **	3000	2200	1160	540	1700	1570

* Based on actual layout of 1.5' x 2.0' ellipse - TA Standard

** has transverse seating.

TABLE 5.01

TP-5-4

STANDING ROOM AVAILABLE IN VARIOUS CAR SERIES

R-44 (A Unit)

Long.	4(3.5 x 13)	=	182	S.F.
Trans.	3(5.0 x 3)	=	45	
Wells	8(4.2 x 3)	=	101	
	Total	=	328	S.F.

R-44 (B Unit)

"A" Unit		=	328	S.F.
Cab Area	3 x 4	=	12	
	Total	=	340	S.F.

R-42

Long.	3.2 x 48	=	155	S.F.
Adj. to Cabs	2(2.5 x 3.3)	=	17	
Wells	8(4.2 x 3)	=	101	
	Total	=	273	S.F.

R-40

Long.	3.7 x 48.8	=	180	S.F.
Adj. to Cabs	2(3.2 x 3)	=	19	
Wells	8(4.2 x 2.7)	=	91	
	Total	=	290	S.F.

R-38

Long.	3.7 x 50.2	=	186	S.F.
Adj. to Cabs	2(3.1 x 3.2)	=	20	
Wells	8(3.8 x 3)	=	91	
	Total	=	297	S.F.

R-16 (Transverse Seats)

Long.	4 x 50.2	=	201	S.F.
Portion of Trans.	3(0.3 x 4.8)	=	4	
Adj. to Cabs	2(3.1 x 3.5)	=	20	
Wells	8(4.2 x 2.7)	=	91	
	Total	=	316	S.F.

TABLE 5.02

Number of Cars in Route Operation

The following formula is used to determine the approximate number of cars required for new route operation in peak-hour.

$$N = \frac{60ntl}{VH}$$

Where:

- N = number of cars required for new route operation in peak-hour, for constant headway, without lay-up.
- n = number of cars per train.
- t = number of tracks operated at the same headway.
- l = length of the line in route miles.
- V = average speed in mph.
- H = headway in minutes.

Allowance should be made for 3 trains at terminals and 10% of N cars for lay-up and relay trains.

Therefore:

$$\text{No. of cars required} = (1.1) N + 3 n.$$

II - SPEED LIMIT

To achieve maximum scheduled speed, trains must be operated at the maximum speeds permitted by the physical characteristics of the track. In general, all signal blocks provide for:

1. Maximum Authorized Speed, dictated by the physical characteristics of track, car equipment capabilities, station spacing, and rates of acceleration and deceleration.
2. Speed, to provide for optimum headway operation, maximum track capacity, and minimum recovery time

in the event of delays to service.

3. Zero Speed, to provide for train protection.

In a Restricted Speed Limit Block a train shall be considered to occupy said block from the time the front of the train enters until the rear of the train exits from the block. Trains approaching a restricted speed limit block from a higher speed block must decelerate before entering, and enter at, or below, the prescribed limit. When leaving the speed limit block the train will not accelerate above the restricted speed until the rear end is clear of the block.

Significant increase in maximum attainable vehicle speed does not preclude a proportional increase in schedule speed. For example, average speed of an R-44 car between two stations 1.0 mile apart, excluding station stop time, is 28 mph for a 30 mph operation, and 36 mph for a 45 mph operation. Therefore, the maximum vehicle speed should be one which will meet all foreseeable requirements of rapid transit service and which is economically attainable with currently available technology.

Figure 5.01 is a graphic presentation of maximum attainable velocity with a R-44 car without considering Station Stop or dwell time.

III - HEADWAY

Headway is defined as the interval of time between successive trains measured from the front end of a leading train to the front end of a following train as they pass a point. A maximum number of trains can be moved through a system when headway is at a minimum.

Maximum capacity and minimum headway are governed by station headway - that is: the incremental time loss per station. The number of trains operating on a particular line is limited by the number that can be passed through the limiting station.

Station headway consists of:

1. time consumed during braking, t_b
2. time consumed by station stop, dwell time or standing time, t_s

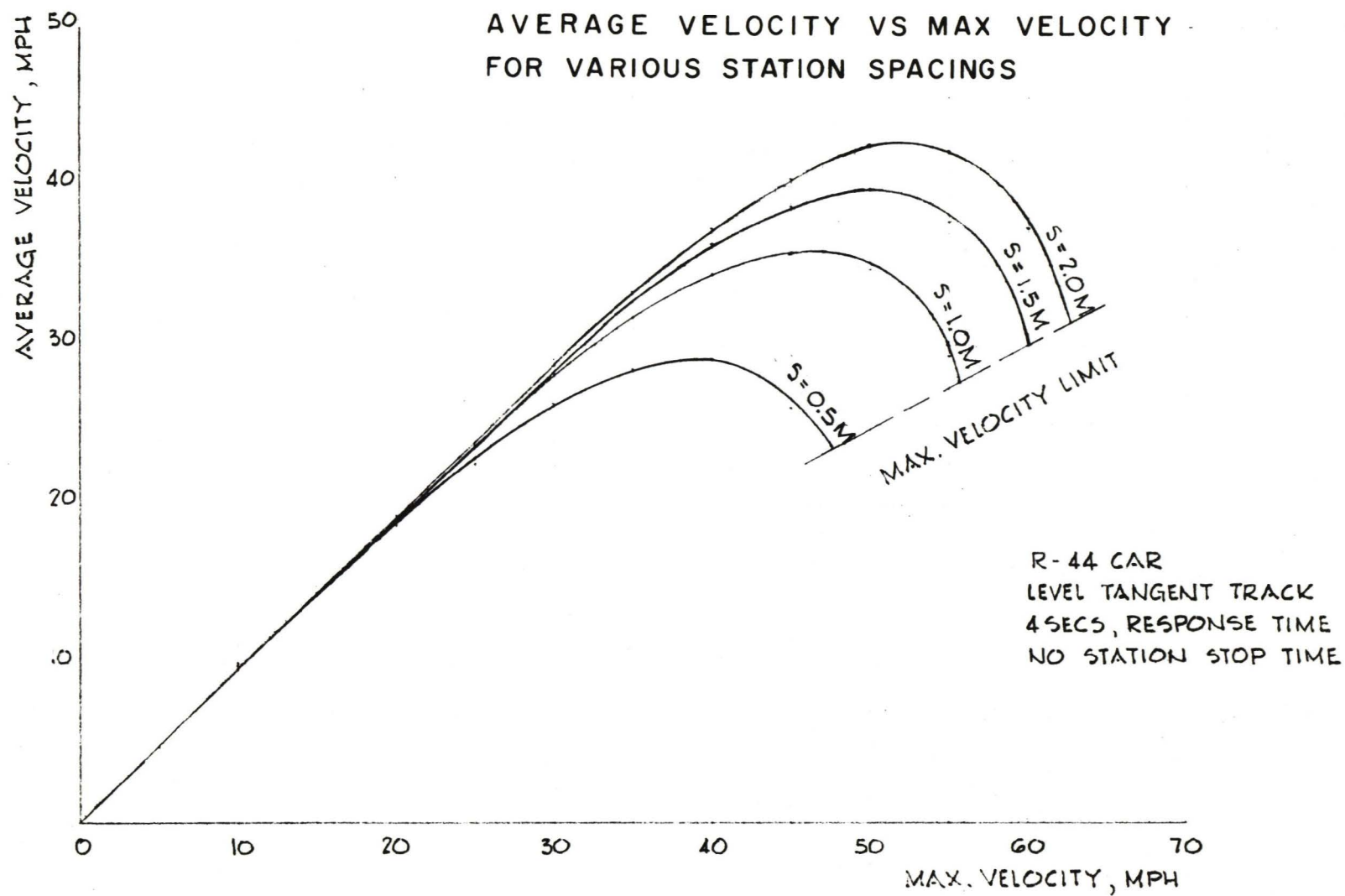


FIGURE 5.01

3. time consumed during acceleration, t_a

Acceleration and deceleration rates are not constants but vary with the type of the car (the reader is referred to Transit Authority's Car Data Book.)

Standing time, t_s is approximately a linear function of the number of passengers boarding/alighting per train door. The effects of crowding during peak-hours on standing time is clearly noticeable at heavily-used stations.

Theoretical Headway with No Station Stop

The New York City Transit Authority (N.Y.C.T.A.) uses a "fixed block" train control (Signal) system. A "fixed block" is a length of track which only one train may occupy at any given time, when the system is operating normally. In addition, leading and following trains are separated by an unoccupied block, which provides for the safety of the system. Figure 5.02 shows a typical fixed block system.

It can be seen from the figure that the distance between trains varies with their position in the "Block."

The distance between trains must provide not only for braking distance but also for the distance the following train would travel during a Reaction Time. The Reaction Time, t_r , is defined as the time interval between the sighting of a signal phase and the actual full application of brakes.

Algebraically, the relation between the minimum stopping sight distance in feet, d_s , and train velocity can be represented as

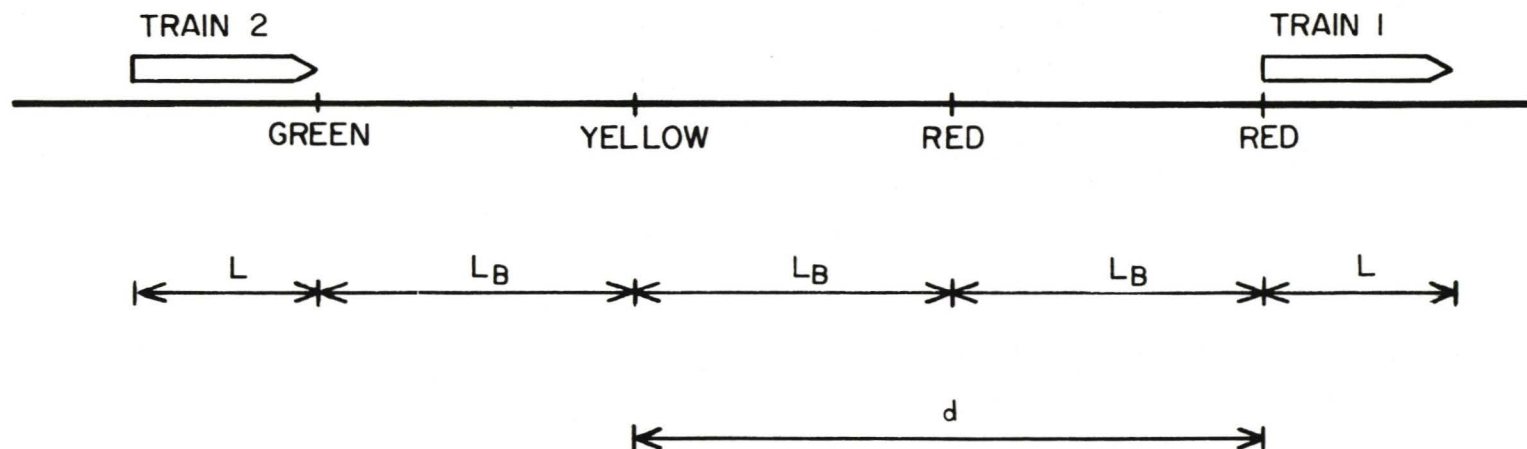
$$d_s = 1.467(Vt_r + \frac{V^2}{2b}) \quad \dots (1)$$

Where:

V = speed in MPH, and

b = rate of deceleration in MPHPS.

The minimum stopping sight distance represented by (1) is sufficient to allow the following train to stop just as it is about to touch the preceding train, under ideal conditions. No margin for error or safety factor is provided. However, a system safety of 35%, to account for variations in adhesion and equipment performance, should be provided.



L_B = LENGTH OF FIXED BLOCK

d = MINIMUM DISTANCE BETWEEN TRAINS FOR MOVEMENT AT A
CONSTANT VELOCITY

L = LENGTH OF TRAIN

ELEMENTARY FIXED BLOCK SYSTEM

FIGURE 5.02

The distance in feet between trains can now be represented as:

$$D_s = 1.35 d_s$$

$$D_s = 1.35 \left((1.467)(Vt_r + \frac{V^2}{2b}) \right) \dots (2)$$

This is the distance between the rear end of a leading train and the front end of the following train. By adding the train length, L , to D_s , we have the separation,

$$S = D_s + L$$

between similar points on the two trains, that is needed for calculation of headway.

The headway, in seconds, can now be represented by:

$$h = \frac{S}{1.467V}$$

$$h = \frac{1.35 \left((1.467)(Vt_r + \frac{V^2}{2b}) \right) + L}{1.467V}$$

$$h = 1.35t_r + 1.35 \frac{V}{2b} + \frac{L}{1.467V} \dots (3)$$

By differentiating (3) with respect to V and setting it equal to zero, we can solve for the critical velocity, V_c , at which headway is minimum:

$$\frac{dh}{dv} = 0 + \frac{1.35}{2b} - \frac{L}{1.467V^2} = 0 \quad \frac{L}{1.467V^2} = 1.35/2b$$

$$\therefore V_c = \sqrt{\frac{2bL}{1.35 \times 1.467}} = \sqrt{1.01bL} \dots (4)$$

Figure 5.03 represents theoretical Headway versus Velocity at fixed train lengths with no Station Stops. Although these curves are for a theoretical system, some general conclusions that can be drawn from such a theoretical system are:

1. At any given speed, headway decreases with a decrease in train length.
2. The longer the train, the higher its critical speed.
3. Once critical speed is reached, any increase in speed increases headway.

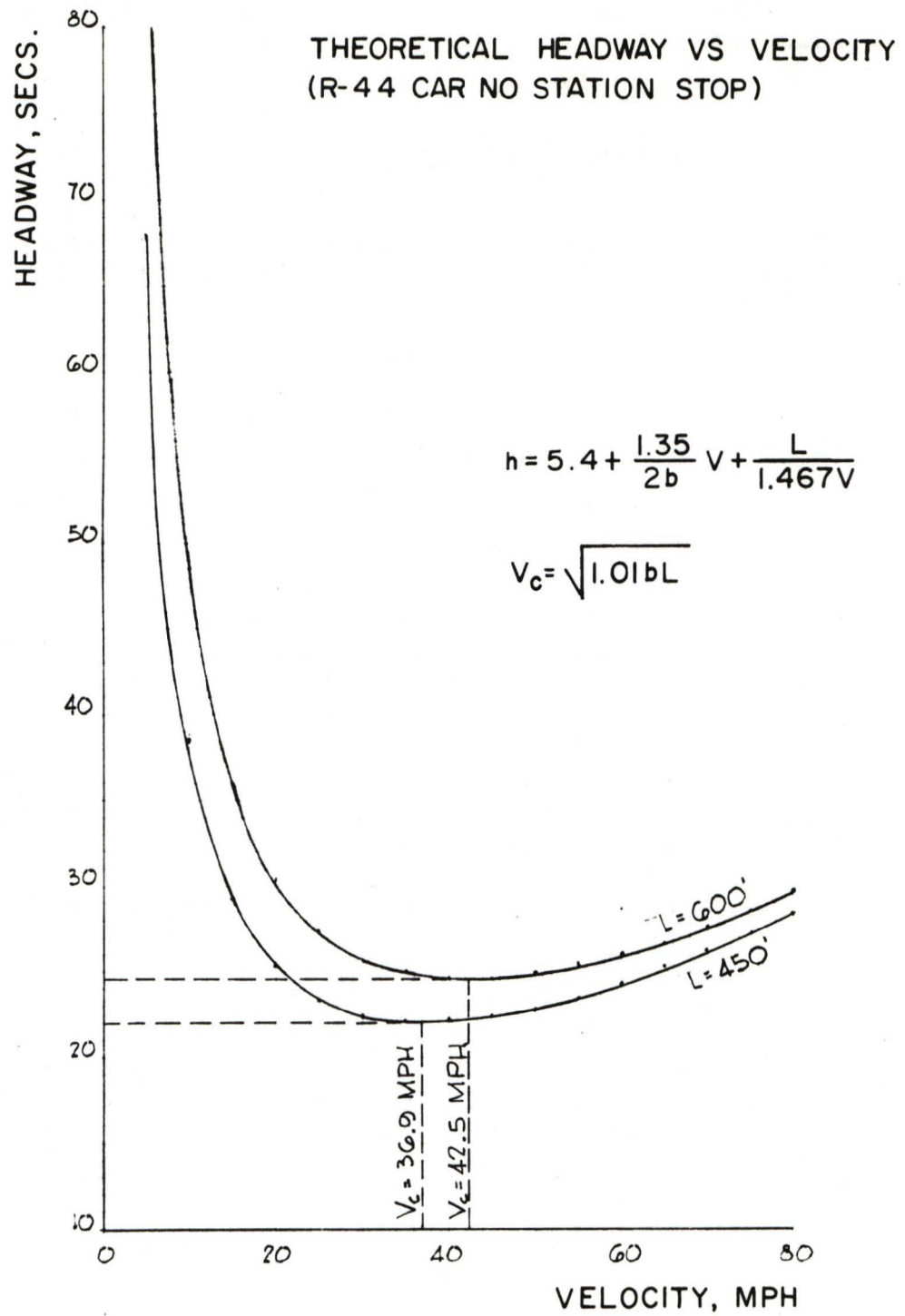


FIGURE 5.03

Theoretical Headway with Station Stop

Assume there exists a train control system that continuously monitors all train positions and has a zero reaction time; that is, whenever a leading train begins to brake, the following train begins to brake simultaneously. Also, disregard the possibility of a leading train stopping in other than a normal mode, such as by derailment. This assumed system is not practical, nor would it be safe if it were, but it allows the reduction of the spacing between trains to the absolute minimum-zero feet. In figure 5.04, this system is illustrated with the leading train shown initially in a station. To obtain the minimum headway, it is assumed that as train #1 accelerates out of the station, train #2 accelerates into the station until it must brake for the station stop.

Assume:

a = rate of acceleration, MPHPS

b = rate of deceleration, MPHPS

L = length of train, feet

d_a = distance travelled during acceleration into station, feet

d_b = distance travelled during braking for station stop, feet

t_a = time to travel distance, seconds

t_b = time to travel distance, seconds

t_s = duration of station stop = 20 seconds

V_p = peak velocity where acceleration ends and braking begins, MPH

Headway in seconds can be represented by:

$$h = t_a + t_b + t_s \quad (5)$$

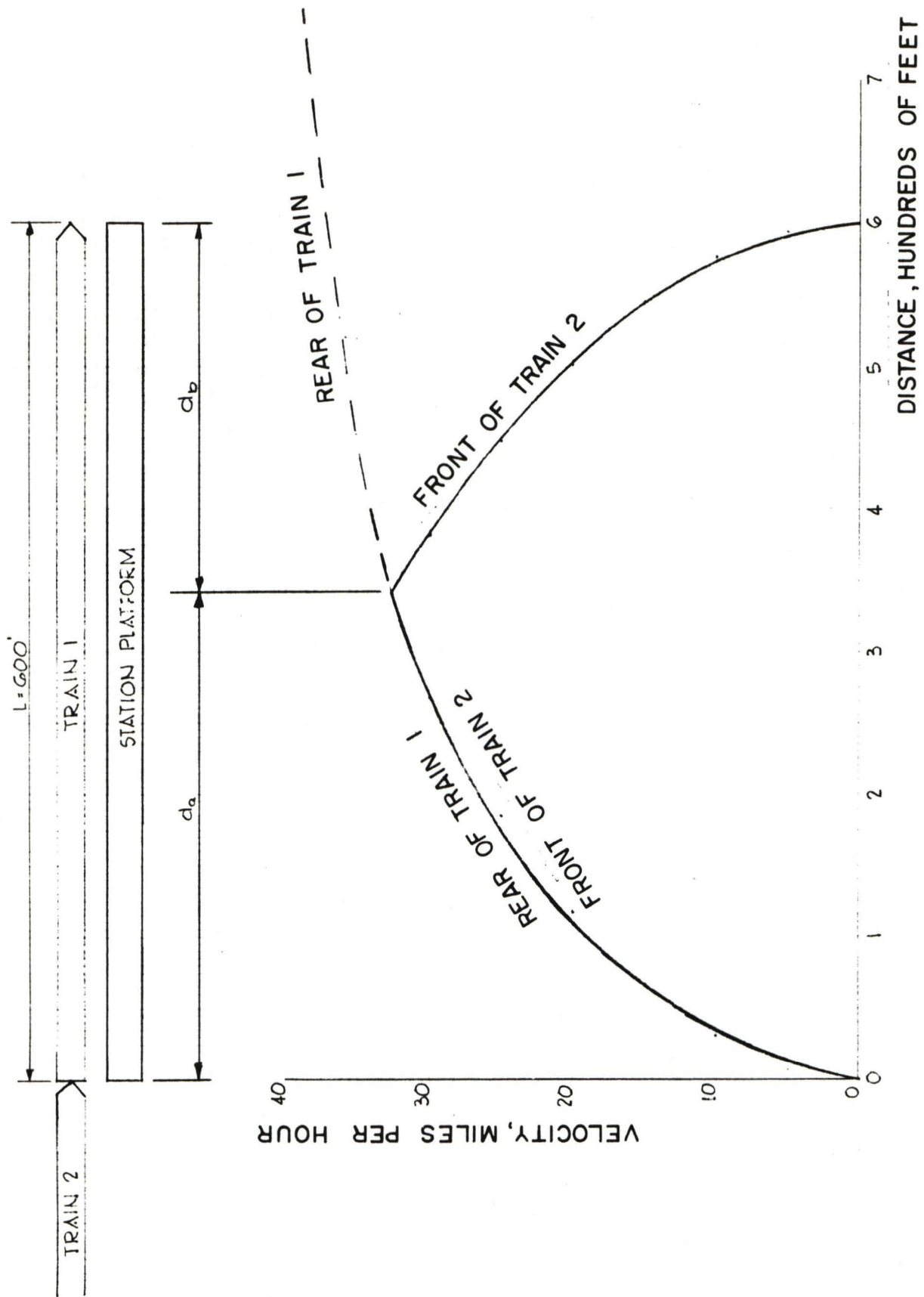


FIGURE 5.04

and

$$V_p = at_a = bt_b \quad \therefore t_a = \frac{b}{a} t_b$$

$$d_a = \frac{1}{2} (1.467) at_a^2 \quad \therefore t_a = \sqrt{\frac{2d_a}{(1.467)a}}$$

$$\text{Similarly, } t_b = \sqrt{\frac{2d_b}{(1.467)b}}$$

$$\text{and } L = d_a + d_b$$

$$\begin{aligned} &= \frac{1.467}{2} (at_a^2 + bt_b^2) \\ &= \frac{1.467}{2} \left(a \left(\frac{b}{a} \right)^2 t_b^2 + bt_b^2 \right) \\ &= \frac{1.467}{2} t_b^2 \left(\frac{b^2}{a} + b \right) \\ &= t_b^2 \left(\frac{(1.467)b(a+b)}{2a} \right) \end{aligned}$$

Therefore:

$$t_b = \sqrt{\frac{2aL}{1.467b(a+b)}} \quad \dots \dots (6)$$

Similarly,

$$t_a = \sqrt{\frac{2bL}{1.467a(a+b)}} \quad \dots \dots (7)$$

for $a = 2.5$ MPHPS, $b = 3.0$ MPHPS, and $L=600$ H.

$$t_a = 13.4 \text{ Secs. and } t_b = 11.2 \text{ Secs.}$$

Therefore:

$$h = 13.4 + 11.2 + 20 = 44.6 \text{ Secs.}$$

The minimum possible headway under idealized conditions is 44.6 seconds with a 20 second station stop. From Figure 5.04, the maximum speed attained by Train Number 2 before it starts to decelerate is approximately

32 MPH. For this speed, minimum headway is approximately 25.5 seconds (Figure 5.03.) When this is compared to the theoretical headway with Station Stop, it is evident that Station Stops are the determining factor for headway in a rapid transit system.

Practical Minimum Headway Considerations

There are a number of simplifications made in the preliminary equation for minimum headway which, when considered in practical terms, will add to the actual minimum headway that can be achieved.

They are as follows:

1. Braking distance is not provided between the rear end of train number 1 and the front end of train number 2 during the period of time when train number 2 is entering the station. (T.A. provides emergency braking distance, plus a margin of safety.)
2. The rate of acceleration is variable and dependent on the car traction system.
3. The type of operation to achieve minimum headway assumes a train protection stop in approach to the station for train number 2. It further assumes that train number 2 will accelerate into the station, and then brake to a stop. This type of operation results in a loss of schedule speed and an increase in power consumption that would be relatively inefficient.
4. There is no provision made to account for the practical tolerances required in the actual acceleration, resulting velocity and braking rate due to equipment tolerances and variations in the available adhesion.
5. There is no provision made to account for the reaction time of the total train control and traction system equipment response.
6. Time required for 'jerk' regulation of the train is not considered.

Practical Minimum Headway and Maximum Capacity

The evaluation of system headway and capacity, on a practical basis, requires that the two limiting components be combined. This combination will be the station headway plus a minimum practical separation between trains, as shown in Figure 5.05.

The minimum separation between trains required to bring a following train to a stop at a service braking rate short of hitting a leading train has been shown to be:

$$S = \frac{1.467V^2}{2b} + L \quad (8)$$

This separation can be broken down into three distinct distances:

d_a = distance travelled during acceleration.

d_b = distance travelled during braking.

d_c = distance travelled at a constant velocity in approach to the station.

$$\therefore S = d_a + d_b + d_c \quad (9)$$

Combining Formulas (8) and (9) and rearranging:

$$d_c = \frac{1.467V^2}{2b} + L - d_a - d_b \quad (10)$$

And it has been shown that the distance travelled in accelerating and braking is:

$$d_a = \frac{1.467V^2}{2a} \quad \text{and} \quad d_b = \frac{1.467V^2}{2b}$$

Substituting in (10) the distance travelled at the constant velocity:

$$d_c = (1.467) \left(\frac{V^2}{2b} - \frac{V^2}{2a} - \frac{V^2}{2b} \right) + L$$

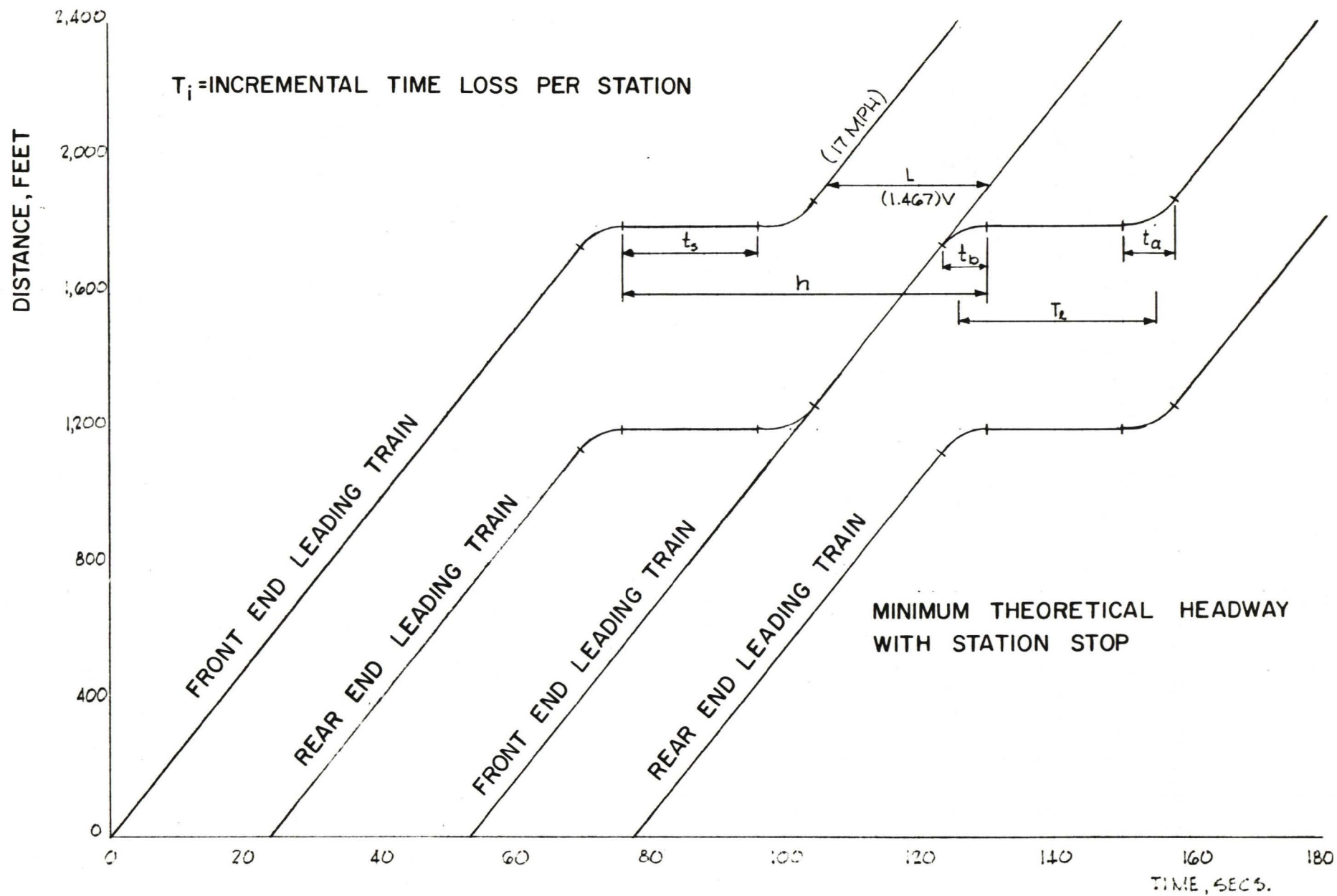


FIGURE 5.05

Simplifying:

$$d_c = L - \frac{1.467V^2}{2a} \quad \dots (11)$$

The time consumed while traveling at the station approach velocity is:

$$t_c = \frac{d_c}{1.467V}$$

and substituting:

$$t_c = \frac{L}{1.467V} - \frac{V}{2a} \quad \dots (12)$$

Adding the time consumed by train number 2 traveling at a constant velocity in approach to the station, to station headway, an expression for a more practical minimum headway is obtained:

$$h = h_s + t_c$$

Where:

$$h_s = t_a + t_b + t_s = \frac{V}{a} + \frac{V}{b} + t_s$$

$$\text{Therefore: } h = \frac{V}{a} + \frac{V}{b} + t_s + \frac{L}{1.467V} - \frac{V}{2a}$$

Combining terms and rearranging:

$$h = \frac{V}{2a} + \frac{V}{b} + \frac{L}{1.467V} + t_s \quad \dots (13)$$

Differentiating h , with respect to V and equating it to zero,

$$\frac{dh}{dv} = \frac{1}{2a} + \frac{1}{b} - \frac{L}{1.467V^2} + 0 = 0$$

$$\therefore V^2 = \frac{L}{1.467} \cdot \frac{2ab}{(2a+b)}$$

$$\sqrt{V^2} = V_{\text{critical}} = \sqrt{\frac{2abL}{1.467(2a+b)}} \quad \dots (14)$$

Figure 5.06 is a plot of the maximum obtainable capacity expressed in train feet per hour past a given point, with a 20 second station stop. Curves are plotted for two different train lengths.

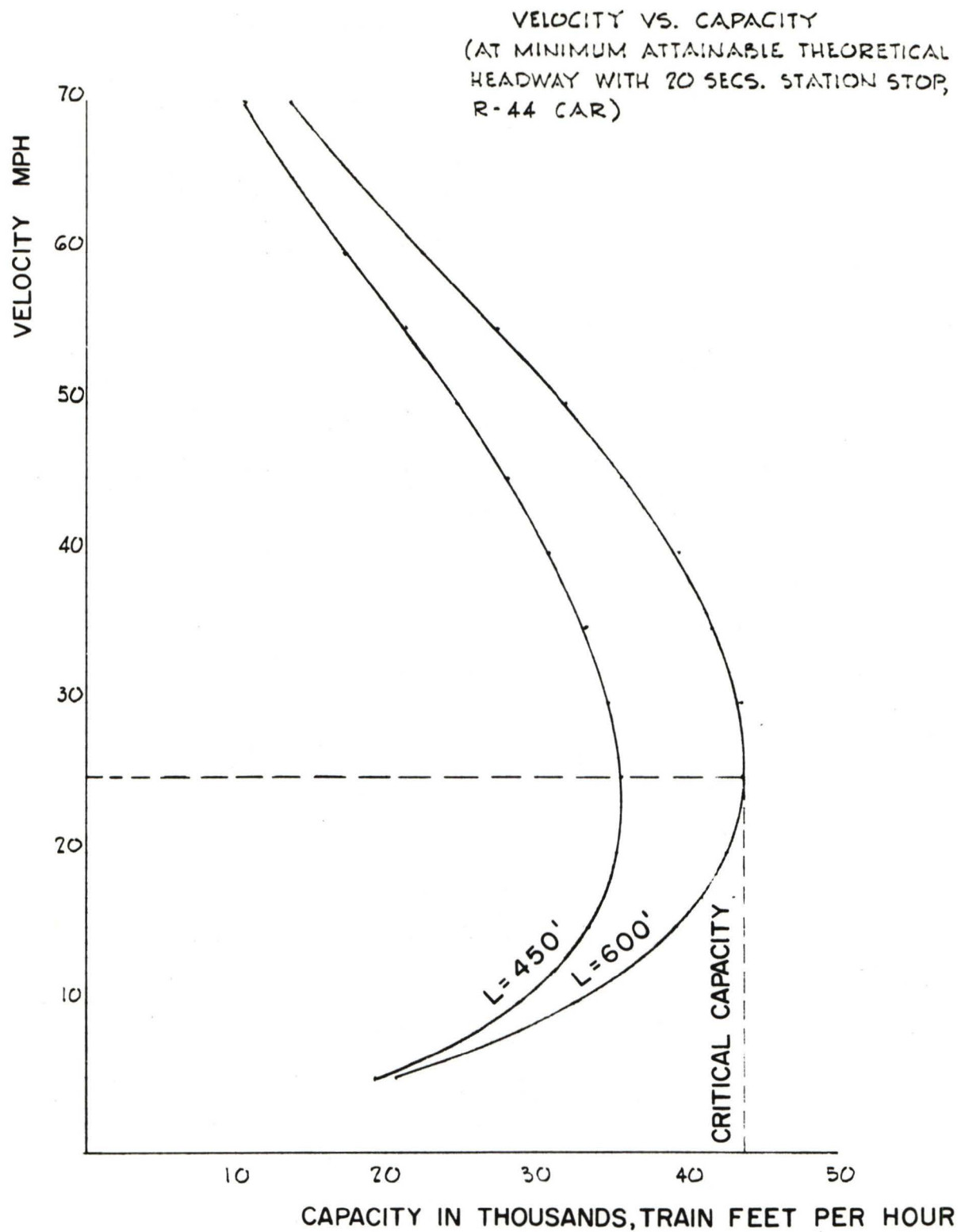


FIGURE 5.06

VELOCITY VS. CAPACITY
WITH 20 SEC. STA. STOP
(R-44 CAR)

V	h (L=600)	h (L=450)	C' _T (L=600)	C' _T (L=450)
---	-----	-----	-----	-----
5	104.3	84.07	20,710	19,270
10	66.3	56.03	32,579	28,913
15	55.3	48.5	39,060	33,402
20	51.17	46.07	42,212	35,164
25	49.73	45.6	43,435	35,526
30	49.9	46.45	43,287	34,876
35	51.87	48.87	41,643	33,149
40	54.9	52.4	39,344	30,916
45	60.1	57.84	35,940	28,008
50	67.34	65.29	32,076	24,812
55	78.48	76.63	27,523	21,140
60	96.51	94.8	22,381	17,088
70	156.27	154.82	13,822	10,464

$$C'_T = 3600 L/h$$

TABLE 5.03

The theoretical minimum headway for a 600 ft. train is calculated to be 49.7 seconds, a capacity of 43,435 train feet per hour, as shown in Table 5.03. This is the equivalent of 72 trains per hour, each of which is 600 feet long. To achieve this capacity, the maximum speed is 25.0 MPH.

Practical Headway in a Practical System

In all computations of headway up to this point the limitations imposed by an actual train control system have been neglected. When an actual system is considered, it is found that the theoretical minimum headways cannot be approached as closely as one would like.

The 3 aspect, 3 block wayside signaling system of intermittent train control presently in use on the New York City Transit Authority System adds seconds to headway due to considerations of:

1. Sighting distance.
2. Limitations imposed by only two permissive aspects.
3. Extra block length necessary due to maximum attainable speed assumption.
4. Non-continuous train control.
5. Restrictions over special work.
6. Restrictions due to curve, grades or roadbed conditions.

The last two items are actually dependent on track layout and would not be appreciably changed by use of a different train control system. The first four items can be affected by a cab signaling system with automatic train control and speed regulation.

IV - ADHESION

Adhesion is defined as the tangential frictional force that develops between train wheels and rail any time a train is in motion. The coefficient of adhesion is a characteristic of the two surfaces in contact and proves to be the limiting factor in determining the maximum tractive effort that can be developed on a rail system.

The coefficient of adhesion is identical to the coefficient of friction and can be calculated by dividing the maximum force developed before wheel slippage begins by the force normal to the direction of travel:

$$K_a = \frac{F_t}{F_n}$$

Where:

K_a = coefficient of adhesion.

F_t = tangential force developed at wheel slippage.

F_n = normal force.

On level, tangent track the normal force is equal to the weight of the train, W :

$$F_n = W$$

and

$$K_a = \frac{F_t}{W}$$

The force that is required to accelerate or decelerate a train is given by the mass of the train (m) multiplied by the rate of acceleration (a) or deceleration (b). Considering deceleration:

$$F = mb$$

The maximum force that can be used for deceleration is that force where the wheels just begin to slip.

Therefore:

$$F = F_t$$

and substituting:

$$mb = K_a W$$

The mass of train is equal to the weight of the train divided by the acceleration due to gravity, $g = 32.2$ feet per second.

$$m = \frac{W}{g}$$

Therefore: $\frac{W}{g} b = K_a W$

Which reduces to: $K_a = \frac{b}{g} = \frac{1.467B}{32.2} = 0.0455B$

And $B = 22K_a$

Where B = braking rate in MPHPS.

These relationships clearly illustrate that adhesion capabilities control braking rates and similarly acceleration rates.

The coefficient of adhesion varies with the physical condition of the surfaces in contact. In general, rough surfaces have relatively high coefficients and smooth surfaces have low coefficients. The adhesion between two surfaces can be lowered by wetting the surfaces; it can be lowered further by oiling the surfaces.

The coefficient of adhesion also varies with the velocity of the train, decreasing as train velocity increases. Figure 5.07 is a series of adhesion versus velocity curves for various rail conditions taken from test data on the Pennsylvania Railroad.

A coefficient of adhesion of 13.7% is a safe, reasonable value to be used in the determination of the maximum allowable deceleration rate for calculating braking distances. An adhesion coefficient of 13.7% corresponds to a deceleration rate of 3.0 MPHPS.

V - BRAKING DISTANCE

The following equation gives the braking distance required for a body traveling at a particular velocity (up to 40 MPH) to decelerate to rest (zero velocity) at a constant rate on level track.

$$\text{Where: } D = \frac{0.733V^2}{B} \quad \dots (1)$$

D = distance traveled in feet

V = velocity in mph

B = braking rate in mphps

A simple mathematical analysis cannot be made to yield braking distances for velocities greater than 40 MPH due to the variation of deceleration with velocity.

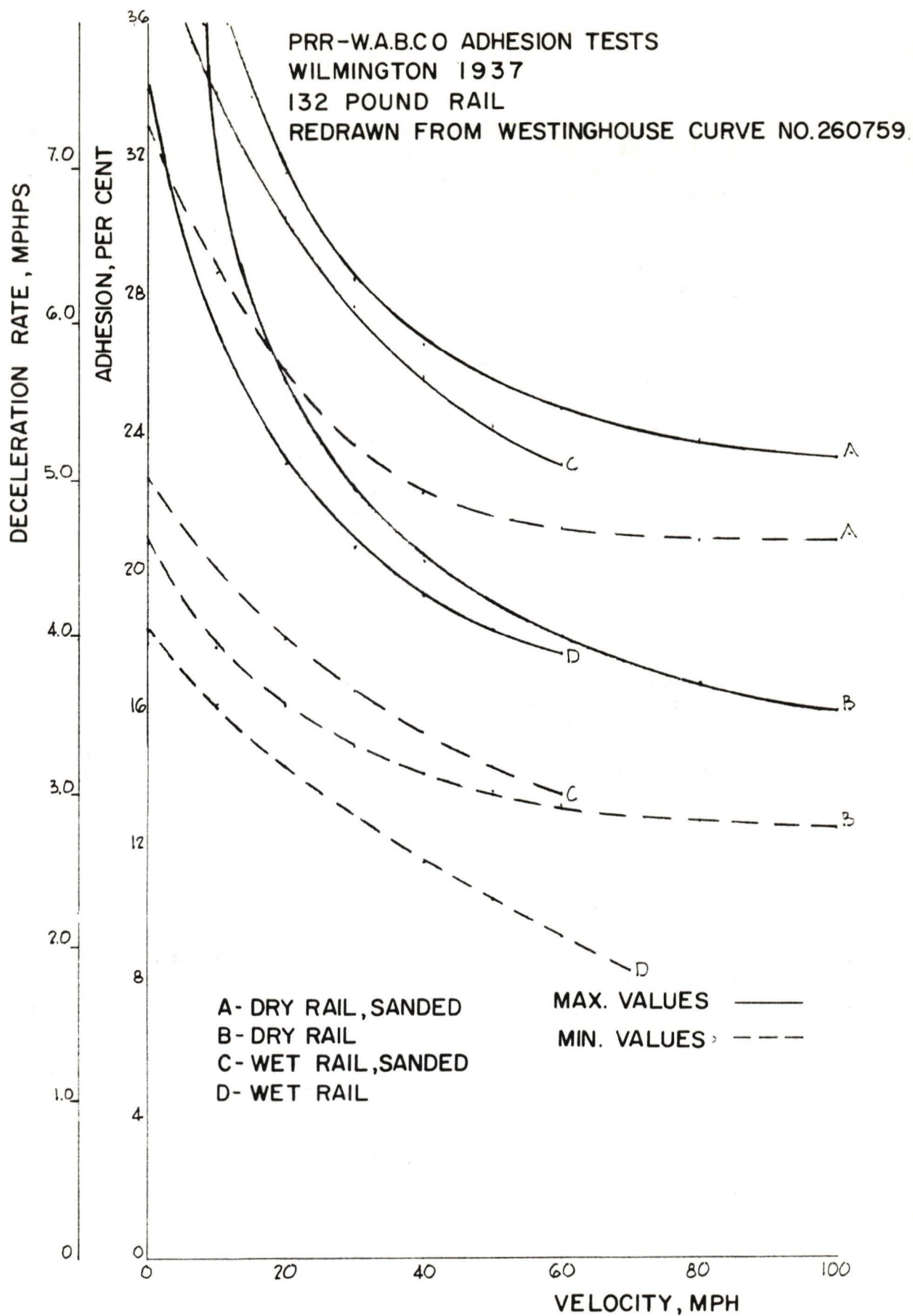


FIGURE 5.07

TP-5-25

An incremental approximation using 5 MPH velocity increments and the average acceleration rate during the increment will yield results that are almost equal to (maximum possible error is less than 1.8%) those obtained through rigorous mathematical analysis.

The distance traveled during a 5 MPH decrease is given by:

$$d_i = \frac{.733}{B_a} (V_i^2 - (V_i - 5)^2) \dots (2)$$

Where:

d_i = distance traveled in decelerating from velocity V_i to a velocity 5 MPH less.

B_a = arithmetical average of the instantaneous deceleration rates at velocities V_i and $V_i - 5$ MPH.

Using the relationship that the braking distance, in any range where the acceleration is uniform, is equal to the average velocity multiplied by the time the velocity is averaged over, the following expression is valid for velocities less than 40 MPH.

$$t = \frac{V}{B}$$

Where t is the total time consumed in decelerating to a stop from a velocity V of 40 MPH or less and B is a constant braking rate.

The time, t_i , consumed in decelerating from velocities greater than 40 MPH is calculated by using the same increments used for calculation of distance, D_i .

$$t_i = \frac{d_i}{(.733)(2V_i - 5)}$$

BRAKING DISTANCE AND TIMES FOR SPEEDS OVER 40 MPH

Velocity Range Traveled Through V_i MPH to $V_i - 5$ MPH	Average Deceleration Rate B_a , in MPHPS	Distance d_i , in feet	Time t_i , in sec.
70 to 65	2.52	197	1.98
65 to 60	2.61	176	1.92
60 to 55	2.69	157	1.86
55 to 50	2.78	138	1.79
50 to 45	2.89	121	1.74
45 to 40	2.96	105	1.63

SYSTEM RESPONSE TIME

The previous braking distances are the distances covered from the time deceleration starts to actual stop. No account has been made for any distances which may be covered in the system response time; that is, the time that elapses from a point where lower speed command is transmitted to a point where deceleration actually begins.

The distance traveled during the response time is given by:

$$D_r = 1.467 V t_r$$

Where:

D_r = distance traveled during response time, in feet.

V = velocity, in miles per hour.

t_r = system response time, in seconds.

Figure 5.08 is a graph of velocity versus braking time, and velocity versus braking distance, with and without response time.

EFFECTS OF GRADES

Downgrades increase braking distance, and upgrades decrease braking distance. The braking distance, distance traveled with brakes applied, is given by:

$$D_b = \frac{DV^2}{V^2 + 30D(\pm G)} \quad (3)$$

Where:

D_b = braking distance, in feet.

D = braking distance on tangent level track, in feet, excluding distance traveled during response time.

V = velocity, in mph.

G = rate of grade

+ for ascending grade

- for descending grade

VELOCITY VS BRAKING TIME
VELOCITY VS BRAKING DISTANCE
(R-44 CAR, LEVEL TANGENT TRACK)

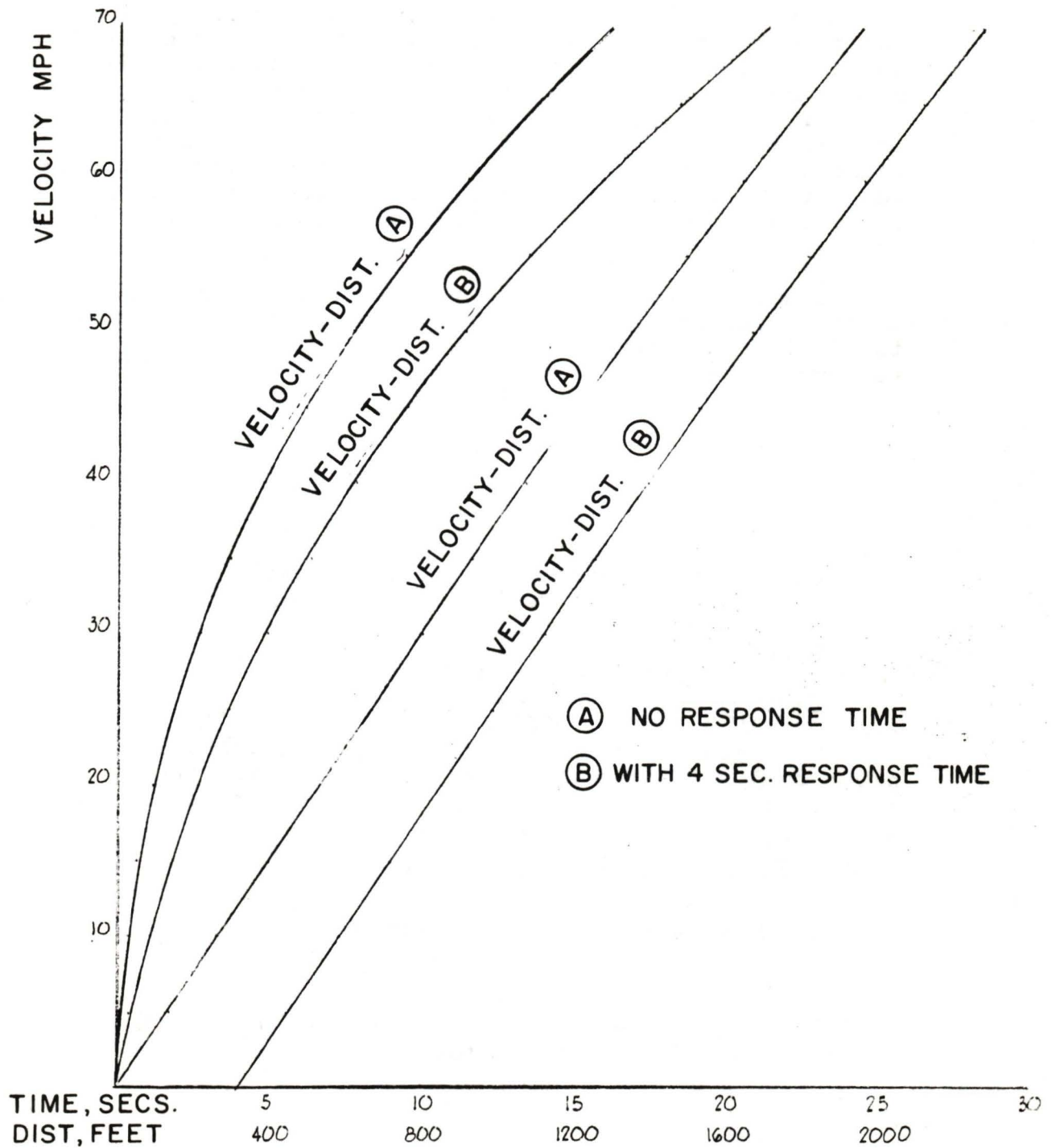


FIGURE 5.08

When braking distances are measured on a level test track, the distance measured is from the point of entrance into the control block to the point at which the train comes to a stop. This measured distance includes both the distance covered with brakes applied and the distance covered during the system response time.

Distance traveled during response time is not a function of grade but only of velocity during the response time. That is, a train traveling at a velocity of V_1 mph on level tangent track will travel the same distance in seconds, during response time, as a train traveling at V_1 mph on a $\pm 2\%$ grade. This is true because the tractive effort produced by the propulsion system with speed regulation control can compensate for force changes due to grades and maintain a constant velocity.

Grade compensations, therefore, are not applied to the measured braking distance but rather to the measured total distance minus the distance traveled during the response time:

$$D = D_t - 1.467 V t_r$$

Where:

D_t = total distance to stop, on level tangent, in feet.

Therefore:

$$D_b = \frac{V^2(D_t - 1.467Vt_r)}{V^2 + 30(D_t - 1.467Vt_r)(\pm G)} \dots (4)$$

The total distance to stop on a grade, D_T , is that given by D_b plus the distance traveled during the system response time. Therefore, the general equation for braking distance on a grade is:

$$D_T = \frac{V^2(D_t - 1.467Vt_r)}{V^2 + 30(\pm G)(D_t - 1.467Vt_r)} + 1.467Vt_r \dots (5)$$

If $t_r = 4$ seconds, (5) becomes:

$$D_T = \frac{V^2(D_t - 5.867V)}{V^2 + 30(\pm G)(D_t - 5.867V)} + 5.867V \dots (6)$$

Table 5.04 is a tabulation of braking distances for velocities of 5 to 70 mph and grades of +5% to -5% with a response time of 4 seconds. This data is used in the design of a train control system.

VI - ACCELERATION

Acceleration and deceleration are limited by the adhesion capabilities of the wheel to rail system. Other factors which affect the desired acceleration characteristics of a rapid transit train are:

1. passenger comfort.
2. traction motor.
3. power demand and consumption.

Passenger Comfort

The generally accepted maximum rate of acceleration is 3 mphps for a rapid transit system requiring standees in the vehicle. Repetitive accelerations above 3.3 mphps tend to make even seated passengers uncomfortable. Jerk regulation, or the control of the rate of change of acceleration, is an aid to passenger comfort when high acceleration rates are used.

Traction Motor

The DC traction motor has an inverse torque-speed characteristic which results in decreased acceleration with increasing speed. The traction motor curves, Figure 5.09, for the Westinghouse 1447 traction motor show the acceleration motor speed characteristics for the tractive motor. The acceleration is limited by the allowable motor current below 960 RPM. The full field curve shows the relationship of acceleration to motor speed when the field is not weakened, which will be the case for operation on lines without a continuous train control system. When operating in continuous train control territory, the motor field will be continuously weakened between 960 and 1750 RPM to produce a constant horsepower (acceleration inversely proportional to speed.) This is accomplished by continuously weakening the field by shunting with resistors or inductive elements. Above 1750 RPM the field is fully weakened to 28% of full field strength and the performance curve follows the inherent speed-torque characteristics.

Negative and Positive Grade Braking Distances Calculated from (6)

PER CENT GRADE

Velocity	-5	-4	-3	-2	-1	0	+1	+2	+3	+4	+5
5	38	37	37	36	35	35	35	34	34	34	33
10	97	93	90	87	85	83	81	80	79	78	77
15	175	166	158	152	147	143	139	136	133	131	128
20	273	256	243	232	223	215	208	202	197	193	189
25	388	363	343	326	312	300	290	281	270	265	259
30	522	487	458	434	413	396	381	368	356	346	337
35	676	627	588	555	528	504	484	466	450	436	424
40	851	787	736	693	657	626	599	576	556	538	522
45	1061	967	900	845	799	760	726	696	670	647	626
50	1272	1169	1086	1017	959	910	867	830	798	769	743
55	1531	1402	1297	1211	1139	1078	1025	980	939	904	872
60	1823	1662	1533	1427	1339	1264	1200	1144	1095	1051	1013
65	2150	1953	1796	1667	1560	1469	1391	1324	1265	1213	1167
70	2526	2283	2092	1934	1805	1695	1601	1521	1450	1388	1333

TABLE 5.04

TP-5-32

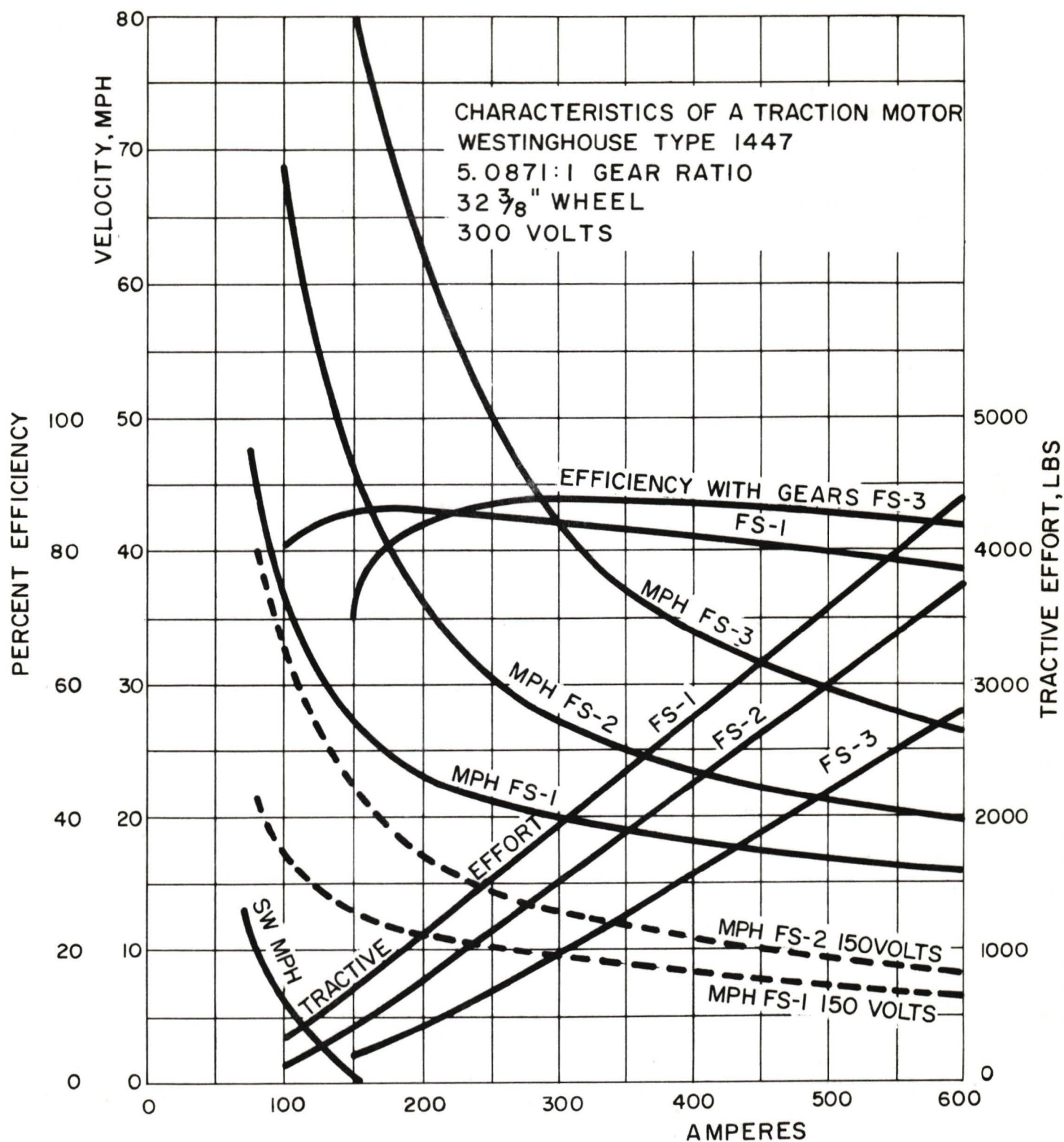


FIGURE 5.09

The DC motor has commutation limits which determine the maximum speed of rotation. For a given wheel diameter, the gear ratio is determined by the desired maximum velocity or balancing speed. The tractive effort required to move the mass of the train at the desired acceleration rate then determines the actual size of the motor. The size of the motor, as related to its rated output, depends on the motor heating. The physical motor size and weight is also dependent on speed and, therefore, on gear ratio and the diameter of the wheels.

If the gear ratio is low, the maximum speed will be high and the rate of acceleration low. If the gear ratio is high, the maximum speed will be low and the rate of acceleration high. Increasing the gear ratio in any particular motor decreases the train speed and increases the tractive effort, both in the same ratio, assuming the current is constant. Any alteration in the diameter of the wheels should be treated as equivalent to an alteration in the gear ratio, an increase in the wheel diameter being equivalent to a decrease in the gear ratio. Conversely reducing the wheel diameter is equivalent to an increase in the gear ratio.

Acceleration versus Train Velocity, Figure 5.10, shows the average acceleration from stop to a given velocity on level track. These accelerations are computed for the W 1447 D Motor with a 5.087:1 Gear Ratio with a balance speed of 80 mph and an initial acceleration rate of 2.5 mphps.

Power Demand and Consumption

A higher acceleration rate is characterized by lower power consumption and higher power demand for any particular run. The theoretical minimum for power consumption occurs when acceleration rate is infinite, since power consumption is calculated from the area under the power-time curve from start to motor cut-off (coasting or braking beginning.) If the acceleration is infinite to 70 mph, then the time to reach 70 mph is equal to zero, and the power-time curve is a single vertical line enclosing zero area. Zero area enclosed would mean zero power consumed in accelerating to 70 mph. As acceleration approaches infinity, tractive effort also approaches infinity and since power input increases with tractive effort, power demand also approaches infinity. In actual practice, it is impossible to approach infinite acceleration. As the acceleration rate is increased, the maximum power demand increases, but the length of time of application of power decreases with the net effect that in the practical range of values for acceleration rates, 1.5 mphps to 3.0 mphps, higher rates mean less power consumed.

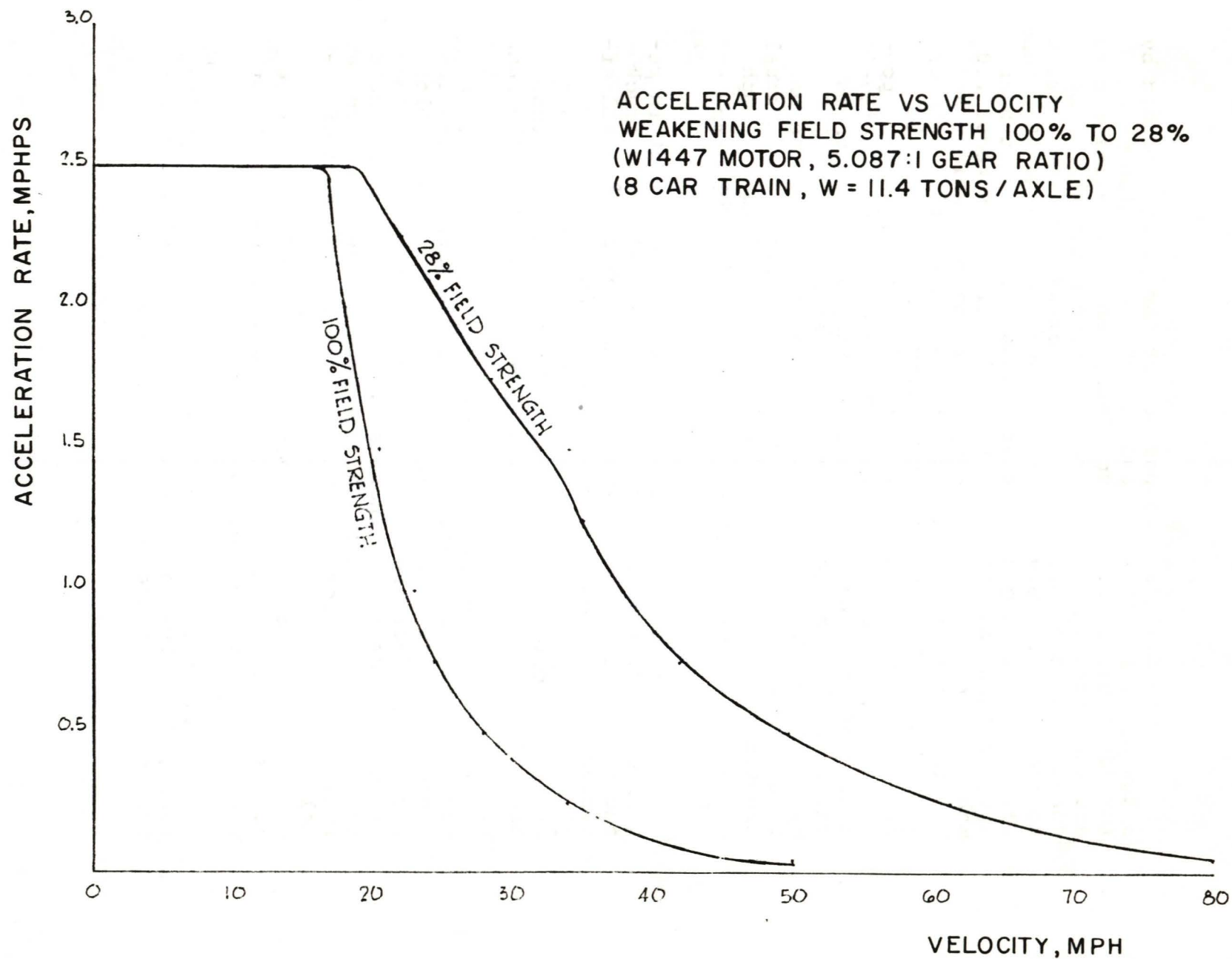


FIGURE 5.10

Figure 5.11 is a comparison of the power consumed by a low acceleration motor and a high acceleration motor for identical runs. The speed-time and power-time curves are idealized as no practical traction motor maintains constant acceleration to 70 mph or draws constant current to that speed. Curve "A" is for an 8-car train, 45.6 tons per car, (car weight and seated passenger load) with an acceleration rate of 2.5 mphps and a braking rate of 2.0 mphps. Curve "B" is for a train of the same weight and braking characteristics but with an acceleration rate of 1.75 mphps. The velocity-time curve in each case is drawn to show a 1.5 mile run in 115 seconds, and the power-time curves are drawn to correspond to the velocity-time profile. The power demand during acceleration is calculated as the power required to accelerate at 2.5 mphps at 70 mph, and is assumed constant during the entire acceleration period (which is not true for an actual traction motor.) The power required to maintain 70 mph is calculated as the power required to overcome train resistance.

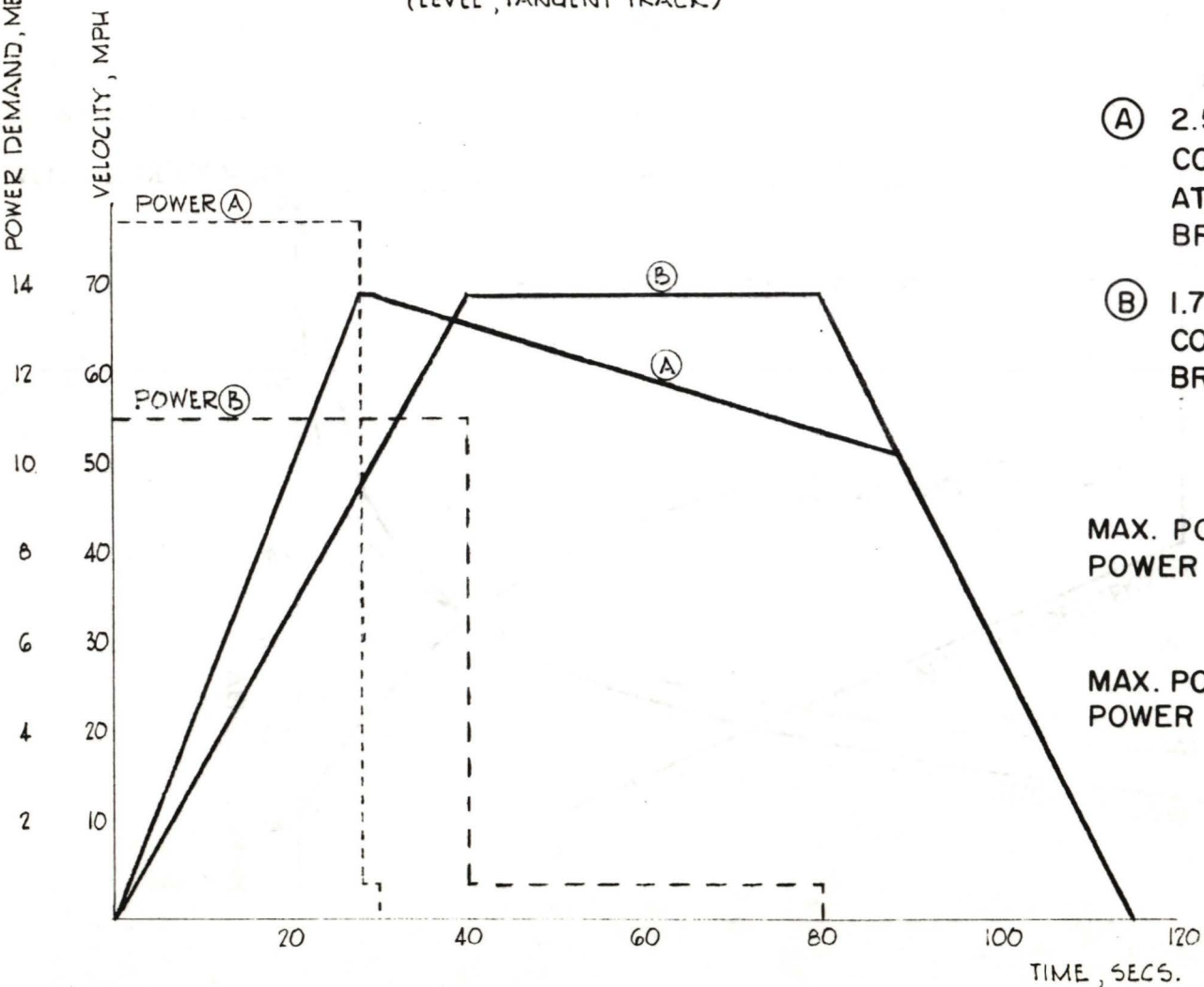
Power in all cases is taken as the power that is required at the rims of the wheels on level-tangent track and then divided by 85% (which is the assumed overall efficiency of the motors, gears, controllers, etc.) to yield the input power. The higher performance train "A" demands almost 40% more power during acceleration than train "B" but consumes 8% less power in the 1.5 mile run.

An additional power savings can be obtained by increasing the deceleration rate. As the braking rate increases, the time to decelerate from a particular velocity to zero decreases and, therefore, the average velocity of the entire run increases. If conditions are held equal, then to maintain the same average velocity over a run, as the deceleration rate increases, the time of acceleration or the time at constant velocity must decrease. A decrease in either acceleration time or time run at constant velocity will yield a corresponding decrease in power consumption.

Figure 5.12 shows the Velocity-Time, Velocity-Distance, Velocity-Deceleration, and Velocity-Tractive Effort curves for the R-44 traction motor.

POWER DEMAND, MEGAWATTS/TRAIN

PERFORMANCE COMPARISON
(8 CAR TRAIN, $w = 11.4$ TON/AXLE, 1.5 MILE RUN)
(LEVEL, TANGENT TRACK)



AVERAGE SPEED 47MPH

(A) 2.5 MPHPS ACCELERATION
CONSTANT TO 70MPH, COASTING
AT 0.3 MPHPS DECELERATION,
BRAKING 2.0 MPHPS.

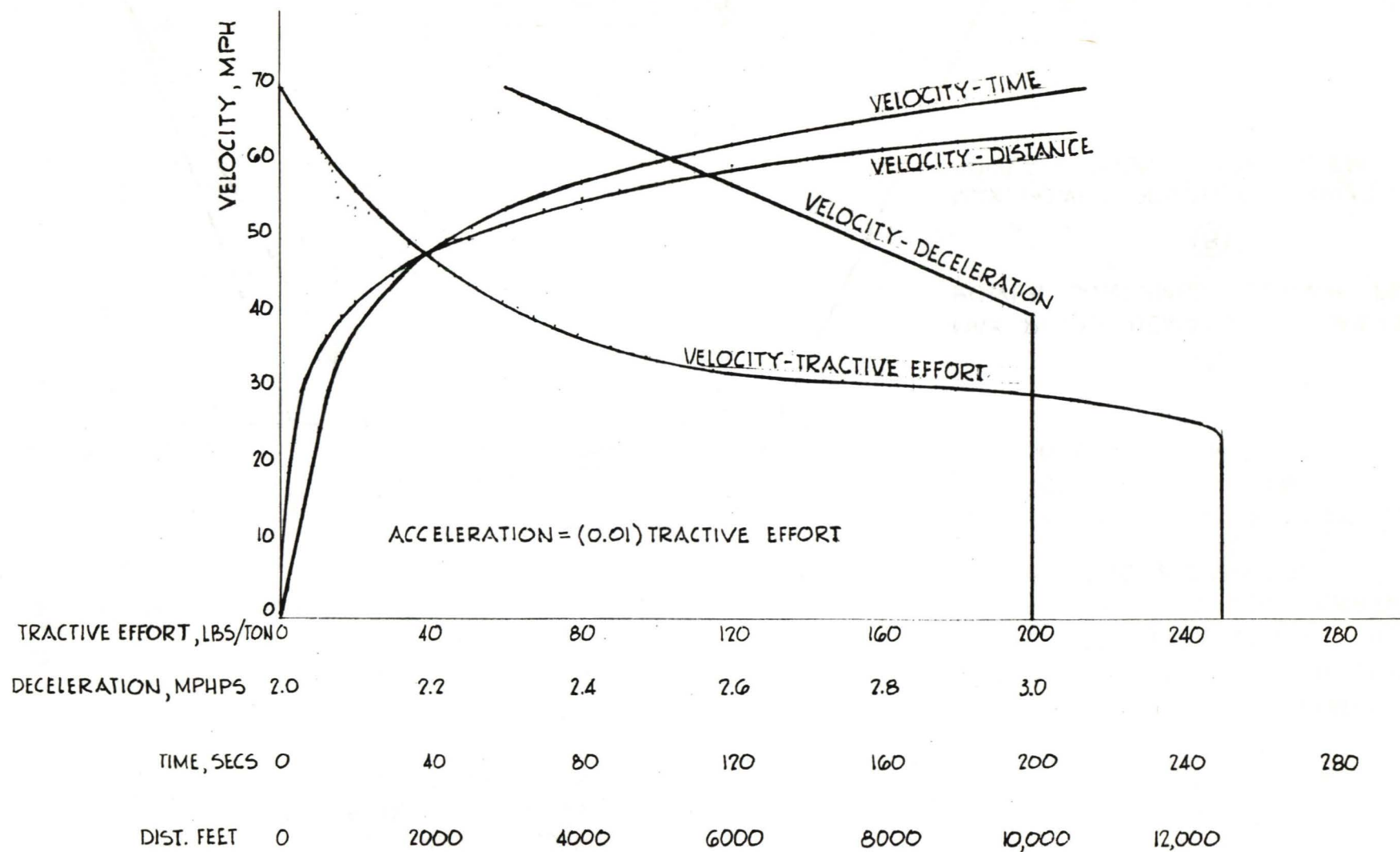
(B) 1.75 MPHPS ACCELERATION
CONSTANT TO 70 MPH,
BRAKING 2.0 MPHPS.

(A)
MAX. POWER DEMAND = 15.7 MW/TRAIN
POWER CONSUMED = 82 KWH/TM

(B)
MAX. POWER DEMAND = 11.3 MW/TRAIN
POWER CONSUMED = 89 KWH/TM

FIGURE 5.11

TP-5-38



CHARACTERISTICS OF A R-44 8 CAR TRAIN
(LEVEL TANGENT TRACK, $w = 11.4$ TONS)

FIGURE 5.12

VII - RESISTANCE

The main impeding forces acting on a moving train are:

1. curve resistance
2. grade resistance
3. train resistance

Curve Resistance

The movement of a train along a curved track is retarded a certain amount by the flanges of car wheels bearing on the rails. This impeding effect is proportional to the wheel base and degree of curve and is taken as 0.8 lbs. per ton per degree of curvature:

$$T_c = .8D = .8 \times \frac{5730}{\text{radius}}$$

Where:

T_c = the tractive force required to overcome curve resistance in pounds per ton.

D = degree of curvature.

Curve resistance is seldom a major factor and is usually neglected.

Grade Resistance

Grade resistance is that additional factor which must be overcome by the car motors if the car is to move on an upgrade. To reach a given rate of acceleration, increased tractive effort must be supplied by the car motors in addition to that necessary for the same rate of acceleration on level track. This factor is considered as a virtual increase in the weight of the truck, with the car motors developing the same tractive effort for the same speed, resulting in a lower rate of acceleration. A positive grade imposes additional work on the car motors, while a negative grade lessens the work-load of the car motors, in which case grade resistance becomes grade-effort and results in an increase in rate of acceleration.

$$T_g = 20 (\pm G)$$

Where:

T_g = tractive effort necessary to overcome the effect of grades in pounds per ton.

G = percent grade

+ for upgrade

- for downgrade

Train Resistance

Train resistance comprises all of the forces which tend to retard the progress of a moving car on tangent level track. These forces are:

1. track resistance due to rolling friction of the car wheels on a more or less uneven rail surface.
2. wind resistance due to the wind pressure on the head of the car and the skin friction on the sides of following cars.
3. frictional resistance due to the bearings of the motor, gears, journals, etc.

Train resistance is expressed in pounds per ton of train weight. It is always present and varies with the speed.

Total train resistance is calculated using the Davis Formula.

$$TR = TR_1 + (N-1) TR_2$$

Where:

TR = tractive effort (level-tangent) necessary to overcome the car bearing (T_{CBF}), rolling friction (T_{CRF}), and wind resistance (T_{CWF}), lbs. per ton.

TR_1 = tractive effort required to overcome resistance of lead car, lbs. per ton.

$$TR_1 = T_{CBF} + T_{CRF} + T_{CWF_1}$$

TR_2 = tractive effort required to overcome resistance of following car, lbs. per ton.

$$TR_2 = T_{CBF} + T_{CRF} + T_{CWF_2}$$

Where:

$$T_{CBF} = (1.3 + \frac{29}{W})$$

$$T_{CRF} = 0.045V$$

$$T_{CWF_1} = \frac{0.0024 AV^2}{WNn}$$

$$T_{CWF_2} = \frac{0.00034 AV^2}{WNn}$$

A = area in square feet of cross-section of car body and trucks.

N = number of cars per train.

n = number of axles per car.

V = velocity in mph.

W = average load per axle, tons.

Therefore:

$$\begin{aligned} TR &= (1.3 + \frac{29}{W}) + 0.045V + \frac{0.0024 AV^2}{Wn} \\ &+ (N-1) \left((1.3 + \frac{29}{W}) + 0.045V + \frac{0.00034 AV^2}{Wn} \right) \\ &= N \left((1.3 + \frac{29}{W}) + 0.045V \right) + \left(\frac{0.0024 + (N-1) 0.00034}{Wn} \right) AV^2 \\ R &= \frac{TR}{N} + (1.3 + \frac{29}{W}) + 0.045V + \frac{(0.0024 + (N-1) 0.00034) AV^2}{NWn} \end{aligned}$$

Where:

R = average train resistance of car,
level-tangent, in lbs./ton.

Figure 5.13 represents a graph of Train Resistance versus Velocity, for N = 8 and A = 100 S.F.

VIII - SPEED-DISTANCE AND TIME-DISTANCE CURVES

Speed-distance and time-distance curves are used to determine the optimum operating speeds, the running times, and the required emergency and service braking distances, including the necessary factors of safety.

The maximum speed-distance curve gives the maximum speed of the front end of a train at any point in the run.

Typical speed-distance and time-distance curves are shown in Figure 5.14.

In order to compute data for the speed-distance and time-distance curves, it is necessary to know the motor tractive effort, at the car wheel, in pounds per ton of car-load, for any speed from standstill to the maximum speed at which the train can travel. This force, applied at the car wheel, must overcome the train resistance consisting of the rolling friction of the wheels and track, wind resistance, motor bearing, and brush friction. The net tractive effort available at the wheel causes the train to accelerate in the direction of the applied force.

The characteristic curves of motor equipment are obtained from witnessed or certified tests made by the manufacturer. These full field and shunt field, or weak field, curves show the speed of the train in MPH, and the gross tractive effort in pounds, developed by the motor. Shunted field, instead of the full field, curves are used in calculations because motors using shunted field connections develop higher speeds during a run. The design of signal layouts is based on the highest attainable speed.

The motor control equipment provides a starting acceleration of 2.5 mphps, which is automatically held constant at all loads on tangent level track until the S.F., or weak field, point is reached.

TRAIN RESISTANCE - VELOCITY CURVES
8 CAR TRAIN

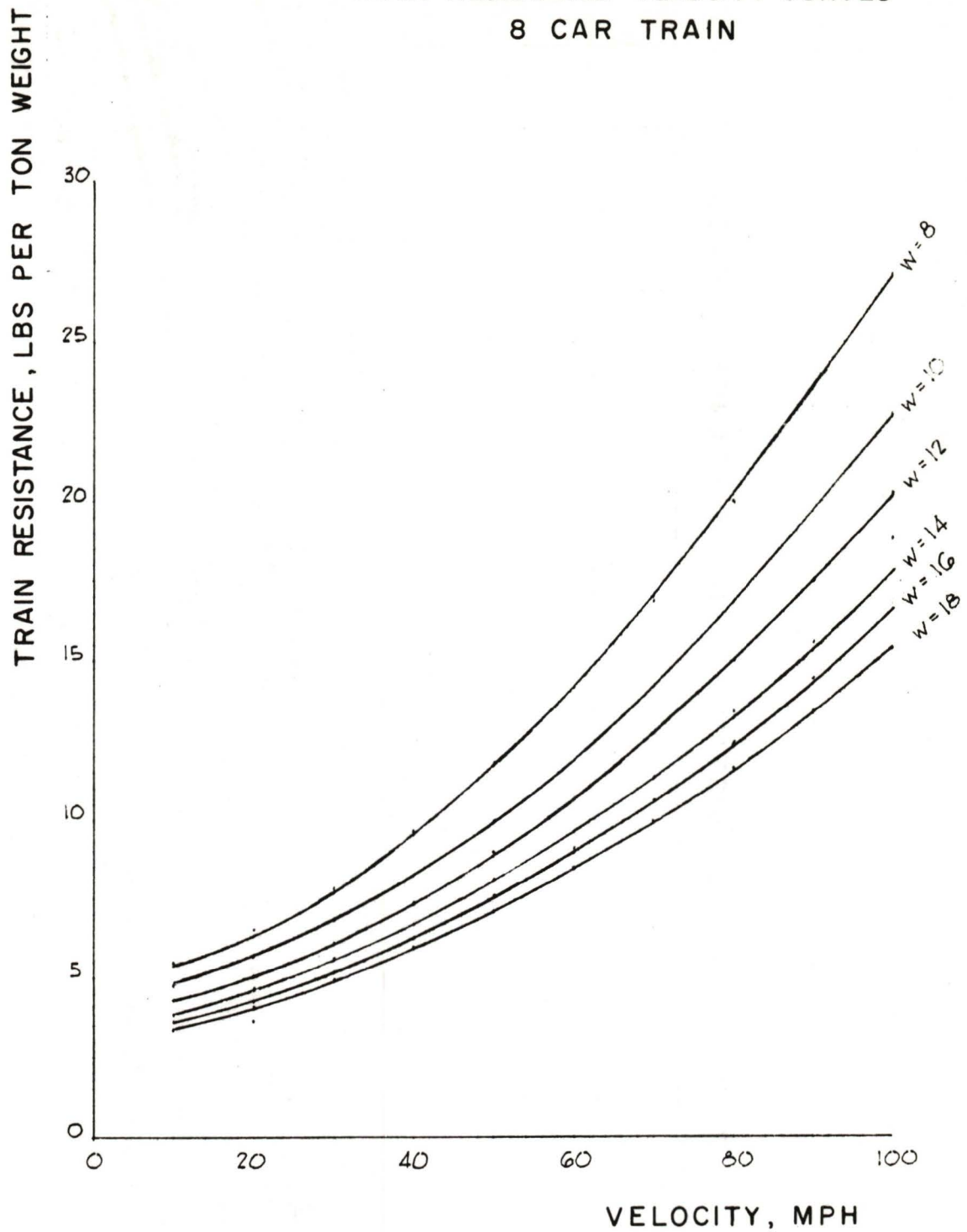


FIGURE 5.13

TP-5-43

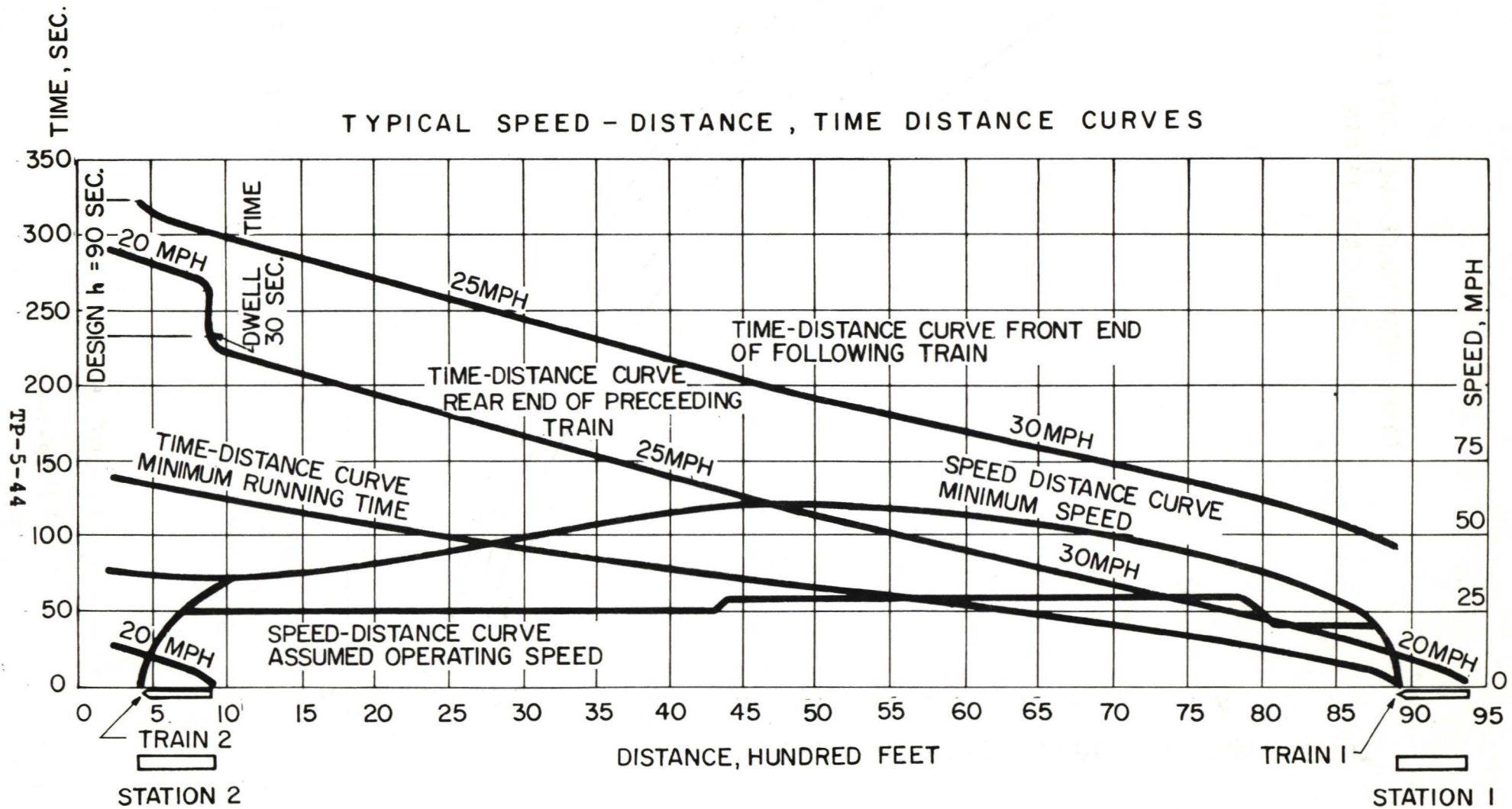


FIGURE 5.14

The gross tractive effort obtained is the total pounds of effort developed by the motor. This value is divided by the total load, in tons, on each motor to determine the gross tractive effort, .

Time distance curves are drawn; one for the rear end of the preceding train starting at time zero, and the other for the front end of the following train starting at a later time, which is equal to the desired headway. These curves show the relation of the front end of the following train to the rear end of the preceding train at any time during the run, and are used to determine whether the number of signals installed and their locations will permit the desired headway. The basic formulae for obtaining the coordinate curve data are:

$$a = 0.01 T_m$$

$$T_n = T_m - (T_R + T_C) \pm T_g$$

$$t_i = \frac{V_2 - V_1}{a_i}$$

$$d_i = 0.73 t_i (V_1 + V_2)$$

Where:

a = acceleration rate at a particular speed, MPHPS.

T_n = net tractive effort, pounds per ton.

T_m = gross tractive effort, at any speed, developed by motor, pounds per ton.

T_R = opposing tractive effort or Train Resistance, pounds per ton.

T_C = opposing tractive effort of curves, pounds per ton.

T_g = tractive effort of grades, pounds per ton.

V_1 and V_2 = any two speeds, MPH

t_i = time required for the increment of speed from V_1 to V_2 , seconds.

d_i = distance, feet, traversed
during this interval of time.

a_i = average rate of acceleration
during this interval, MPHPS.

In determining a_i during any interval of speed, the value T_n used must be the average of T_n at the beginning and end of the interval. This gives an average acceleration for the interval and, therefore, to minimize error, the increments of speeds, $(V_2 - V_1)$, should be kept comparatively small. For manual computation the increment of speed is generally selected so that the increment of distance does not exceed 150 feet. Also for manual computation changes in curvature and grades are considered as not taking effect until the center of the train reaches the point of change.

Using the basic formulae and information on motor tractive effort and train resistance, the coordinate points for the curves can be obtained and plotted. Computerizing these calculations allows much smaller increments of distance to be used and reduces the approximations required in areas of curves and grades, thus providing much greater accuracy in the final results.

IX - SUPER-ELEVATION

A subway car traveling at a uniform speed on level track around a curve exerts a centrifugal force

$$F_c = \frac{WV^2}{gR} \quad (1)$$

Where:

F = centrifugal force, (pounds)

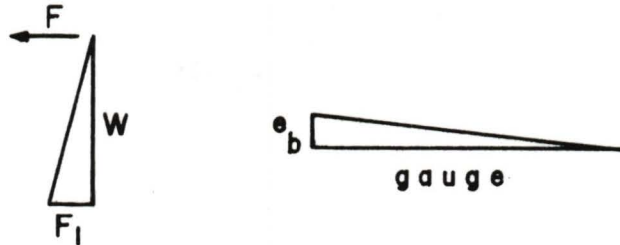
W = weight of the car, (pounds)

R = radius of curve, (ft.)

g = acceleration due to gravity
(32.2 ft/sec²)

Balanced Super-Elevation

For balanced super-elevation e_b , the centrifugal force must be resisted entirely by the component of the weight parallel to the plane of super-elevation.



$$\frac{F_i}{W} = \frac{e_b}{\text{gauge}}$$

Rearranging,

$$F_i = \frac{e_b W}{\text{gauge}} \quad (2)$$

for balanced super-elevation,

$$F = F_i$$

substituting and solving for e_b

$$e_b = \frac{V^2}{R} \times \frac{\text{gauge}}{g}$$

applying the appropriate values,

$$e_b = 3.7745 \frac{V^2}{R} \quad (3)$$

Where:

e_b = balanced super-elevation in inches.

V = velocity in mph.

Unbalanced Super-Elevation

For unbalanced super-elevation, e_{unb} , a centrifugal force equal to three (3) pounds per hundred (100) pounds of passenger-weight (w) is allowed to act on the rider.

$$F_1 = \frac{W V^2}{g R} = 3$$

Rearranging:

$$\frac{V^2}{R} = \frac{3g}{W} \dots \dots (4)$$

$$e_{unb} = \frac{V^2}{R} \times \frac{gauge}{g}$$

Rearranging:

$$\frac{V^2}{R} = \frac{e_{unb} \times g}{gauge} \dots \dots (5)$$

Equating (4) and (5)

$$e_{unb} = \frac{3 \times gauge}{W}$$

$$e_{unb} = \frac{3 \times 56.5}{100} = 1.7 \text{ in.}$$

Relationship between Balanced
and Unbalanced Super-elevation

$$e_b = 3.7745 \frac{V^2}{R}$$

Assume maximum balanced super-elevation of 6.5 inches

Assume maximum unbalanced super-elevation of 1.7 inches

$$\therefore e_b = 6.5 \text{ in.}$$

$$e_{unb} = 1.7 + 6.5 = 8.2 \text{ in.}$$

$$\frac{e_{unb}}{e_b} = \frac{8.2}{6.5} = 1.26$$

Therefore:

$$e_{unb} = 1.26 e_b$$

$$V_{unb}^2 = 1.26 V_b^2$$

$$V_{unb} = 1.12 V_b$$

Figure 5.15 is a graph of velocity versus super-elevation for various radii.

X - MAINTENANCE FACILITIES

A subway car is a combination of systems composed of sub-systems and components which have different rates of overhaul requirement.

Components must be replaced or overhauled intermittently every three years, every six years, or every twelve years of service. Truck frame bushings and wear plates can give eighteen years of service.

An overhaul program, based on the known or estimated service life of the system, sub-system or component, should be developed for the entire fleet of cars. This program should be planned on an integrated car class systems' basis.

An integrated systems overhaul program will:

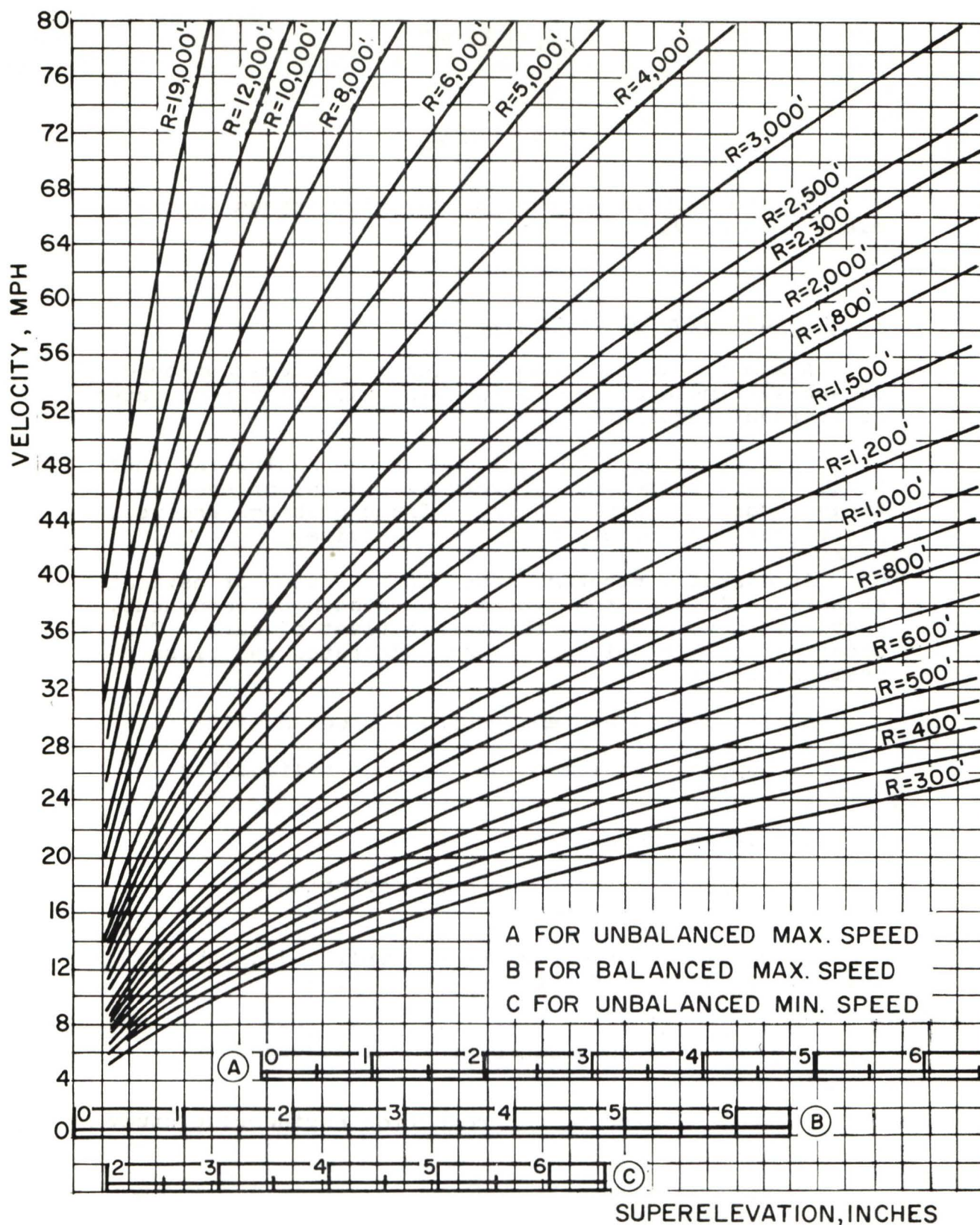
1. upgrade equipment and service reliability
2. reduce repair-shop loading
3. improve maintenance cost performance

Integrated systems can be accomplished in three phases, as shown in Figure 5.16 to 5.18.

Phase 1 - Acceptance of integrated car
class systems overhaul concept

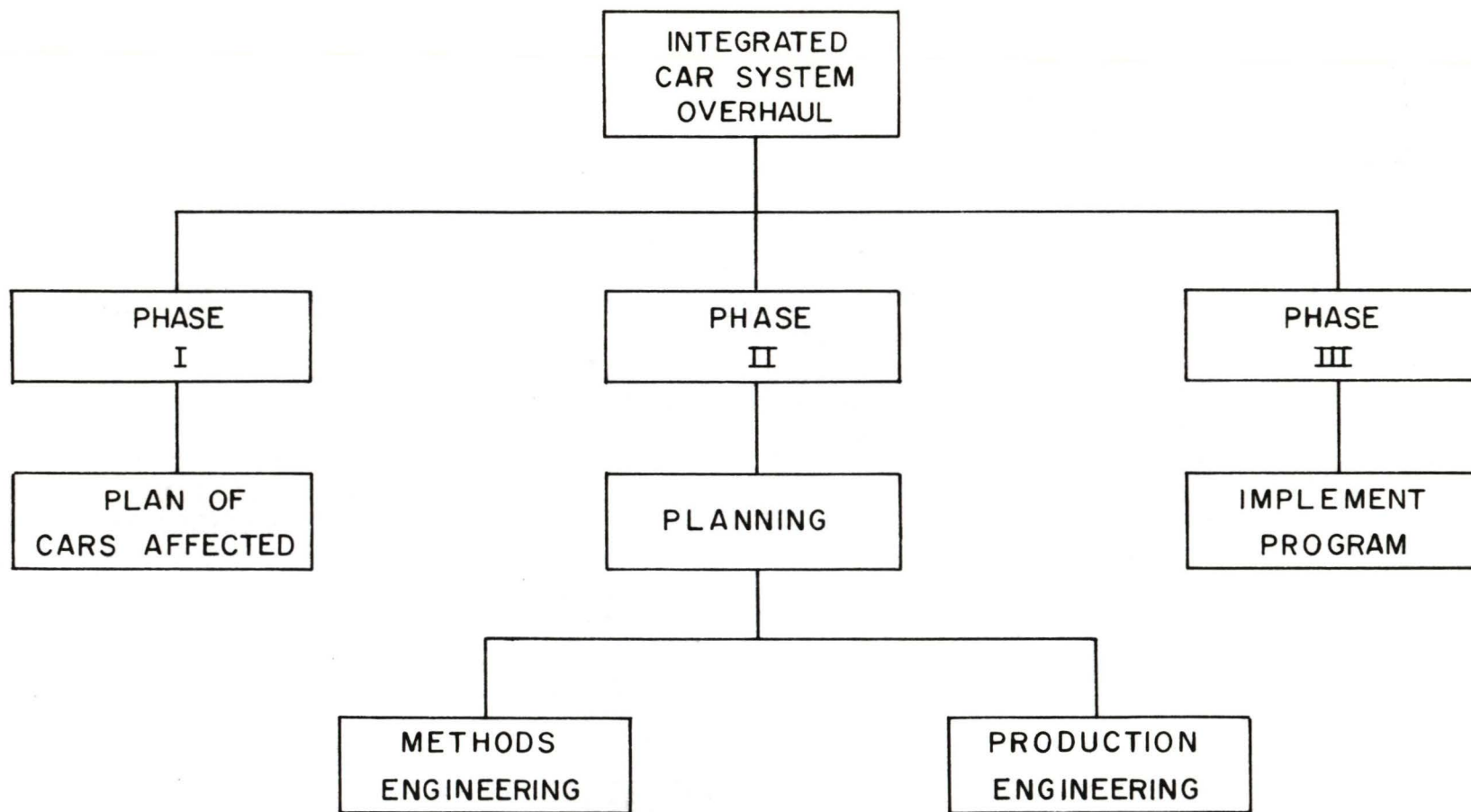
Phase 2 - Methods and Production **engineering** study

Phase 3 - Implementation



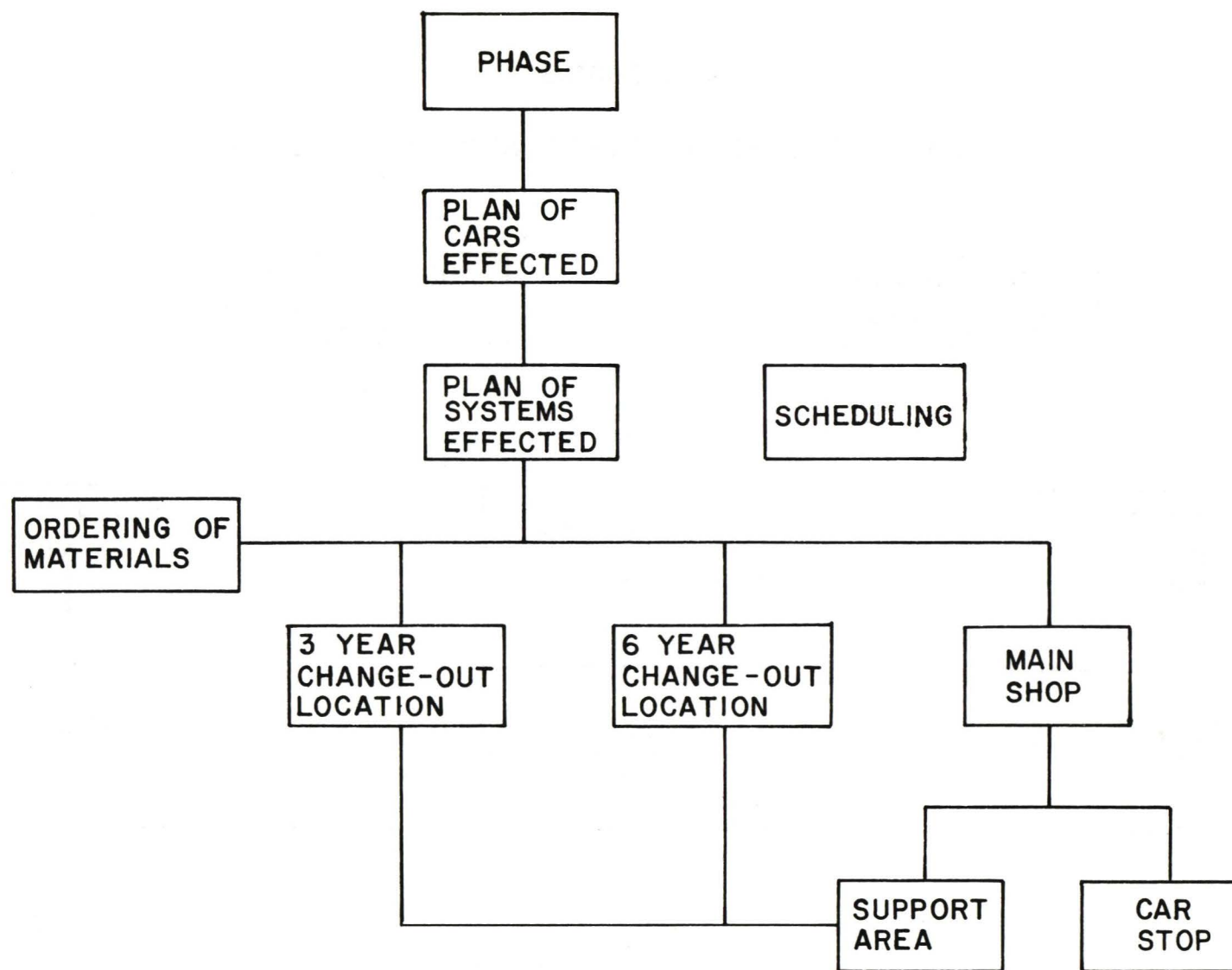
VELOCITY VS SUPERELEVATION

FIGURE 5.15



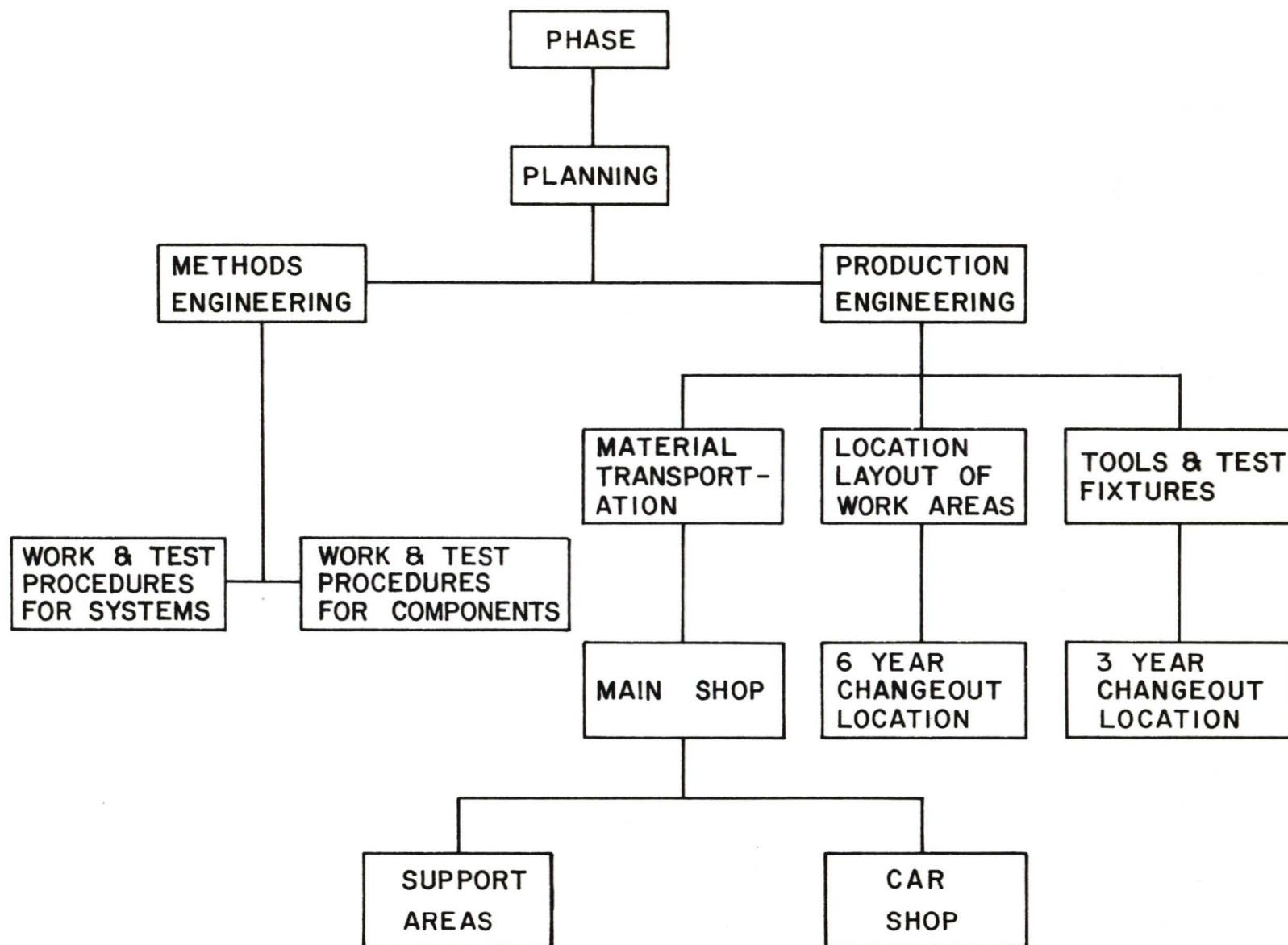
INTEGRATED CAR SYSTEM OVERHAUL PROGRAM

FIGURE 5.16



INTEGRATED CAR SYSTEM OVERHAUL PROGRAM

FIGURE 5.17



INTERGRADED CAR SYSTEM OVERHAUL PROGRAM

FIGURE 5.18

Under this systems overhaul program, much of the work can be scheduled at the home inspection barn, or at some other barn, where car space is available, reducing some of the work-load of the base shops.

Examination of a list of components requiring charge out on a three year and six year basis will indicate that these items have a great effect on service reliability. Typically, some of these items are:

traction motors,
compressor motors,
propulsion control relays,
air brake operating unit valves, etc.

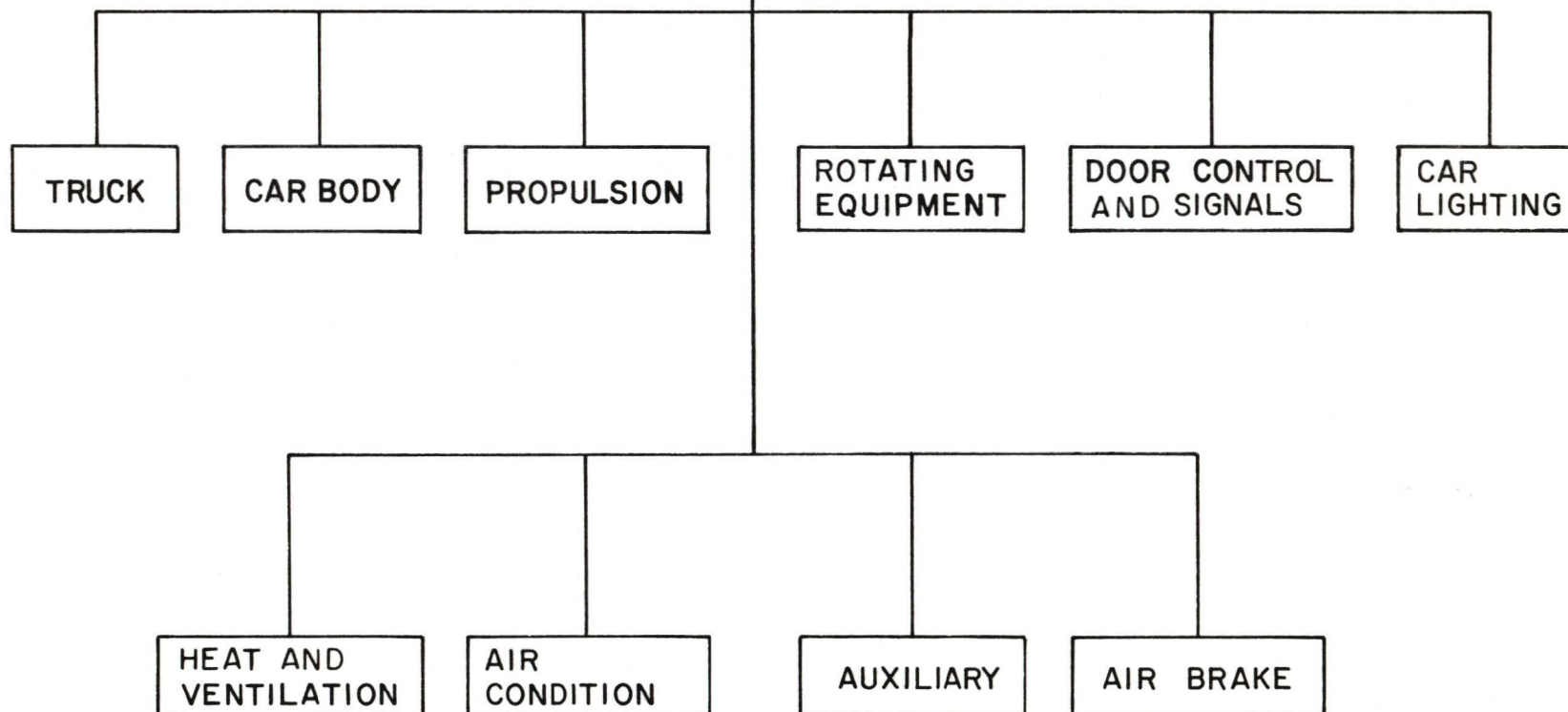
Therefore, it is important to overhaul car system components before failures occur. A system overhaul program, properly designed, is one which schedules system component change-out so that maximum service life is obtained without reducing reliability.

For overhaul purposes, the subway car can be considered to have the following systems and major components:

1. Trucks
2. Carbody
3. Propulsion
4. Rotating Equipment
5. Door Control and Signal
6. Car Lighting
7. Heat and Ventilation
8. Air-Conditioning
9. Auxiliary Circuits
10. Air Brake

The major components of a subway car are shown in Figure 5.19.

MAJOR COMPONENTS
OF CAR



TP-5-55

CARS SYSTEMS
INTERGRATED CAR SYSTEM OVERHAUL PROGRAM

FIGURE 5.19

Requirements

In planning for a car maintenance repair facility, first it is necessary to determine the number of cars to be accommodated.

The following track requirements are based on a single shift operation. A work month consists of 20 (8-hour daily) work days, and a work week consists of 5 work days, and a work year consists of 240 work days.

Inspection

Car inspection is performed on a six week cycle, with each inspection lasting 8 hours (1 work day.)

$$\frac{\# \text{ cars}}{30 \text{ work days}} = \# \text{ inspections per work day}$$

$$\frac{\# \text{ inspections}}{\# \text{ cars/train/track}} = \# \text{ tracks required}$$

Renovation

Interior cleaning and renovation are also performed on a six week cycle. The number of tracks required will be the same as for inspection. A platform, level with the car door sill, is required between adjacent tracks.

Exterior Car Cleaning

Car-washing is performed on a two week cycle. A single track is required and should be located such that cars can pass through it before going to storage.

Wheel Truing

Wheel truing is performed on an 18 month cycle.

$$18 \text{ months} \times 20 \text{ work days/mo.} = 360 \text{ work days.}$$

$$\# \text{ cars} \times 4 \text{ pairs of wheels/cars} = \# \text{ pairs of wheels.}$$

$$\frac{\# \text{ pairs of wheels}}{360 \text{ days}} = \# \text{ pairs per day.}$$

Overhaul Programs

For preventive maintenance programs and periodic re-

placement of car units, a section of the shop will be required for the detrucking and heavy repair of subway cars. Facilities should be provided for the refurbishing of car wheels, motors, compressors, air-conditioning units and the repair and replacement of air brake and electric units.

Detrucking

Trucks are changed on a 6 year cycle. The truck changing operation is accomplished by a mechanical elevating table located in the center of the shop to permit a full train in the shop for stripping and reconnecting the trucks.

Wheels

Provision should be provided for a wheel shop capable of handling wheel refurbishing on a 6 year cycle.

Motors

Facilities should be provided for changing and overhauling motors on a 6 year cycle.

Air-Conditioning Equipment and Air Compressors

A service area for the combined servicing of air-conditioning and air compressor units should be capable of providing service for the entire fleet of cars on a 3 year cycle.

Miscellaneous

Service tracks for the removal and replacement of major components, repair of damaged and electrically defective cars should be incorporated in the major repair area. Additional main repair tracks and unscheduled repair tracks should be provided in the heavy overhaul and repair area to cover emergency conditions.

The maintenance facility areas required should be structured to meet production goals.

Also, it is necessary to provide trackage for work trains, miscellaneous equipment and yard maneuvers, and other operations not covered in this report.

XI- POWER SUPPLY

The electrical energy for power, supplied to the New York City Transit System, is purchased from the public utilities in the areas involved. The Consolidated Edison Co. (Edison) furnishes the major portion of this energy with the Long Island Lighting Co. (LILCO) furnishing that used on the Rockaway Peninsula.

The bulk of the Edison high tension AC energy is supplied in two categories. That which is supplied at the three former city-owned power plants and transmitted over Transit Authority cables to our substations is called "Plant Delivery." High tension energy supplied directly to our substations over Edison cables is called "Substation Delivery." The remainder of the Edison energy is delivered directly to individual service points. The LILCO energy is supplied directly to substations and service points over its cables.

The "Substation Delivery" nominal voltage in Manhattan and The Bronx is 13,200 volts, and in Brooklyn and Queens it is 26,400 volts.

The high tension AC energy received at the substations is converted to 625 volts DC and delivered through circuit breakers and cables for the operation of trains.

Power for Train Operation

In comparing power requirements for the car, the consumption, demand and cost of operation of the car are considered.

To determine the power required for the operation of the car, propulsion motor information furnished by the various manufacturers is compared with present system experience. Based on this information, estimates of power consumption and demand required for the various proposals are calculated.

1. Traction

The information furnished by the propulsion suppliers is used to estimate the various traction motor proposals and compare them with present equipment.

2. Car Auxiliaries

In estimating the average power consumed by the present car auxiliaries (lights, compressors, motor-generator sets, etc.), assumptions are made as to the number of hours the units operate and the average number of miles the cars travel per day. This is translated into kilowatt hours per car mile for these auxiliaries. However, to arrive at a composite experience figure for all types of cars, a further assumption is made regarding the married pairs and the single unit cars. The married pairs (R27 to R38) with one motor-generator set and one compressor per pair are pro-rated with the single units (R10 to R16) with a motor-generator set and compressor per car. This accounts for the somewhat lower consumption (6.8 KWH/TM) for the R40 and R42 cars compared to the R10 to R38 Division 'B' cars (8.0 KWH/TM.) Power consumption is increased proportionately for the 75 foot car.

3. Car Heat

To estimate the power consumed by car heating, it is assumed that one point of heat (4 KW) is used for four months, 24 hours per day. This power is then averaged over the full year.

4. Air-Conditioning

The estimate for power consumed for car air-conditioning is based on the following assumptions and averaged over the year:

1. Cars operated 12 hours per day with air-conditioning equipment in service.

2. The equipment would be operating:

- a. 63% of the time it is in service during June, July, August and September.
- b. 30% of the time during April, May, October and November.

3. 45 KW per car is used in the calculations for air-conditioning and re-heat.

Power Demand

System design criterion for the averaged power demand established for the IND R1 to R9 cars is 100 Kilowatts (KW) per car, or 1000 KW for a 600 foot train. This standard includes power for traction, car auxiliaries and heat. Requirements for substation capacity are based on ten car trains operating at maximum capacity on all tracks at an average speed of 18 mph. The R10 to R38 cars have operated satisfactorily with this design and subsequent upgrading. The kilowatt hours per train mile for these cars average 66.4.

Average power consumption for the various cars is shown in Table 5.05.

Using this data for the ratio to estimate the probable increase necessary to operate the proposed cars and adding 45 KW per car for air-conditioning, the following proposition is established.

R10 to R38 car train operating power is to R10 to R38 car train power demand as future train operating power is to future train power demand (x).

Power Cost for Train Operation

To determine the approximate cost of power to operate a 600 foot train for one year, assume a car or train operates 60,000 miles per year. Using the cost of a DC KWH, the cost per KWH is established. Power cost for local operation is nearly twice the power cost for express operation.

Power for New Lines

The concept of diversifying the conversion units in smaller substations rather than concentrating many units in a single, large, centrally located substation should

AVERAGE POWER CONSUMPTION

KWH PER TRAIN MILE

DESIGNATION	RIO-38	R 42	R 44
Motor	GE-1240 W-1447	W-1447C	W-1447D
Gear Ratio	7.235:1	7.235:1	5.087:1
Maximum Speed - MPH	50	50	70/80
Acceleration Rate - MPHPS	2.5	2.5	2.5
Number of Cars - 600 Ft. Train	10	10	8
<u>AVER. POWER-600Ft. Train - KWH/TM</u>			
TRACTION	56.5	56.5	66.5
AUXILLIARIES	8.0	6.8	6.4
HEAT	1.9	1.9	1.5
AIR - CONDITIONING		9.8	7.9
AVERAGE POWER - KWH / TM*		69.4	81.7
KWH / CM		6.94	10.21

* 1/2 Mile Station Spacing - Crush Load

TABLE 5.05

TP-5-61

be utilized because of its many advantages.

This concept provides for the supply of power at frequent intervals along the rails of the subway. Efficiency is, therefore, increased since blocks of power required by the trains are moved a shorter distance. The possibility of electrical corrosion (electrolysis) on underground structures due to stray return currents from the running rails is minimized because of shorter return paths. It eliminates the large concentration of power in one substation and makes possible a deployment of power supply that has the distinct benefit of reliability in that a substation failure affects a smaller section of the system.

The power system should be designed to ensure safe, efficient and continuous operation of the rapid transit system. Design should be coordinated with the requirements of the power company providing primary and auxiliary power to the substations and auxiliary power to buildings, shops, stations and wayside locations.

Special (allocated) high tension feeders should be assigned to furnish sufficient power to provide minimum operating service (trains operating at series speed) in the event of a serious disturbance on the Edison system which would cause a failure of the normal supply. These feeders should have two sources of supply from bulk distribution points, normally operating from one source, with no connected network load. In the event of a power shut-down, these feeders should be available for service to the transit system immediately after the restoration of power at one of the supply points.

Direct current traction power should be provided by rectifier substations with a rated voltage output of 625 volts at 100 percent load.

The nominal third rail potential shall be 600 volts with a maximum of 675 volts and a minimum of 450 volts. Under abnormal operating conditions, a rail voltage of 425 volts can be tolerated.

The negative rail potential difference should be limited to twelve volts maximum in any substation zone on land and eight volts maximum in under river tunnels.

Substations

The location and capacity of traction power substations is based on supplying power to trains as demanded

by the operating schedule during maximum traffic periods within the limits of permissible voltage drops. A schedule speed of 30 miles per hour is assumed, which is dependent on station spacing.

The system should be capable of supplying power for normal train service with a loss of the two largest units in a sub-station or zone. The two hour rating of silicon rectifiers (150 percent of full load) should be used in computing for the second contingency, i.e., the loss of the second unit.

Routes or lines should be supplied from separate sub-stations where possible so that a power disturbance on one will not affect the other. However, where location, convenience and economics prove it applicable, switching arrangements should be provided for supplying an adjacent line or lines in emergencies.

Generally, on a four track route, sub-stations shall consist of two 3000 or 4000 KW silicon rectifier units with associated switchgear and equipment. On a two track route, the substation may house only one 3000 or 4000 KW unit and its required accessories.

Specific location of the substation will be governed by:

- a. availability of property,
- b. subsurface conditions,
- c. location and size of buried utilities.

The power system should be designed with a view on reducing corrosion by electrolysis to a minimum. Sub-stations properly spaced and located close to the right of way, with resultant short feeders, will keep the voltage of the rail system low and reduce the likelihood of current leakage to the soil. This return system, represented by the negative rail or rails, should have a low resistance to the return current and a high resistance between the rails and earth to impede the flow of stray current to the earth. When the distance between the feeder breakers and the third rail connections is more than 200 feet, track breakers housed in a circuit breaker house adjacent to, or within the confines of the subway, or aerial structure, should be provided.

Substations should be as close to passenger stations as possible to be near their source of maximum load (starting of trains.) Where economically feasible, substations may be placed within the confines of a passenger station, preferably on the mezzanine level. Underground substations should have a subway entrance and an access from the street. The street access should have sufficient clearance for handling all substation equipment.

Substations are normally unattended. A conversion unit is provided with control and protective system to:

- a. perform the necessary operations, in correct sequence, for starting and connecting the unit to its load and shutting down and disconnecting the unit.
- b. protect the unit against damage caused by operating under faulty conditions.

On main line tracks, there should be at least three separate sources of power for each third rail section. The feeds should be of sufficient capacity to be capable of supplying power for normal service with any one feed out of service.

The rectifier shall be designed for forced air cooling with filters in the air intake. The cooling fans or blowers should be designed for a low noise level. In a surface substation, the rectifier should be cooled by substation air at all times. In a subsurface substation, the rectifier should be cooled by substation air until the ambient air temperature rises above a set value. Then, automatically, the air shall be recirculated within the unit and cooled by an air to water heat exchanger.

Feeder breakers should be housed in a separate compartment which shall be at a higher level than the substation drainage level. This is to prevent flood water from damaging the circuit breakers and thus interfering with train service.

Substations below sewer level should be equipped with automatically-operated pumps and a sewerage ejector system, both of sufficient capacity to discharge cooling water and waste to the sewers. A high water alarm should be provided to detect high level of water in the sump so that indication may be transmitted over the supervisory

control to the controlling location.

Underground substations should be equipped with a motor-driven exhaust fan capable of exhausting 10,000 cubic feet of air per minute through the hatchway to the street above.

In a separate compartment of the substation, a toilet, lavatory and slop sink should be provided. This room should be large enough to accommodate six (6) lockers and a bench. It should be equipped with thermostatically controlled electric space heaters and electric hot water heater.

Auxiliary Electrical Systems

A.C. power electrical systems required to serve the lighting and auxiliary electrical and mechanical equipment throughout the new transit lines include:

1. Lighting
2. Heating
3. Ventilating
4. Air-Conditioning
5. Escalators
6. Fare Collection
7. Communications
8. Train Control
9. Emergency Power
10. Television
11. Public Address
12. Illuminated Signs
13. Clocks
14. Alarms
15. Power for Concessions

Auxiliary Electrical Systems (Cont'd)

16. Drainage Pumping
17. Ejectors
18. Elevators
19. Snow Melting Apparatus

Each station should have two (2) A.C. power distribution rooms. The normal Electrical Distribution Room (E.D.R.) should be located adjacent to the air-conditioning chiller room on the mezzanine. The reserve E.D.R. should be located on the platform level. These rooms are to feed all electric power for the stations, and for tunnel lighting up to the next station on the line. In addition to the normal and reserve E.D.R., a panel room should be provided at the opposite end of the mezzanine from the normal E.D.R., and in the event of side platforms, a panel room should be located on the platform directly across from the reserve E.D.R.

Each fan chamber shall have one (1) A.C. power distribution room. This room should be located near the fan control room and it will feed all electric power for the fan chamber, except for lighting which will be fed from the tunnel lighting circuits.

Each under-river or deep-tunnel fan chamber shall have two (2) A.C. power distribution rooms. The normal E.D.R. should be located near the fan control room, and the reserve E.D.R. adjacent to the normal E.D.R. These rooms will feed all electric power for the fan chamber.

A.C. power distribution rooms should be the supply center for all electrical power, with the exception of propulsion power. They should contain main breakers, safety switches, fuses, metering equipment, transformers, and any other equipment necessary for the distribution of A.C. power. Allowance should be made for future system growth by providing all A.C. power service facilities with the capacity to handle a 50% increase over the calculated installation load.

Edison power is to be brought into the normal E.D.R. at 208/120 volts, 3 phase, 4 wire, 60 hertz, and transformed to the utilization voltage of 480/277 volts. Medium voltage power, from a T.A. substation, is to be brought into the reserve E.D.R. through an allocated feeder, and transformed, where required, to the utilization voltage of 480/277 volts.

This power will be used for signals, lighting, ventilation, and other vital equipment in the event of failure of the normal Edison power. The transfer of power sources will be accomplished by means of an automatic transfer switch.

Also, in the event of failure of all electrical power, partial lighting is to be provided by rechargeable emergency battery packs, which will be an integral part of selected lighting fixtures.

A central air-conditioning facility should be located at each new station to supply its air-conditioning needs, including the air-conditioning of concessions. A survey should be made as to the probable number and size of all concessions to be located at a station. The air-conditioning facility shall be large enough to handle anticipated requirements and a 25% allowance for growth.

The central facility shall have the ability to supply air-conditioning for all enclosures including the following:

1. towers and supervisory quarters
2. crew rooms
3. concessions
4. toilets
5. mezzanines
6. platforms

XII -BIBLIOGRAPHY

1. New York City Transit Authority, "Integrated Car System Overhaul Program for a 7000 Car Fleet.
2. New York City Transit Authority, "Report on Application of Computers to Signal System Design.
3. New York City Transit Authority, "Standards for New Lines", 1969.
4. Highway Research Board, "Highway Capacity Manual", 1965.

Chapter 6

Capital

Chapter 6

PRELIMINARY ENGINEERING

TABLE OF CONTENTS

I	PRELIMINARY ENGINEERING STUDIES	TP-6-1
II	SOURCES OF INFORMATION	TP-6-2
III	GENERAL CONSIDERATIONS	TP-6-4
IV	GUIDELINES	TP-6-4
	Number of Tracks	TP-6-4
	Locations of Stations	TP-6-4
	Plan and Profile	TP-6-6
	Storage Yards and Repair Shops	TP-6-8
V	PLAN PREPARATION	TP-6-9
	General Practice	TP-6-9
	Lettering	TP-6-9
	Scales	TP-6-9
	Abbreviations	TP-6-12
	Study Drawings	TP-6-13
	Plan Checking	TP-6-15
VI	ESTIMATES	TP-6-16
VII	REPORTS	TP-6-17
VIII	BIBLIOGRAPHY	TP-6-19

Chapter 6

PRELIMINARY ENGINEERING

1 - PRELIMINARY ENGINEERING STUDIES

Preliminary engineering (feasibility) studies determine the physical and economic feasibility of a project.

Two types of feasibility studies are prepared:

1. System Expansion
2. System Improvement

System expansion studies deal with future subway lines. They involve the conceptualization of a new route and its various alternatives and its relationship to the existing system.

System improvement studies deal with the modernization and alteration of existing lines. They involve track realignment, elimination of operational bottlenecks, modification of "A" division lines for "B" division operation, platform extensions, upgrading of station facilities (installation of escalators, widening of stairways, etc.) and many other modernizations which improve the level of service.

These studies initiate from the Planning Division and many sources including:

- a) Departments and Divisions within the N.Y.C.T.A.
- b) City, state and federal transportation agencies
- c) Other governmental agencies
- d) Privately sponsored transportation groups and associations
- e) Civic groups and individuals

The results of preliminary engineering studies define the scope of the project. They determine the number of tracks required, their basic alignment, the profile of their base of rail and the limits of the construction or reconstruction work required. The results of the study should minimize interference with existing transit operations, indicate any construction difficulties that might arise and prepare a sequence of construction, if necessary.

II - SOURCES OF INFORMATION

Preliminary engineering studies must observe the standards set by the various departments and divisions of the N.Y.C.T.A.

The following is a list of information supplied by each department or division with relation to preliminary engineering studies:

<u>Department or Division</u>	<u>Information</u>
Car Maintenance Department	provides requirements for car maintenance facilities on line and in yards
Civil Engineering and Architectural Division	provides structural, architectural, hydraulic, track and yard standards
Concessions and Real Estate Division	assists in site selection
Construction Division	advice on construction methods
Equipment Division	provides requirements for lighting, electrical and mechanical equipment
Industrial Engineering Bureau	provides studies of related nature
Legal Department	advises on the legal aspects of route selection and assists in property acquisition
Maintenance of Way Department	provides track alignment plans, station facility maps, and requirements for maintenance of way facilities
New Car Engineering Department	provides data for all rolling stock

<u>Department or Division</u>	<u>Information</u>
Planning Division	prepares preliminary engineering studies, estimates and reports, preliminary property acquisition and disposal of property or air rights
Power Department	provides requirements for power structures and assists in substation location
Record Room	provides contract and "as built" drawings
Signals and Communications	provides requirements for signals and determines operational speeds for a given study
Station Department	provides turnstile registration counts and special counts
TA-MABSTOA Operation and Maintenance Division	provides information concerning bus routes, schedules and ridership and coordinates bus feeder lines with proposed and existing transit systems
Transportation Department	provides schedules and information concerning mainline and yard operations, determines storage requirements for existing and proposed yards, prepares schedules for new route operations. Provides cordon counts, also provides information on required operating facilities and analyses of track configurations

III - GENERAL CONSIDERATIONS

The first step in studying an established or approved new route, connection to or improvement of the existing system, is to prepare a feasibility study or functional plan. This plan differs from the usual structural or architectural detailed plan in that it is a layout showing the functions of each track, facility or improvement to be provided as related to the entire project. The feasibility study or layout may be considered as two parts; the plan (horizontal alignment) and the profile (vertical alignment.) Both must be consistent to properly locate the structure in the street and to avoid, if necessary, surface and subsurface obstructions. These become extremely important where special track facilities, flexings, and stations are to be provided. Special facilities in plan must be consistent with and correspond to workable grades in profile. Similarly, stations must be located in plan consistent with track facilities and at the same time be located on favorable grades. Upon completion of the functional track layout, a diagrammatic plan is made to enable a quick determination of train operation, switching facilities required, and the relation of main and branch lines. Such a plan offers a means of determining routing of different services, and aids in fixing the number of trains per hour to be accommodated on the various branch and trunk lines.

IV - GUIDELINES

Number of Tracks

The number of tracks required for smooth operation should be determined by the expected capacity of the line, assuming 30 trains per hour per track for existing systems and up to 45 trains per hour per track (only when there are no flexing or merging modes) for new routes independent of the existing system. Another factor is whether the line is a branch line or a trunk line. Additional trackage, where necessary, should be provided for switchback of services, lay up of trains, and for reducing station dwell time, etc.

Location of Stations

The location and number of stations on a particular line are determined during the planning phase. Past experience and a study of the travel habits of passengers

has brought about a change in the ideas regarding the needs for express and local train operation. It is obvious that if maximum train capacity is attained in the outlying sections, where practically all passengers are destined for the Central Business District (CBD), it is quite unnecessary to have the train stop at intermediate local stations since no one desires to leave and since cars are loaded to capacity, no one can board the trains. In such cases, expenditures for constructing facilities for through express service appear to be warranted and have been recommended. In the CBD the station stops for the express service are frequent, since the entire load is usually discharged in a comparatively short distance. If the express stops were spaced too far apart, it would cause unnecessary transfers between expresses and locals. (The interested reader is referred to items 4 and 5 in the bibliography.)

Station locations in intermediate areas of the city are determined by importance of location and local travel habits of the public. In this regard consideration is given to business, entertainment, commercial and industrial areas, and feeder bus lines crossings. Local stations in residential areas are usually spaced, under the foregoing considerations, about one half mile apart (if studies of passenger demand support that spacing.) Express stations in residential areas are most likely to be spaced at two mile intervals. In terminal areas it is desirable to space express stations much closer to lessen congestion in discharging passengers. Station distance between CBD and residential areas on Super Express Lines is several miles.

Particular attention is devoted to planning stations with regard to mezzanines. Where a station, due to the contour of the surface or the necessity of a deep crossing, must be deep, a mezzanine should be provided. Mezzanines are desirable to permit transfer in both directions. Where no mezzanine is provided, two 24 hour controls are necessary. Economic analysis of operating and maintenance costs indicate that the construction of a single mezzanine, where only one control is utilized, is more desirable operationally than two separate controls with no mezzanines.

Transfer facilities should be provided at important points where lines cross or converge. A transfer arrangement where two island platform stations cross requires an intermediate level to permit construction of a mezzanine or passageways. Arrangement of transfer facilities should be made for greatest convenience of passengers, and should

reduce the amount of climbing to an absolute minimum. Installation of escalators is given serious consideration at all locations.

Plan and Profile

Curves should be designed on the basis of maximum attainable speed. An effort should be made to reduce the amount of curvature and increase the radius since high total curvature and short radii increase operation and maintenance costs and require heavy power consumption. Increasing the radius will shorten the length of the line and reduce the structural costs but should be weighed against the cost of private property and the cost of relocation of families and business as a result of acquiring their property.

To obtain required clearances between tracks on curves, concentric curves of the proper radii with varying transition curves are more desirable than eccentric curves.

Track crossings are accomplished by separating the tracks horizontally and vertically. These separations, referred to as flexings, are also used to place tracks in any desired location for purposes of sorting or mixing of services, for connecting branch and main lines, and to obtain desired station platform arrangements for convenient passenger transfer, or other reasons.

Where connections are to be made to existing transit lines, they should be located at favorable grade locations to reduce switching difficulties, and to cause least disturbance to existing operations during construction. Methods of construction at connecting points are studied and their comparative costs evaluated.

Provisions for future connections to the proposed line are investigated but seldom provided structurally, except where future construction under operating conditions indicates prohibitive future cost by omitting the provision.

Auxiliary trackage for emergency crossovers and lay-up tracks should be provided at regular intervals for flexibility of operation and the removal of bad-order trains to avoid delays in operation. Such provisions are planned so that in the event of a serious delay, operations could be maintained in both directions from that point. Special treatment is given such matters at areas of greatest congestion.

Additional trackage should be provided at flexing and branching points to provide pockets or reservoir trackage to hold trains so as not to block service. Underground storage space, where available at moderate cost, is desirable to eliminate as much dead mileage or nonrevenue operation as possible.

A connection to one of the railroads should be provided at some point in the line for the purpose of getting new rolling stock into the yards from main line railroad delivery points.

Theoretically, the most economical and generally satisfactory profile of a line would be one with stations located at crests. In starting, the downgrade would assist the motor in acceleration and the upgrade at the approach to a station would assist the brakes in deceleration. In a subway this does not permit the use of mezzanines and increases the cost of construction between stations. For that reason, the profile is usually planned to follow the street surface. Stations in open cut should be as high as possible to reduce climb. Generally, the profile should follow the street surface but this is not feasible if the street surface is a series of dips and rises. An effort to get minimum excavation may lead to false economy. It is often more economical from a power expenditure standpoint to maintain a uniform grade with slightly higher excavation quantities rather than climb up and down in profile.

Level grades are not a particularly desirable objective in a subway and should not be considered. A slight grade is preferable as it simplifies the track drainage problem. Frequent low points in the profile are objectionable since they require too many sump pumps, and increase the cost of installation, maintenance, and operation.

In fixing the location of the proposed line vertically, careful consideration should be given to crossings of other transit lines, large utilities, sewers, gas and water mains, cable banks, and other subsurface structures. Care should be taken to avoid blocking restoration or relocation of utilities. The feasibility study is designed to minimize physical interference with utilities, and to reduce restoration costs. Before adopting a profile, methods of support and underpinning during construction and difficulties of construction, by having to pass under existing transit structures, should be considered and evaluated. If large sewers cross the proposed subway route, a vertical profile is adopted to go over or under them. Where it is

impossible to go over them and the cost of depressing the structure is excessively severe, sewer crossings are made by inverted siphons (siphons are to be used only where no other alternative exists.) Cost studies should be made as to the desirability of passing over or under existing rapid transit lines or other large subsurface structures. Special attention is given to the approach grades at both sides of the crossings.

In subway construction, the type of structure will depend on subsurface conditions. The studies indicate the desirability of open cut, tunnel, double deck or other type of construction.

Where sound rock is encountered, it may be more economical to depress the profile of the entire line or perhaps only the express tracks and perform the deep level construction entirely in tunnel. This economy is also balanced against the increase in cost of additional power consumed in the dip and rise of the tracks. Comparative estimates of the cost of tunneling or open cut should be made, especially where street traffic is heavy.

In subway construction, whenever possible, the centerline of the structure should coincide with the centerline of the street. On wider streets this allows for sheeting and bracing the excavation and reduces underpinning and easement costs.

Storage Yards and Repair Shops

In planning new lines the location of storage yards is given detailed study. The storage yard should be designed to accommodate about 90% of all the cars in service on the line. Storage should be provided at terminals to eliminate the dead mileage to and from a distant yard to the starting or terminating point of revenue operation. Real estate costs, however, are a factor and must be weighed against locating the yard at an intermediate point where land may be cheaper. Yard leads at intermediate points on the line will require flexing and additional trackage.

Inspection facilities should be provided at all storage yards but for a new line and its branches one storage yard should be provided with major repair facilities.

V - PLAN PREPARATION

General Practice

A standard size sheet should be used for uniformity, ease of handling and filing purposes. Oversize sheets are permitted when the standard sheet will not show a complete and clear portion of the project. Figure 6.01 indicates all the necessary information that should be shown on the sheet and the respective locations.

If more than one sheet is required, the sheets should be numbered so that the project reads from North to South or East to West with a key plan showing the proposed project as the first sheet. If only one sheet is required the key plan should be located on the drawing.

Lettering

Single stroke Gothic Lettering (large and small capitals) should be used because it is more uniform and easier to read than script. Good lettering requires uniformity of shape, style, size, weight, slope and spacing. Lettering may be free hand or done with the aid of a lettering guide.

On a drawing that is to be microfilmed or reduced in size, the lettering must be large enough to be legible on the reduced print.

Scales

The designer should select a scale (civil engineer's) that gives a clear picture of the project on a minimum number of sheets. He should realize that in certain cases (clearances from property, buildings, sewers, etc.) the accuracy required will determine the scale.

The following horizontal scales are generally used:

1. System Expansion Studies 1"=40', 80', 100', 200'
2. System Improvement Studies 1"=10', 20'

A vertical scale of 1"=10', 20' is suitable for both types of studies.

For a cross-section, the appropriate scale should be chosen to show all necessary details clearly.

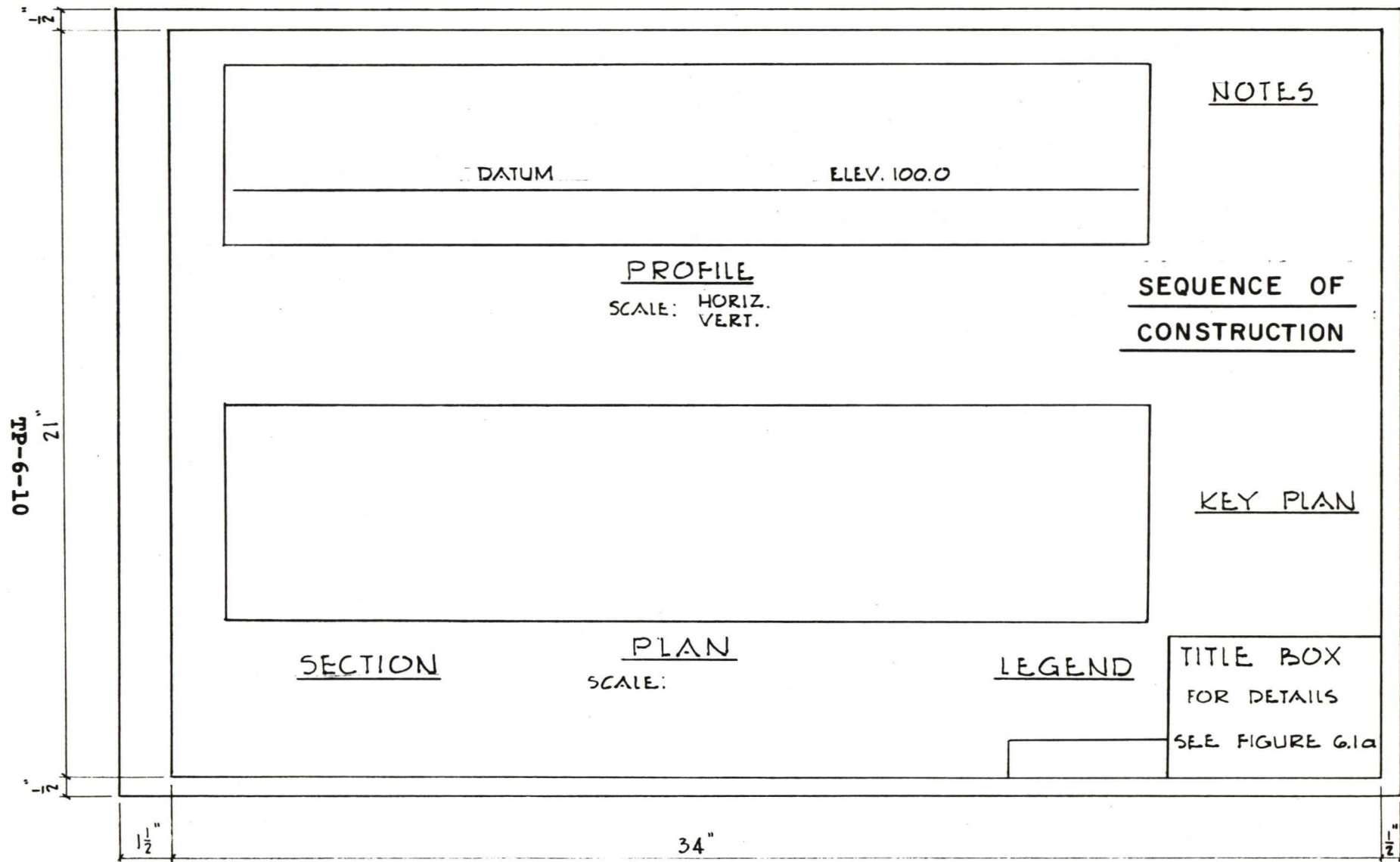


FIGURE 6.01

TP-6-11

				NEW YORK CITY TRANSIT AUTHORITY				1"
				ENGINEERING DEPARTMENT				
				PLANNING DIVISION				
				DESCRIPTION OF DRAWING				2"
DATE			SHEET OF					
DESIGNED		SCALE AS SHOWN	FILE NO.					
CHECKED			DWG. NO.					
NO	DATE	BY	REMARKS	IN CHARGE				1"
REVISIONS								
1/2"	1"	1/2"	5"	1 1/2"	1 1/2"	1"	2"	

FIGURE 6.01 a

Abbreviations

The following is a list of abbreviations frequently used on preliminary study drawings.

avenue	Ave.
base of rail	B of R or B.R.
boulevard	Blvd.
Brooklyn Manhattan Transit	BMT
drive	Dr.
elevation	Elev.
grade	Gr.
Independent System	IND
Interborough Rapid Transit	IRT
length of curve	L
length of spiral	Ls
length of vertical curve	L(vc)
north bound	NB
point of curve	P.C.
point of compound curve	P.C.C.
point of curve to spiral	P.C.S.
point of intersection of horizontal curve	P.I.
point of intersection of vertical curve	P.I.V.C.
point of reverse curve	P.R.C.
point of switch	P.S.
point of spiral curve	P.S.C.
point of spiral to tangent	P.S.T.

point of tangency	P.T.
point of tangent to spiral	P.T.S.
radius	R
rate of change of vertical curve	r
road	Rd.
railroad	R.R.
route	Rt.
street	St.
southbound	S.B.
superelevation	e
throw	F
track	Tk.
Transit Authority	T.A.
turnout	T.O.
top of rail	T. of R. or T.R.
velocity	V

Study Drawings

The first step in preparing a preliminary engineering drawing is to prepare a base map consisting of plan (horizontal) and profile (vertical) views of the proposed project. The profile is located directly above the plan and should be consistent with the plan.

On the plan view the street system should be oriented so that the North arrow points upwards. The plan should show the center line of existing subway and elevated lines, rights of way of railroads, highways, large interceptor sewers, utilities and any other structures that will affect the alignment. Schools and housing developments should be shown because of their importance in determining the location of stations.

The Transit Authority profile is referenced to an arbitrary datum, elevation 100.00, which is 2.653 ft. above mean sea level at Sandy Hook. The profile is drawn for the center line of the street. It should show approximate street surface, center line of intersecting streets, the outline of existing subway and elevated structures indicating base of rail, large interceptor sewers, base of rail of railroads and any other structures that will influence the vertical alignment. The rock line should be shown if enough data is available.

If more than one sheet is required, each should be matched with the preceding and following sheets to give a continuous plan and profile for the entire project.

The horizontal and vertical alignments should be designed based on the guidelines discussed previously and in accordance with the Track Standards of the N.Y.C.T.A. The plan should show the alignment for the center line of each track indicating the properties of the curves and point of switch for turnouts and crossovers.

The profile is drawn for the centerline of the structure showing the base of rail elevation and indicating all grades and properties of the vertical curves.

Both plan and profile should show station (platform) locations, transfer facilities to existing transit lines and when flexing of tracks occur should show the points of clearance.

The following information should be shown on the drawing if conditions warrant.

Property: Private property required should be indicated on the plan by block and lot number and should be tabulated listing block and lot numbers, address, description (number of stories, brick or frame, residential or commercial), assessed valuation and remarks (fee title or partial fee.)

Sequence of construction: It may be necessary in some cases to establish a sequence of construction. This will facilitate the construction work and minimize disruption to existing operations.

Sections: A section is drawn to clarify a portion of the study. A section may be drawn at points of flexings and complicated alignments, stations, passageways, trans-

fer facilities and anywhere else that would help clarify the study.

Notes: Any information that clarifies the study should be shown on the drawings.

Plan Checking

Conflict between the checker and the designer often arises from a correction that involves opinion rather than design error. The design as presented may not be the best possible design, however, it does reflect considerable time and thought. For any design project there are many solutions that will give a satisfactory product. If the design as presented shows sound judgement and economy of design, the checker must accept this product as presented even though, as a designer, he might have taken a slightly different approach to the problem. However, the checker should not be under the impression that his job is only to make a mechanical check of the work as submitted and ignore the possibility of redesign which would effect a savings of time or money, or improve the design. The checker's responsibilities are:

1. To check the accuracy of design as submitted.
2. To point out any mistake or inaccuracy on the plan or estimate.
3. To point out the omission of any information necessary for the clarity of the plan.
4. To call for redesign of any portion of the project that will not function due to failure to observe design criteria, or principles of engineering.
5. To discuss the possibilities of redesign, with his supervisor, of a portion of the project that he feels to be inadequate, inferior or uneconomical.
6. To point out any portion of the design that, although adequate, does not agree with the design manual, standard plans, Division or Department bulletins, or established procedures.

VI - ESTIMATES

At the completion of the feasibility study a preliminary estimate is made to determine its approximate cost. The amount of time spent on a preliminary estimate may vary from merely applying a cost per mile factor to the length of the line to estimating cost from quantity take-offs.

When the information is required expeditiously, the cost per mile method is the most practical. The route is divided into portions having similar conditions and a cost per mile based on previous experience with similar structures is allocated for each portion. In arriving at the total figure, current construction costs and trends are carefully considered and the prices are updated accordingly.

When a more accurate estimate is required the costs are estimated directly from quantity take-offs based on typical design sections. This type of estimate is accurate enough to be used for capital budget requests.

Both methods consider the locality, crossings of rapid transit and other railroads, soil conditions, subsurface structures and utilities, buildings along the route and any other structure that affects the costs.

Generally an allowance of 10% (this may be increased up to 30% for jobs involving reconstruction work on an existing structure) is added to the basic estimate for construction costs to cover various contingencies that may arise.

To increase the accuracy of the estimate, preliminary cost figures for items such as power, track, line equipment, signals, real estate acquisition and rolling stock should be obtained from the respective departments and divisions.

The preliminary estimate for cars required for a trunk line is generally assumed as 15 cars per track mile and is based on thirty trains per hour in each direction at an average speed of 20 miles per hour. For a branch line the number of cars per track is considerably smaller. For a complete route consisting of trunk line and several branches, the usual assumption for the estimate is 11 cars per track mile. To this estimate about 10% should be added for cars under inspection or repair. In many instances where new lines are integrated with existing services the determination of the required number

of cars becomes more complicated. In such cases the Transportation Department actually prepares a simulated schedule of services to determine the actual number of cars required.

In addition to estimating the capital cost of construction, track, signals and line equipment, it often becomes necessary, in many instances, to evaluate the annual cost of operation when comparing different routes. This is generally made on an annual car-revenue-mile basis. Using this as a yardstick in conjunction with the latest available operating expense data, the annual cost of maintenance of way, maintenance of equipment (cars), transportation, power and other miscellaneous items can be readily compared for different routes. Cost of operating stations, of course, will depend on the number planned for a line.

VII - REPORTS

The final phase of preliminary engineering is the preparation of a report. "A report is a written presentation that communicates information to the reader in an unbiased manner and in a form most useable by the reader for the purpose of solving a specific problem."¹¹

A report should provide a basis of action for contingencies. Many decisions to take action are made without a written record of the facts that influenced them. If a contingency arises requiring modification, the task of the person handling the contingency would be reduced if a report were available to explain the existing conditions.¹

The basic parts of a report are:

1. Letter of transmittal
2. Introduction
3. Body
4. Terminal section

The letter of transmittal should contain a brief summary of the report and should state any conclusions and recommendations. Also, it is proof of having submitted the report.

The introduction should contain the following information about the report: subject, authorization, purpose, background material, limitations, sources of information, a brief conclusion and a plan of presentation.

The body of the report should contain all the necessary information and data that must be presented and evaluated. The material should be developed according to plan of presentation.

The terminal section should state the solution to the problem. This section should contain the conclusions, recommendations and opinions developed in the preparation of the report. It is not a summary of the body and should not introduce any new material except to reinforce the solution.

VIII - BIBLIOGRAPHY

1. H. K. Glidden, "Reports, Technical Writing and Specifications", McGraw-Hill Book Company, Inc., New York, 1964.
2. Los Angeles County Road Department, "Highway Design, Manual of Instruction.
3. New York City Transit Authority, "Lectures on Routing, Studies and Planning".
4. Vukan R. Vuchic, "Rapid Transit Interstation Spacing for Maximum Number of Passengers", Operation Research Society of America, Transportation Science.
5. Vukan R. Vuchic and Gordon F. Newell, "Rapid Transit Interstation Spacing for Minimum Travel Time", Operations Research Society of America, Transportation Science.

ENVIRONMENTAL GUIDELINES



INTRODUCTION

INTRODUCTION

INTRODUCTION

Contemporary environmental control can create an artificial environment in buildings that will meet all the physical, psychological and physiological demands of the occupants. It is not necessary to go to this extent in a subway system environment, but it is necessary that the environment be improved over conditions that often exist today. By so doing, the comfort of the passenger will be increased and marginal passengers encouraged to use the system.

In addition to operational acoustical problems to be overcome for the benefit of system passengers, subway operation can have a significant impact on the community. There is a growing awareness of noise pollution and its effect on the environment. Today's subway designer is confronted with not only technical problems to solve, but in many areas overriding social problems relating to the community will dictate design solutions, particularly in this field. Besides these standards stated here, all Federal, State, and City Laws governing standards in noise and vibration should be met also.

STAFF DIVISION ENGINEER

ANTHONY PAOLILLO

AUTHOR

AZMY RAFAIL

INDEX

INDEX

ENVIRONMENTAL GUIDELINES

INDEX

CHAPTER

1	GOALS	.E-1-1
	a - Improving Acoustical Environment for Patrons . . .	.E-1-1
	b - Reducing Impact on the Community	.E-1-1
2	EFFECTS OF NOISE AND VIBRATION . . .	.E-2-1
3	STANDARDS USED IN MEASUREMENTS . . .	.E-3-1
4	CONSTRUCTION NOISE AND VIBRATION LEVELS	.E-4-1

Chapter 1

1-10-60

Chapter 1

GOALS

The two basic goals of the subway industry in its effort to control noise and vibration are:

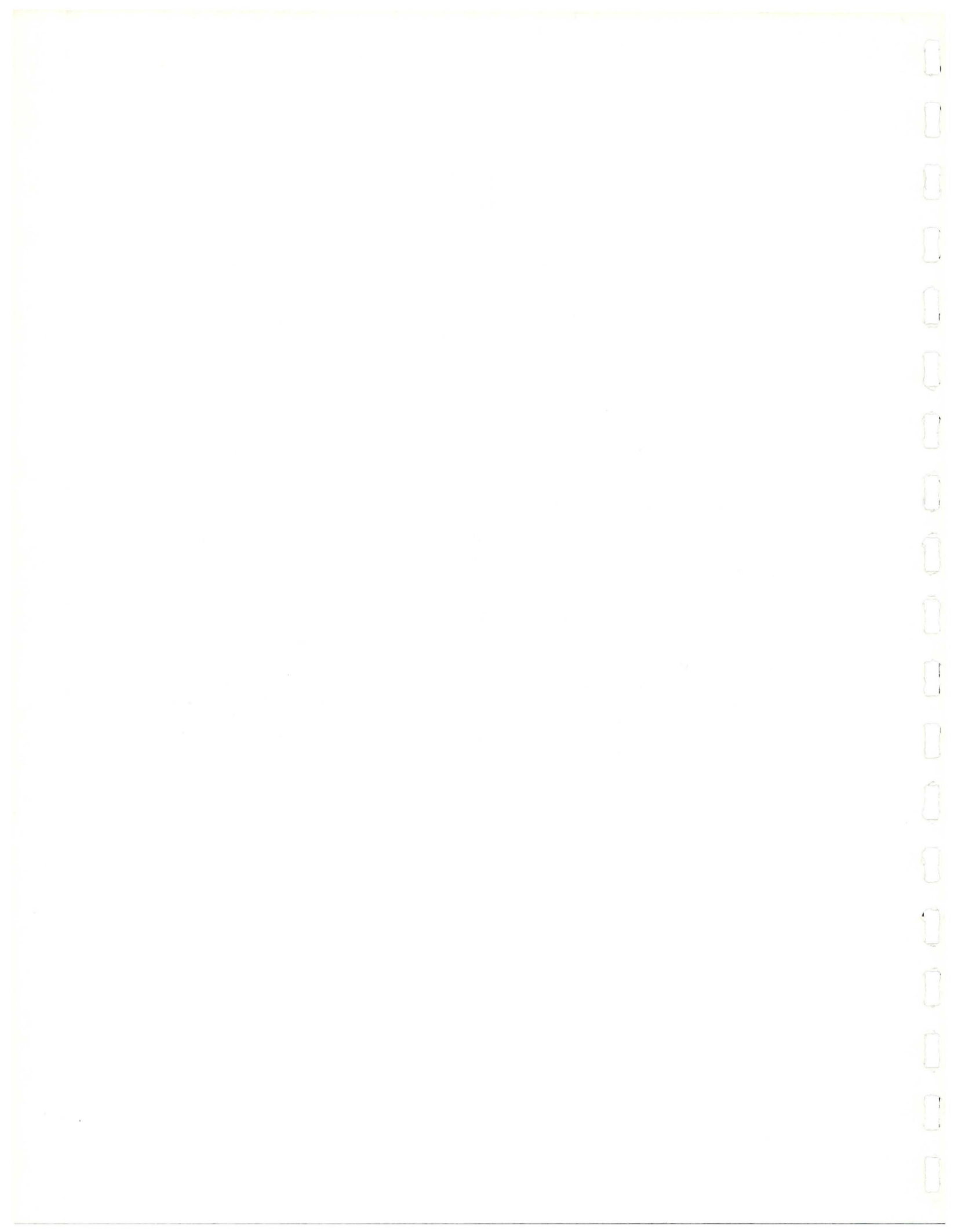
- to provide system patrons with an acoustically comfortable environment by maintaining noise levels in vehicles and stations within acceptable limits.
- to reduce the impact of system operation on the community by minimizing transmission of noise and vibration to adjacent properties.

a Improving Acoustical Environment for Patrons

This is achieved through control of noise and vibration in vehicles, in underground and above ground stations, in tunnels and in tracks.

b Reducing Impact on the Community

Increased community acceptance requires control of air-borne noise from surface and aerial transit operations and from transit ancillary areas, such as yard operations, vent and fan shafts of the ventilation systems, electrical substations and air-conditioning chiller plants. The design must also provide control of ground-borne vibrations and resultant noise from subway operations.



Chapter 2

2-10-10

Chapter 2

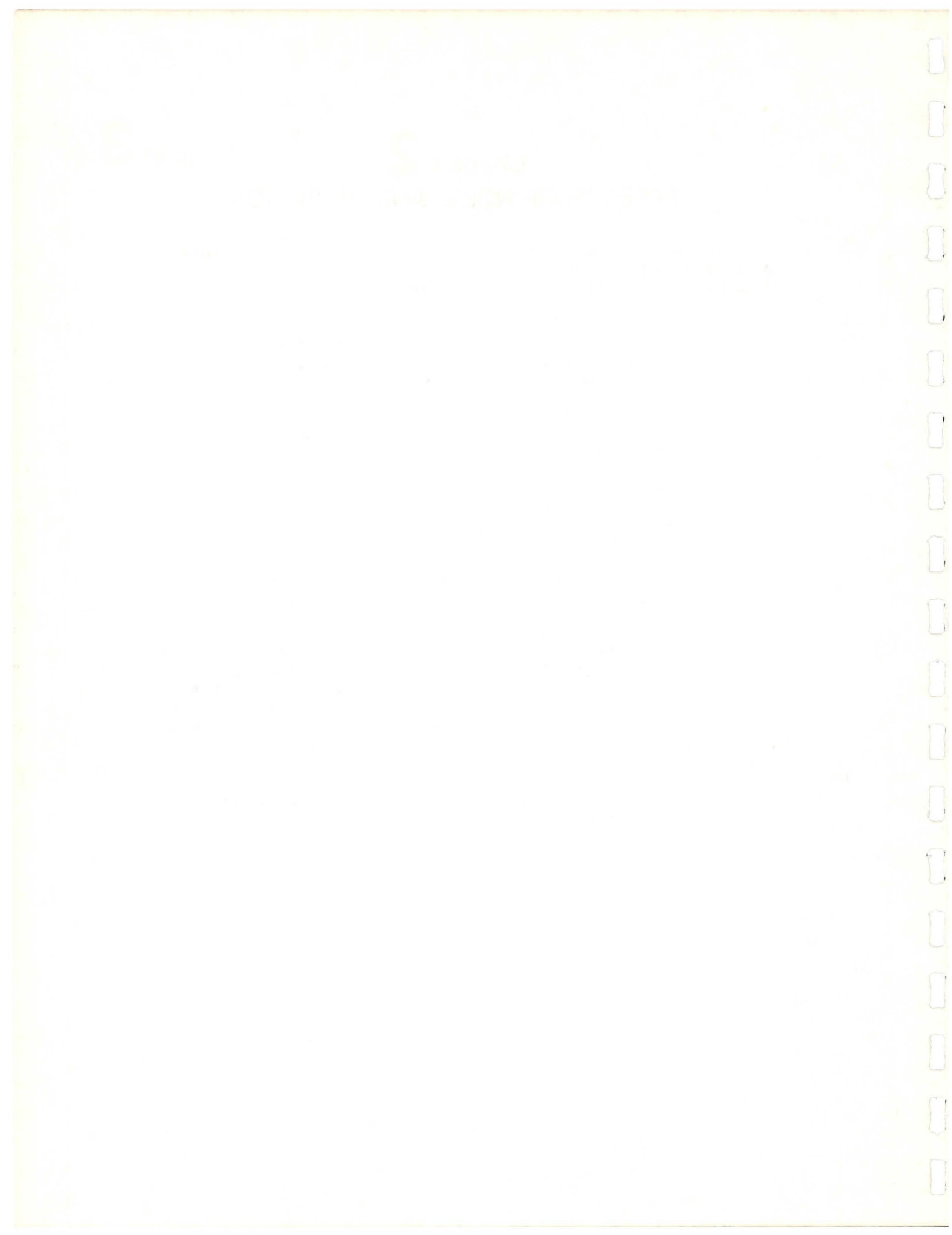
EFFECTS OF NOISE AND VIBRATION

An understanding of the effects of noise and vibration is necessary for the establishment of acceptable criteria. The effects of noise and vibration include:

- Psychological Effects: including annoyance, interference with rest or sleep, interference with work performance and interference with sound communication.
- Economic Effects: such as decreased property values or interference with commercial activities.
- Physiological Effects: including discomfort levels, permanent hearing loss, temporary hearing loss, and other general effects on health.
- Vibration Effects: including damage to the adjacent buildings and discomfort levels.

The basic type of criteria are absolute limits related to measurable physical quantities. They usually deal with hearing damage and protection, speech, communication or interference with other tasks and subjective reactions such as annoyance and are used in ensuring an acceptable acoustical environment for passengers and employees of the system.

In vibration, the criteria is set for minor damage to normal construction of buildings.



Chapter **3**

8-10-1970

Chapter 3

STANDARDS USED IN MEASUREMENTS

Noise or Sound Levels are measured with a sound level meter which meets the Type 1 or Type 2 requirements of American National Standards Institute (ANSI) S1-4-1971, Specification for Sound Level Meters.

All noise levels are in A-weighted sound levels, per ANSI S1.4-1971 in Decibels referenced to 0.0002 microbar.

The "slow" meter response is assumed for all noise level measurements except those involving measurements of transient sources or impact noises.

Sound Analyzer shall conform to ANSI S1.11-1966.

6. 1970

1970-1971

Chapter **4**

4-10-10

Chapter 4

CONSTRUCTION NOISE AND VIBRATION LEVELS

A. Maximum noise levels due to construction work shall be as follows:

1. Sound levels for public noise exposure due to construction will be measured at the closest point adjacent to the site of the Works in normal use by the public while construction work is in progress and shall not exceed the following levels:

<u>Duration Per</u> <u>Day In Hours</u>	<u>Sound Level</u> <u>In dBA</u>
8	90
6	92
4	95
3	97
2	100
1-1/2	102
1	105
1/2	110
1/4 or less	115

Sound level for impulsive or impact noise (noise of duration less than one second) shall not exceed a peak sound pressure level of 140 dB when measured on an approved impact noise analyzer. In lieu of the above procedure, 125 dB measured on the C scale of a standard sound level meter at fast response will be accepted as an equivalent measure of the peak sound pressure level.

2. Additional sound levels for noise due to construction will be measured at the street line of the structure adjacent to and along the area of the Construction operations, and shall not exceed the following:-

a) Residential Structures:

Daily, except Saturday and Sunday, 7:00 A.M. to 11:00 P.M. 75 dBA

Daily, except Saturday and Sunday, 11:00 P.M. to 7:00 A.M. 60 dBA

11:00 P.M. Friday to 7:00 A.M. Monday 60 dBA

b) Business - Commercial Structures:

Daily, including Saturday and Sunday, ALL HOURS, a maximum of 85 dBA.

c) Factory - Commercial Structures:

Daily, including Saturday and Sunday, ALL HOURS, a maximum of 90 dBA.

B. Vibration Levels:

- a) Maximum particle velocity at the nearest building due to construction or operation should not exceed two (2) inches per second.
- b) During blasting, two seismograph instruments and three component photographic recording instruments of the Leet type or equivalent shall be used. Maximum amplitudes for all components as well as resultant for all frequencies of vibrations, duration of motion in excess of one one-thousandth of an inch.

STATION PLANNING GUIDELINES



INTRODUCTION

REPRODUCED

INTRODUCTION

These Standards for Station Planning are designed to provide guidance to the Project Architect during the process of initial planning and design. It furnishes the basic criteria applicable to stations with which the Project Architect should be familiar.

Stations consist primarily of space, equipment and people. It is the task of the Project Architect to integrate the people with the space they pass through and the equipment they use and view. The station design should therefore be one which satisfies the operational needs of the transit system and the aesthetic needs of the passenger.

These Standards do not constrain the imagination of the Project Architect, instead they permit and encourage him to evolve the best design possible within budgetary constraints by coordinating all the elements in a pleasing and meaningful way.

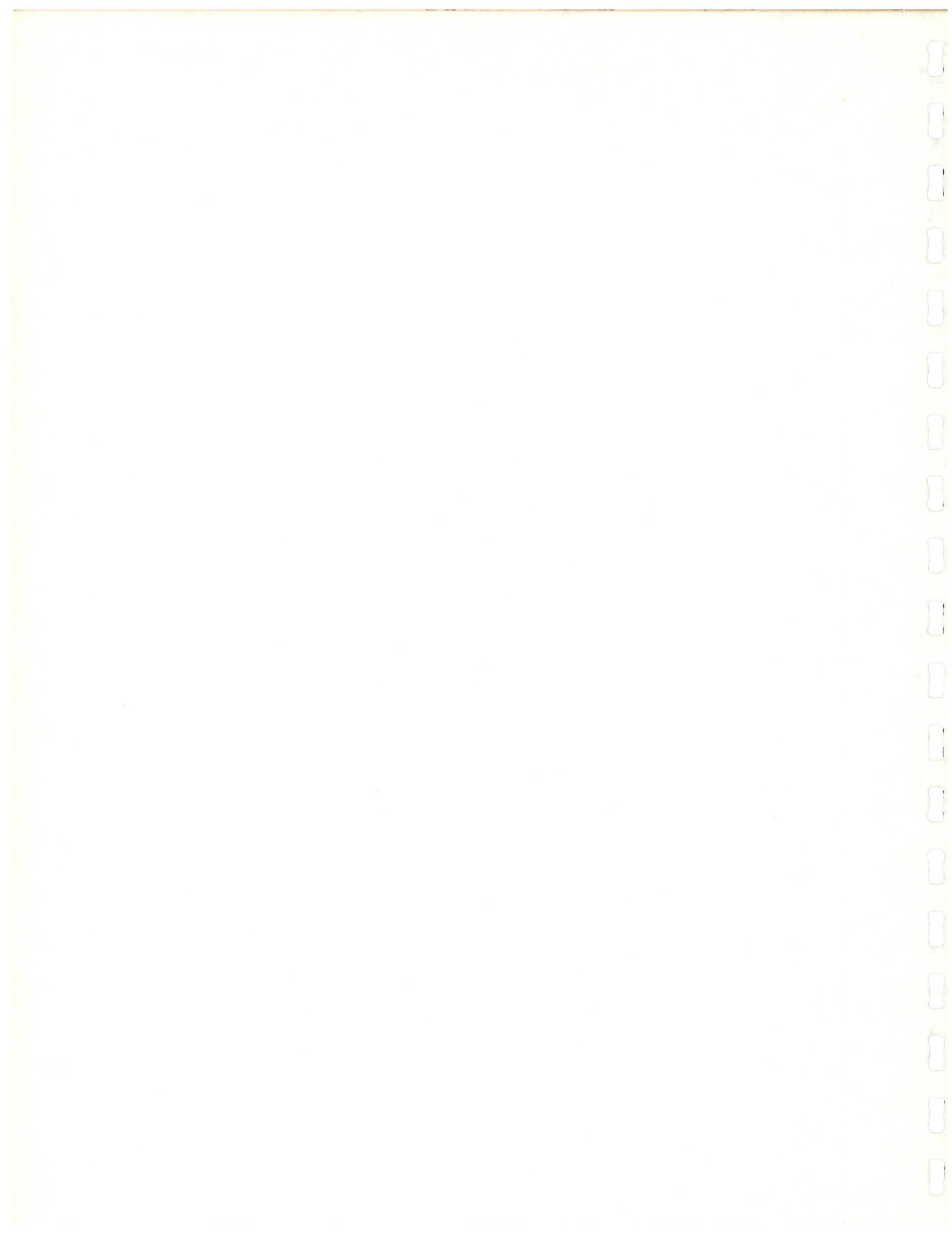
If it should become necessary or desirable for the Project Architect to deviate from these Standards he must substantiate the need for the deviation and submit the proposal to the Transit Authority Executive Officer for approval.

CHIEF ARCHITECT

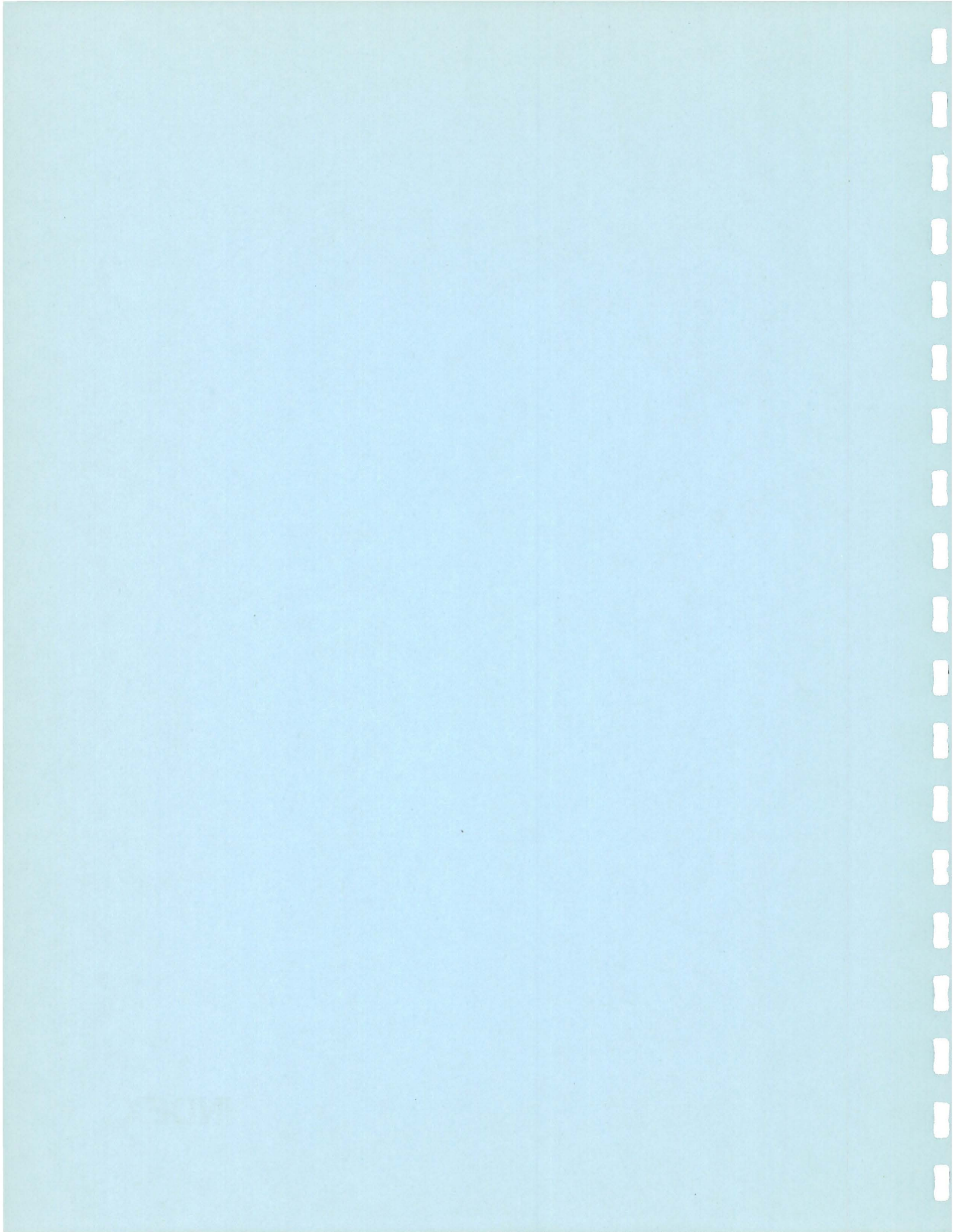
PAUL KATZ

AUTHOR

LAWRENCE ISSAC



INDEX



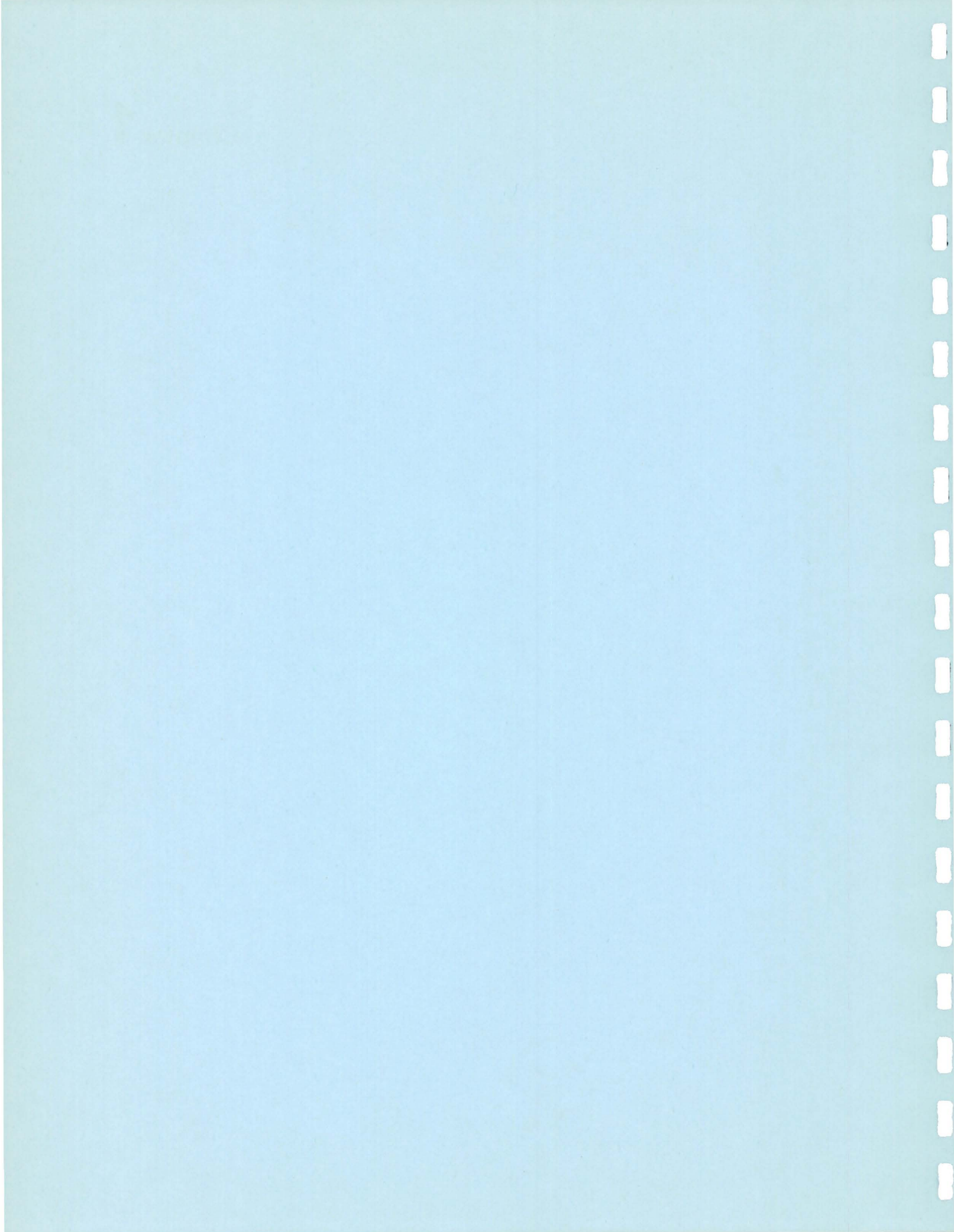
STATION PLANNING STANDARDS

INDEX

CHAPTER

1.	GLOSSARY.....	SP-1-1
2.	STATION ELEMENTS.....	SP-2-1
3.	VERTICAL CIRCULATION.....	SP-3-1
4.	LIGHTING.....	SP-4-1
5.	PASSENGER FLOW.....	SP-5-1
6.	FINISHES.....	SP-6-1
7.	REFUSE DISPOSAL.....	SP-7-1
8.	ACOUSTICS.....	SP-8-1
9.	HANDICAPPED.....	SP-9-1
10.	REFERENCE DATA.....	SP-10-1

Chapter 1



Chapter 1

GLOSSARY

TABLE OF CONTENTS

1.	ABOVE GROUND STATIONS.....	SP-1-1
2.	ADVERTISING.....	SP-1-1
3.	BASE OF RAIL.....	SP-1-1
4.	BELOW GROUND STATIONS.....	SP-1-2
5.	CONCESSIONS.....	SP-1-2
6.	CONTROLS.....	SP-1-2
7.	FULL-TIME.....	SP-1-2
8.	GRAPHICS.....	SP-1-2
9.	INSIDE CONTROLS.....	SP-1-2
10.	MEZZANINE.....	SP-1-2
11.	OPEN CUT STATION.....	SP-1-2
12.	OUTSIDE CONTROLS.....	SP-1-2
13.	PART-TIME.....	SP-1-2
14.	PEAK HOURS.....	SP-1-2
15.	PLATFORM.....	SP-1-3
16.	PLATFORM LOADINGS.....	SP-1-3
17.	RIGHT OF WAY.....	SP-1-3
18.	STATION.....	SP-1-3

- 19. STREET ENTRANCE.....SP-1-3
- 20. TOKEN BOOTH.....SP-1-3
- 21. TRACK SPACE.....SP-1-4
- 22. TWENTY MINUTE PEAK.....SP-1-4

Chapter 1

GLOSSARY

- | | |
|--------------------------|---|
| 1 Above Ground Station: | A station in which the tracks, platforms, mezzanines, etc. are located on an elevated structure or rest directly on grade or an embankment. |
| 2 Advertising: | Those areas such as wall, railing and free standing spaces, which the Transit Authority leases for advertising posters. |
| 3 Base of Rail (B of R): | The profile line representing the elevation of the bottom surface of running rails. |

- 4 Below Ground Station: A station in which the tracks and platform are located below grade and completely covered.
- 5 Concessions: Those areas the Transit Authority leases to private enterprise.
Types
-Vending Machines
-Retail Stores (including banks, newsstands, etc.)
-Storage
- 6 Controls: The turnstiles and exit gates which separate the paid area from the unpaid area.
- 7 Full-Time: A 24 hour period.
- 8 Graphics: The identification, directional and information signage needed to orient the passenger within the station environment.
- 9 Inside Controls: That portion of a station which is in the paid area. Passengers cannot enter this area without paying a fare or presenting proper credentials.
- 10 Mezzanine: An intermediate level or space.
- 11 Open Cut Station: A station in which the tracks and platforms are below grade and uncovered.
- 12 Outside Controls: The portion of a station which is in the unpaid area. Passengers may enter this area without paying a fare.
- 13 Part-Time: Part of a 24 hour period.
- 14 Peak Hour: That hour during the AM and/or PM, on an average day, at which time the station has the largest passenger volume.

15 Platform:

The section of the station parallel to, but raised from the tracks, where trains halt to load and unload passengers.

Types:

- Island Platform: a platform situated between two sets of tracks.
- Side Platform: a platform situated alongside one set of tracks.

16 Platform Loading:

The area or areas on a platform through which passengers enter and exit.

Types:

- Center loading
- End loading
- Quarter point loading
- Third point loading

17 Right of Way:

Lands or rights used or held for railroad operation.

18 Station:

That complete volume of space comprising the station site including all structures within it through street entrances.

19 Street Entrance:

Sidewalk or Plaza

- direct access to station from or through sidewalk or plaza.

Building Entrance

- access to station through transit structure or private property.

20 Token Booth:

A bullet resistant enclosure housing the token agent from where tokens are purchased. This enclosure may be free standing as a booth or an integral part of the architectural station design.

21 Track Space:

That section of the subway which contains running and contact rails over which trains operate.

22 Twenty Minute Peak:

The busiest 20 minute portion of the peak hour (varies from 33-1/3% to 40% of the peak hour).

Chapter **2**

St. John's

Chapter 2

STATION ELEMENTS

TABLE OF CONTENTS

ABOVE AND BELOW GROUND STATIONS.....	SP-2-1
A. ENTRANCES: Full-time and Part-time.....	SP-2-1
B. MEZZANINES: Full-time and Part-time.....	SP-2-2
C. CONTROL AREAS.....	SP-2-3
D. VERTICAL CIRCULATION.....	SP-2-4
E. HORIZONTAL CIRCULATION.....	SP-2-4
F. PLATFORM.....	SP-2-5
G. EMERGENCY FACILITIES.....	SP-2-6
H. GRAPHICS.....	SP-2-7
I. SEATING.....	SP-2-8
J. PIPE IDENTIFICATION.....	SP-2-8
K. TOILETS.....	SP-2-8
L. PUBLIC TELEPHONES.....	SP-2-9
M. ADVERTISING.....	SP-2-9
N. CONCESSIONS.....	SP-2-9
O. MAINTENANCE, SERVICE & EQUIPMENT ROOMS.....	SP-2-9
P. DOOR SIZE AND TYPES.....	SP-2-10
Q. PUBLIC ADDRESS SYSTEM.....	SP-2-12
R. TELEVISION SURVEILLANCE.....	SP-2-12

S.	DESTINATION SIGNS.....	SP-2-13
T.	TWO-WAY RADIO COMMUNICATIONS.....	SP-2-13
U.	TOKEN BOOTHS.....	SP-2-14
V.	TELEPHONES AND MISCELLANEOUS EQUIPMENT.	SP-2-14
W.	GENERAL REQUIREMENTS AND CRITERIA FOR COMMUNICATIONS EQUIPMENT.....	SP-2-15
	SUBWAY CAR DATA AND CLEARANCES.....	SP-2-16

Chapter 2

STATION ELEMENTS

ABOVE AND BELOW GROUND STATIONS

A. ENTRANCES: Full-time and Part-time

SIDEWALK ENTRANCES

- Sidewalk entrances are to be located at the building line where feasible.
- Provide closure facilities at foot of all street stairs for emergency and part-time operation.
- All exterior stairways, moving stairs, approaches to stairways and landings are to be provided with snow melters. Control switch for snow melters shall be located in nearest 24 hour token booth.

OFF-STREET ENTRANCES

- This type of entrance is preferred where feasible.
- Types: Entrance through transit facility
Entrance through private property
- All openings between transit facilities and private property shall have provisions for self-closing fireproof doors.

PASSAGEWAY ENTRANCE

- Entrance by means of a passageway from another station or other facility.

GENERAL REQUIREMENTS

- Temporary barricades are to be provided at all entrances.

B. MEZZANINES: Full-time and Part-time

MEZZANINE TYPES

- Full length mezzanine
- Partial mezzanine

CLEAR HEIGHTS

- Location, passenger density, site conditions, etc. are to be considered in determining mezzanine heights.
- Minimum height: 9'-0"
- Optimum height: 12'-0"
- 2'-0" space required above finished ceiling for AC ducts.

GENERAL REQUIREMENTS

- Floor drainage
- Electric outlets
- Water hose connections

C. CONTROL AREAS

TOKEN BOOTH (STANDARD TA DESIGN)

STANDARD TOKEN BOOTH SIZES

- Standard height: 7'-3"
- Adjacent to wall or free standing:
6'-0" wide by 6'-0" or 12'-2" long
- Recessed: 18"-2" wide front (minimum)

TYPES

- Booth adjacent to wall
- Free standing booth
- Booth recessed into wall

VARIATIONS PERMITTED:

- Exterior material below window color band provided bullet resistant features are retained
- Color
- Shape provided standard modular unit sizes are retained

GENERAL REQUIREMENTS

- Provide token agent with complete visibility of turnstiles and exit gates
- Locate booth within 10 to 15 feet of the turnstiles or within the line of control
- Token vending machines as required
- Change vending machines as required

TURNSTILES (STANDARD TA DESIGN)

FULL-TIME SUPERVISED AREA

- Low two-way turnstiles

PART-TIME SUPERVISED AREA

- Low two-way turnstiles with overhead closing grille
- High one-way turnstiles as required

NON-SUPERVISED AREA

- High one-way turnstiles

EXIT FACILITIES (STANDARD TA DESIGN)

FULL-TIME SUPERVISED AREA

- Low exit gates
- Two-way turnstiles

PART-TIME SUPERVISED AREA

- Low exit gates with overhead closing grille
- Two-way turnstiles
- High revolving exit gate as required

NON-SUPERVISED AREA

- High revolving exit gate

RAILINGS & PARTITIONS (STANDARD TA DESIGN)

Railings and/or partitions are to separate the paid from the unpaid areas and shall be high or low as required.

CLOCK

One clock shall be appropriately placed within each control area.

D. VERTICAL CIRCULATION

TYPES

- Stairs
- Ramps
- Moving Stairs

E. HORIZONTAL CIRCULATION

TYPES

- Passageways
- Moving Walks

F. PLATFORM

TYPES

- Side Platform
- Island Platform

DIMENSIONS

CLEAR HEIGHT

- Measured from center line of platform to underside of lowest portion of ceiling
- Minimum: 10'-0"
- 2'-6" required above finished ceiling for AC ducts

LENGTH

- Division A - IRT: 525 feet
- Division B - IND & BMT: 615 feet

SIDE PLATFORM WIDTH

- Measured from side wall finish to platform edge.
- 12'-0" minimum without columns.
- Columns not recommended.

ISLAND PLATFORM WIDTH

- Measured from platform edge to platform edge.
- 20'-0" minimum without columns.
- 25'-0" preferred width.
- 22'-0" minimum with single row of columns.
- 25'-0" minimum for terminal stations.
- Single line of columns (recommended)

GENERAL REQUIREMENTS & CRITERIA

- Slope platform towards track for drainage and provide gutter at walls with drainage facility.
- Provide electric outlets and water connections along the platform as required.
- The elimination of platform columns is preferred when feasible.

- When platform columns are required the minimum distance between a column and the platform edge shall be 5'-0".
- All accessories required for the operation of the transit system and exposed within the station (ie. conductor's board, signal equipment, antennas, etc.) are to be incorporated into the total design.
- Provide platform edge and warning strip as per standard TA design.
- All above ground stations are to be provided with full length canopies and full length windbreakers.
- All platform and mezzanine columns must be fire-proofed when located within property lines.
- Platform and mezzanine steel columns may be enclosed.
- All approaches to vertical circulation on above ground platforms are to be provided with electric snow melters.
- All station sidewalls adjacent to a track are to be provided with "grab bars".
- Grab bars are to be of 1/2 inch round stainless steel 15 inches long, spaced 10'-0" on center.
- Grab bars are to be mounted 5 foot from floor (base of rail or toe bench) to bottom of bar.

G. EMERGENCY FACILITIES

Fire Lines

- Wet fire lines are to be installed in each station with siamese inlet standpipe connections at street level near station entrance conforming to Fire Department standards.
- The wet fire lines are to be situated in a manner which will provide three (3) hose valves per platform. They are to be recessed in a fire hose cabinet (Standard TA Design) in the station sidewall at side platforms and

on the escalator/stair wing walls at island platforms.

- Each cabinet is also to be provided with a hose bib connection for station cleaning.
- The fire hose cabinet shall contain a 2-1/2 inch hose valve; 75 feet of 1-1/2 inch racked neoprene lined polyester hose with plastic fog nozzle; and in a separate compartment, a 3/4 inch hose outlet to be used for station washing.
- Eight foot by six foot water meter room shall be provided at approximately 1200 foot intervals. At stations the meter room shall be larger if it is to supply both the fire line water service and any other services that may be required.
- Appropriate graphics are to be provided at all locations.

EMERGENCY EXITS

- Each station is to be judged on its own merits as to the need for emergency exit facilities.
- Stations that have double end loading conditions will not require an emergency exit unless directed otherwise.
- Stations that have single end or single quarter point loading conditions will require an emergency exit close to but beyond the station limits.

H. GRAPHICS

- All graphics required throughout the transit system are to be designed in accordance with the "Transit Authority Graphics Standards Manual".
- The Architect is to provide the General Contractor with full size lettering layouts during the construction phase of the contract.

I. SEATING

TYPES

- Individual seats grouped.
- Benches with separators for individual seating.
- Benches and seats are to have replacable units.

LOCATION

- Within control areas.
- Along platform as required.
- Arranged not to interfere with passenger circulation.

J. PIPE IDENTIFICATION

- To be coded as per TA standards.

K. TOILETS

TYPES

- Public toilets for men and women at transfer and major stations only.
- One employee toilet per station.
- Crew room toilets with provisions to suit each specific situation.

GENERAL REQUIREMENTS

- Public toilets shall have an attendant station, supervising both the mens and womens toilets.
- With provisions for closing the facility at night.
- All public toilets to be located in the paid area of the station, preferably within view of the token agent.
- All stalls are to have coin locks.

HANDICAPPED REQUIREMENTS

- Each public toilet (men & ladies) shall have one stall with the following requirements:
- Width: 3'-0"
- Depth: 4'-8" minimum 5'-0" preferred
- Door width: 2'-4" swing out, not to interfere with access to other stalls.
- Handrails on each interior side of the stall, 33" high and parallel to the floor, 1-1/2" clearance

- between rail and wall, fastened securely at ends and center of rail.
- Water closet with seat 20" from the floor.
- Stall to be identified with appropriate graphics.

L. PUBLIC TELEPHONES (STANDARD TA DESIGN)

- Public telephones within view of the token agent are to be provided in and outside of the paid areas of the station.
- The Telephones shall have a '911' emergency provision.
- One phone to be provided for the hard of hearing and shall be identified with appropriate graphics.

M. ADVERTISING (STANDARD TA DESIGN)

LOCATION

- Not to conflict with graphics.
- To be treated as elements within the total station design concept.
- To be grouped in selected areas.

N. CONCESSIONS (STANDARD TA DESIGN)

LOCATIONS

- Not to obstruct passenger flow or interfere with the operation of transit facilities.
- Accessible to normal passenger flow.
- Concessions not permitted on platforms.
- Not to interfere with other concessions or advertising.
- All concessions to be observable by the token agent.

GENERAL REQUIREMENTS

- Automatic vending must be within view of the token agent and is to be grouped in units of an approved modular design.
- All manned concessions and storage areas to be provided with sprinkler systems.
- Concessionaires are to use rubber-tired dollies and hand trucks only rather than steel wheeled which tend to damage stair and floor finishes.
- Areas chosen for concessions are to be designed as part of the total station concept and not as an after-thought.

O. MAINTENANCE, SERVICE & EQUIPMENT ROOMS

The following rooms shall be provided as required. For heating, ventilation and air cooling requirements, see ventilation and air cooling standards.

EQUIPMENT ROOMS

- Electrical Distribution Room (normal and reserve)
- Ejector Pit
- Electrical Duct Manhole
- Central Instrument Room
- Pump Room (with pump below)
- Relay Room
- Circuit Breaker House
- Fan Room
- Climate Changer Room (with adjacent Stationary Engineers Room)
- Moving Stair Machinery & Pit Areas
- Panel Board Room
- Telephone Compartment Room
- Radio Base Station Room
- Other Areas as required

SERVICE ROOMS

- First Aid Storage Closet (for medium station)
- First Aid Treatment Room (for major station)
- Storage Rooms
- Dispatcher's Office
- Police Quarters
- Toilets, Public & Employee
- Other Areas as required

MAINTENANCE ROOMS

- Porter's Closet (mezzanine & platform)
- Refuse Disposal Area
- Track Lubrication Room
- Maintainer's Quarters (for Signals, Tracks, Power, Structure & Line Equipment Groups)
- Dressing & Locker Room
- Utility Room (for automatic floor scrubber)
- Other Areas as required

P. DOOR SIZE AND TYPES

- All doors 3'-0"x7'-0" with louvers except-

- Ejector Pit - louvered double doors
4'-0" x 7'-0"
- Fan Room - dust tight sliding door
3'-6" x 7'-0"
- Pump Room - non-louvered sliding door
4'-0" x 7'-0"

ELECTRICAL DISTRIBUTION ROOM

General

Personnel doors

- 3'-0" x 7'-0" H.M. Class 'A' Fire Door
- panic hardware
- swing out
- dustproof

Equipment doors

- pair of 4'-3" x 8'-0" H.M. Class 'A' Fire doors, swing out
- or - 8'-6" wide x 8'-0" high Class 'A' rolling fire door
- dustproof

Requirements for rooms located above tracks

- Personnel - Two doors located at opposite ends of room
- Equipment - Removable floor hatch (8'-0" x 10'-0")

Requirements for rooms located adjacent to track duct bench

- Personnel - Two doors located at opposite ends of room
 - Doors are to be receded when opening on to duct bench
- Equipment - Rolling Door
 - Drum located on interior side of room

All other locations

- Personnel - Two doors located at opposite ends of room
- Equipment - Pair of H.M. doors

Q. PUBLIC ADDRESS SYSTEM

All stations shall be equipped with a public address system which may be utilized by the master token booth, part-time dispatchers, key dispatchers or the Transportation Department Jay Street Command Center, subject to an established priority of control.

Key dispatchers shall be provided with turrets to permit selective announcements to designated stations. In addition, key dispatchers shall be capable of two-way communication with the Jay Street Command Center via a loudspeaking telephone system.

Speakers shall be located in platform, mezzanine, passageway and control areas.

Auxiliary equipment required for the public address system shall be installed in equipment cabinets which shall be located in the Telephone Compartment Room.

R. TELEVISION SURVEILLANCE

Television cameras shall be provided for platform and mezzanine coverage, in passenger elevators, and for other areas (like passageways) where designated. The cameras shall provide visibility of at least 90% of the required areas of coverage.

Cameras shall be of the fixed lens type without power zoom or tilt. However, cameras shall be provided with adjustable mountings that will allow the horizontal and vertical viewing angles to be changed in accord with the field conditions.

Television monitors shall be located in the master token booth. At least two monitors shall be provided.

Sequential switchers, as required, shall be installed in the booth to allow the booth agent to use one monitor to view scenes from several cameras in sequential time intervals. This switch shall provide control of up to 10 cameras inputs. The switch shall permit the agent to stop the sequencing and provide continuous display of any desired input.

S. DESTINATION SIGNS

The R-44 car is, and future new cars may be equipped with an identra system. This will enable trains approaching a station to identify themselves and their destination. Illuminated "destination" signs may be required on station platforms to display this information to the public.

T. TWO-WAY RADIO COMMUNICATIONS

Two-way FM radio communication shall be provided for train operations and the Transit Police. Both Police and Transportation radio systems share a common outdoor antenna at outdoor locations and antenna cable system underground. However, each system utilizes separate transmitter-receivers and each system is connected into its own radio command center at Jay Street by carrier frequency equipment via T.A. cable.

Radio base stations shall be provided at stations as required and the equipment shall be installed in a separate communications room at these stations.

Base stations shall be designed to provide satisfactory coverage in accord with T.A. standards over at least 95% of the area required to be covered, both outdoors and underground. In outdoor areas, remote receivers or other auxiliary equipment shall be provided, as required, at stations. In underground locations, auxiliary antenna cable and/or "firecracker" antennas shall be installed as required to provide radio coverage in mezzanine, passageway and control areas.

This auxiliary antenna cable shall be of a coaxial type, either radiating ("Radiax") or non-radiating ("Heliax") as required.

Antenna cable run through the station platform area which connects to the underground system along the right-of-way is expected to be of the twin-lead transmission line type. However, note that consideration is being given to the use of coaxial type antenna cable throughout.

All wire, cable and conduit shall be concealed.

U. TOKEN BOOTHS

At each station, one token booth shall be designated as the Master Token Booth and shall be equipped with public address and TV facilities as described above in Paragraphs QR and T.

In addition, each token booth shall have the following communications equipment:

Each booth shall be provided with a telephone.

Each booth shall be provided with a public intercommunication system. This system shall permit the booth agent to talk to people at the selling window. A separate amplifier shall be provided for each selling window. All required equipment for this system shall be installed in the booth.

Each booth shall be provided with a Station Department intercommunication system. This system shall enable the booth agent to communicate with designated field supervisors and with Jay Street Station Department headquarters. The auxiliary equipment required for this system shall be installed in the Telephone Compartment Room. T.A. cable shall be used to connect the booth agent to field supervisors and Jay Street.

In addition, the following communications equipment may be required in token booths:

At outdoor stations, where required, emergency alarm equipment shall be installed in a designated token booth.

Where elevators are installed in stations, an elevator intercommunication unit shall be installed in a designated token booth.

V. TELEPHONES AND MISCELLANEOUS EQUIPMENT

Telephones shall be provided in rooms as required (e.g., Relay Rooms, Signal Rooms, Crew Rooms, Dispatcher's Offices, Electrical Distribution Rooms, Equipment Rooms of various types, etc.) and on station platforms

as required. The type and quantity of telephones required at each location must be checked with the department involved. (Note that these are T.A. System telephones, not public telephones.)

Smoke detector equipment shall be provided in relay rooms, radio rooms and other locations, where designated.

Fire protection equipment including fire extinguishers, sprinkler systems and automatic fire fighting systems shall be provided where designated.

Security alarm systems shall be provided where designated.

W. GENERAL REQUIREMENTS & CRITERIA FOR COMMUNICATIONS EQUIPMENT

All communications equipment provided shall meet or exceed applicable T.A. standards. Otherwise, they shall be in accord with the best quality applicable industry standards.

Wire and cable shall have fire retardant insulation and shall not produce noxious fumes.

In public areas, all conduit, wire and cable, shall be concealed. All other equipment shall be concealed to the extent possible.

Equipment in public areas, like speakers, T.V. cameras, etc., shall be installed to be vandal proof and secure to the extent possible, but accessible for maintenance by authorized personnel.

Twin lead antenna cable shall be mounted at least 6" away from other cable and structural metal (including reinforced concrete walls.) Materials used to conceal this cable shall not be painted, especially not with lead or other metallic base paints.

The following data is provided as general information for the Project Architect.

SUBWAY CAR DATA & CLEARANCES

DIVISION A - IRT

CAR DIMENSIONS

- Length: 51'-4"
- Width: 8'-9 1/2"

CAR CLEARANCES

- Center of car to wood edge of station platform: 4'-8-1/4" plus excesses if any.
- Center of track to face of wall and/or column finish; 7'-0" plus excesses if any.

DIVISION B - IND & BMT

CAR DIMENSIONS

- Length: 60'-6" & 75'-0"
- Width: 10'-0"

CAR CLEARANCES

- Center of car to wood edge of station platform: 5'-2" plus excesses if any.
- Center of track to face of wall and/or column finish: 7'-0" plus excesses if any.

Chapter **3**

6-11-10

Chapter 3

VERTICAL CIRCULATION

TABLE OF CONTENTS

1. STAIRS.....	SP-3-1
Stair Widths.....	SP-3-1
Riser & Tread.....	SP-3-1
Intermediate Stair Landings.....	SP-3-2
General Stair Criteria.....	SP-3-3
2. MOVING STAIRS.....	SP-3-3
General Requirements.....	SP-3-3
3. ELEVATORS FOR THE HANDICAPPED.....	SP-3-4
4. RAMPS... ..	SP-3-4
General Requirements.....	SP-3-4

Chapter 3

VERTICAL CIRCULATION

1 - STAIRS

STAIR WIDTHS

- Stair widths are to be determined by projected patronage.
- The minimum width for any stair is 8'-0". Permission is to be acquired from the Chief Engineer for any conditions requiring less width.

RISER AND TREAD

- Riser height: 6-1/2" wherever feasible.
Exception: see 'GENERAL STAIR CRITERIA'.

- Minimum height: 6", Maximum height: 7".
- Tread width: 11-1/2" wherever feasible.
Exception: see 'GENERAL STAIR CRITERIA'.
- Minimum width: 10-1/2", Maximum width: 12".
- Sum of two risers plus one tread, excluding nosing, shall be no less than 24" nor more than 25-1/2".
- Minimum vertical headroom over riser nosing: 7'-6".
- Maximum number of risers in one stair run: 14.
This may be increased to a maximum of 18 risers when stair is adjacent to escalator.
- Minimum number of risers in one stair run: 2.
- Solid risers and treads.
- Non-slip finish for all treads.
- Winders not permitted.
- Provide electric snow melters for exterior stairs.
- Provide drainage for exterior stairs.

INTERMEDIATE STAIR LANDINGS

- Minimum length of landing for a straight run stair: 4'-6" (5'-0" recommended).
- Minimum width of landing: equal to width of stair.
- Provide electric snow melters for exterior landings.
- Provide drainage for exterior landings.

STAIR HANDRAILS

- Height: 2'-8" from nosing to top of handrail.

- Minimum clearance: 2-1/2" between edge of hand-rail and wall.
- Handrails and Center Stair Railings are to be 3'-0" high above landings and continuous through all intermediate landings.
- Extend handrails 18" beyond top and bottom risers wherever possible, however, no less than 12" is permitted.
- Handrails for both sides of a stair.
- Maximum stair width without Center Railing: 7'-4".
- Handrail end shall return to wall.
- Minimum height of railing around stair well opening: 3'-8".

GENERAL STAIR CRITERIA

- Stairways shall not merge into stairways of lesser capacity unless provisions for future widening are included.
- In high density and/or traffic areas provide a minimum of four entrances per control area.
- Where stairs occur alongside a moving stair, the nosing line should be set to match the slope of the moving stair and the stair situated in a manner that the handrail remains below the moving stair deck plate.
- Paint bottom and top riser of each stair run yellow as per TA standards.

2- MOVING STAIRS

- GENERAL REQUIREMENTS
- Escalation is to be provided by including at least one up and one down moving stair from street to mezzanines, galleries and platforms in addition to normal stair requirements.

Moving stairs to and from street level are to be located at the point of greatest passenger traffic wherever possible.

- Speed: 90 & 120 feet/minute.
- Reversible moving stairs.
- Automatic starting treadle, top and/or bottom, where and when specified.
- Access to machinery rooms and moving stair pits outside of passenger flow wherever possible.
- Emergency shut-off switches at head and base of moving stair and in nearest full time token booth.
- All escalators shall have sprinkler systems.
- Handrails are to be black and are to have white circular inserts spaced approximately 2'-0" on center.

3- *ELEVATORS FOR THE HANDICAPPED*

- Each station is to be provided with an elevator from the street to the mezzanine and from the mezzanine to each platform. Design criteria as per TA standards.

4- *RAMPS*

GENERAL REQUIREMENTS

- Slope of ramp: 8% maximum.
- Width determined by projected patronage.
- Continuous handrails along both sides.
- Provide electric snow melters for exterior ramps.
- Provide drainage.

Chapter **4**

100-100000

Chapter 4

LIGHTING

TABLE OF CONTENTS

1. GENERAL REQUIREMENTS.....	SP-4-1
Concept.....	SP-4-1
Fixture Criteria.....	SP-4-2
Lamp Criteria.....	SP-4-2
Illumination Levels.....	SP-4-2
Area.....	SP-4-2
2. EMERGENCY LIGHTING.....	SP-4-3
Emergency Illumination Levels.....	SP-4-3
Area.....	SP-4-3
3. GENERAL REQUIREMENTS.....	SP-4-3
High Area Lighting.....	SP-4-3
4. REFERENCES.....	SP-4-4

Chapter 4

LIGHTING

1- GENERAL CRITERIA

Lighting should be of a nature and type applicable to a rapid transit station. Passenger safety and ease of maintenance should be given prime consideration. The following criteria should be considered minimum and varied to allow the lighting to complement the station design concept.

CONCEPT

- Illumination levels within any major area should be varied to create interest and to point out specific local area functions. Similar functions should have the same illumination levels throughout the station. Typical areas to be emphasized

would be platform edges, tops and bottoms of stairways and moving stairs, token booths, information signs, etc. Glare from lighting sources should be kept to a minimum.

FIXTURE CRITERIA

- Enclosed type fluorescent fixtures may be used only in mezzanine and entrance areas.
- Fixtures shall be readily maintainable and fabricated of industrial grade materials to minimize vandalism.
- Mounting positions for fixture shall be permanently fixed after final installation.

LAMP CRITERIA

- Fluorescent and mercury lamps are to be used for all station areas. Incandescent lamps may be used only in pipe chambers, escalator enclosures, equipment and maintenance areas, etc.
- Mercury lamps may be utilized for special application and effects and not for broad general application. The mercury lamp is to be a non-reflector type, phosphorous coated of 100,175 and 250 watt sizes.
- Fluorescent lamps shall be warm white only of 4 foot and 6 foot lengths.

ILLUMINATION LEVELS

- The listed illumination levels are average, maintained, in service values with a floor working plane and Maintenance Factor of 0.65.

AREA	ILLUMINATION LEVEL (fc)
- Platform, below ground	20
- Platform, above ground with canopy	15
- Platform, above ground without canopy	5

AREA	ILLUMINATION LEVEL (fc)
- Mezzanine & Other Public Areas	20
- Control Area	30
- Concession Area	30
- Utility Rooms	15
- Electrical Distribution Rooms	20
- Storage Areas	5
- Entrance Stairway	10

2- EMERGENCY LIGHTING

- Emergency lighting shall be accomplished by using the station lighting fixtures with the addition of a rechargeable battery pack and electronic unit making the same fixture useable for both normal and emergency operation. Emergency lighting shall be for a minimum of three hours of continuous operation.

EMERGENCY ILLUMINATION LEVELS

- The listed illumination levels are average, maintained, in service values with a floor working plane and Maintenance Factor of 0.65.

AREA	ILLUMINATION LEVEL (fc)
- Platform, Mezzanine & Other Public Areas	1
- Stairs & Moving Stairs	2
- Utility Rooms	0.5
- Electrical Distribution Rooms	1

3- GENERAL REQUIREMENTS

HIGH AREA LIGHTING

- For maintenance purposes, provide telescoping scaffolding with appropriate storage facilities on each platform.

4- REFERENCES

- Guidelines and Principles For Design of Rapid Transit Facilities
Institute For Rapid Transit
(Draft Copy - December 1971)
- IES Lighting Handbook
Illuminating Engineering Society

Chapter **5**

3-10-20

Chapter **5**

PASSENGER FLOW

TABLE OF CONTENTS

1. INTRODUCTION.....SP-5-1
2. MAXIMUM THEORETICAL CAPACITIES.....SP-5-2
3. OPPOSING TRAFFIC FLOW.....SP-5-2
4. FUTURE PASSENGER GROWTH.....SP-5-3

Chapter **5**

PASSENGER FLOW

1-INTRODUCTION

The various guidelines in this section have been calculated to achieve rapid, safe and convenient passenger flow and are to be used by the architect, to determine the DESIGN CAPACITIES for all traffic flow elements within a station (i.e., turnstiles, stairs, passageways, etc.).

Note: All calculations are to be based on hourly peaks unless otherwise specified.

2- MAXIMUM THEORETICAL CAPACITIES FOR ALL TRAFFIC FLOW ELEMENTS OTHER THAN MOVING STAIRS

TRAFFIC FLOW ELEMENTS	MAXIMUM THEORETICAL CAPACITIES
- TURNSTILES	2,400 persons/hour
- HIGH ENTRANCE TURNSTILES	1,200 persons/hour
- EXIT GATES	3,000 persons/hour
- HIGH REVOLVING EXIT GATES	1,680 persons/hour
- STAIRS All stair widths are to be designed in multiples of two feet wherever possible.	1,000 persons/hour per foot of width in the up direction.
- PASSAGEWAYS Any slope up to 8 percent	2,000 persons/hour per foot of width in the up direction.
- RAMPS Any slope greater than 8 percent (not recommended)	1,500 Persons/hour per foot of width in the up direction.

3- OPPOSING TRAFFIC FLOW

For passenger flow in opposing directions reduce capacities as follows:

PASSENGER FLOW	REDUCTION FACTOR
100% in one direction	0%
75% in one direction	20%
50% in one direction	10%

4 - FUTURE PASSENGER GROWTH

To provide for future increases in passenger volume, an additional design reduction factor of 50% shall be applied. See example below.

EXAMPLE

Two way turnstile - 75% entering
- 25% exiting

1. Turnstile maximum
theoretical capacity....2,400 persons/hour

2. Provision for passenger flow reduction:
use reduction factor
of 20%.....480

1,920 persons/hour

3. Provision for future
increase in passenger
volume: use reduction
factor of 50%.....960

4. DESIGN CAPACITY.....960 persons/hour

NOTE: All DESIGN CAPACITIES are to be based on anticipated hourly or twenty minute peaks as required.

5. SPEED

MAXIMUM THEORETICAL CAPACITIES FOR SINGLE & DOUBLE WIDTH MOVING STAIRS

NOTE: The maximum theoretical capacities are based upon the following moving stair data:

Speed of 90 feet/minute = 68 treads/minute
Speed of 120 feet/minute = 90 treads/minute

- SINGLE: 2'-8" wide (TA permission required)
3 persons/every 4 treads
- DOUBLE: 4'-0" wide (recommended)
3 persons/every 2 treads

SPEED - 90 feet/minute

MAXIMUM THEORETICAL
CAPACITIES

- SINGLE: 3,100 persons/hour
- DOUBLE: 6,200 persons/hour

FUTURE PASSENGER GROWTH

To provide for future increases in passenger volume apply a 20% design reduction factor.

SPEED - 120/feet/minute

MAXIMUM THEORETICAL
CAPACITIES

- SINGLE: 4,000 persons/hour
- DOUBLE: 8,000 persons/hour

FUTURE PASSENGER GROWTH

To provide for future increases in passenger volume apply a 25% design reduction factor.

EXAMPLE

MOVING STAIRS - speed 120 feet/minute
- single width

1. Maximum theoretical capacity.....4,000 persons/hour
2. Provision for future increase in passenger volume; use reduction factor of 25%.....1,000
3. DESIGN CAPACITY 3.000 persons/hour

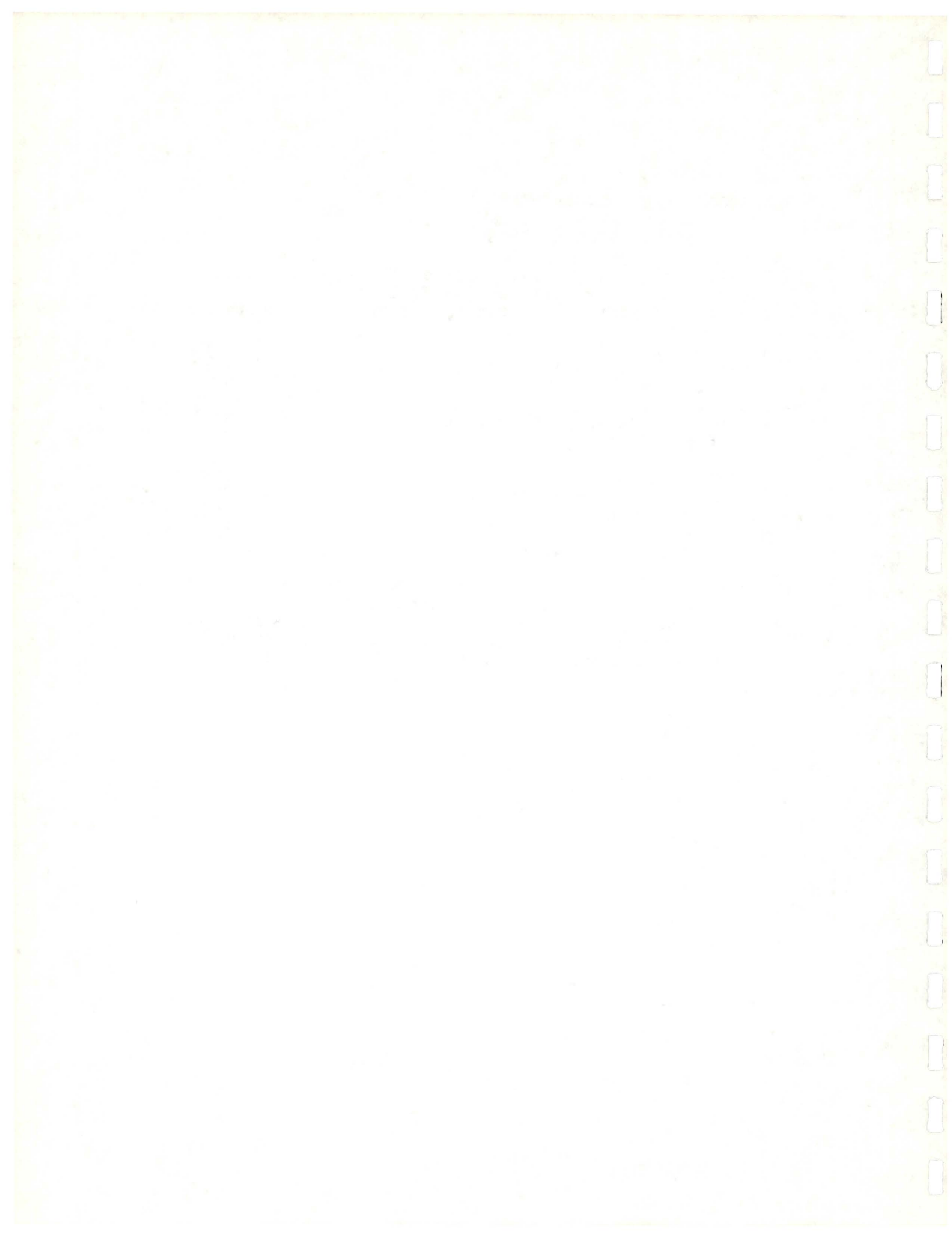
NOTE: All DESIGN CAPACITIES are to be based on anticipated hourly or twenty minute peaks as required.

RESERVOIR SPACE REQUIREMENTS

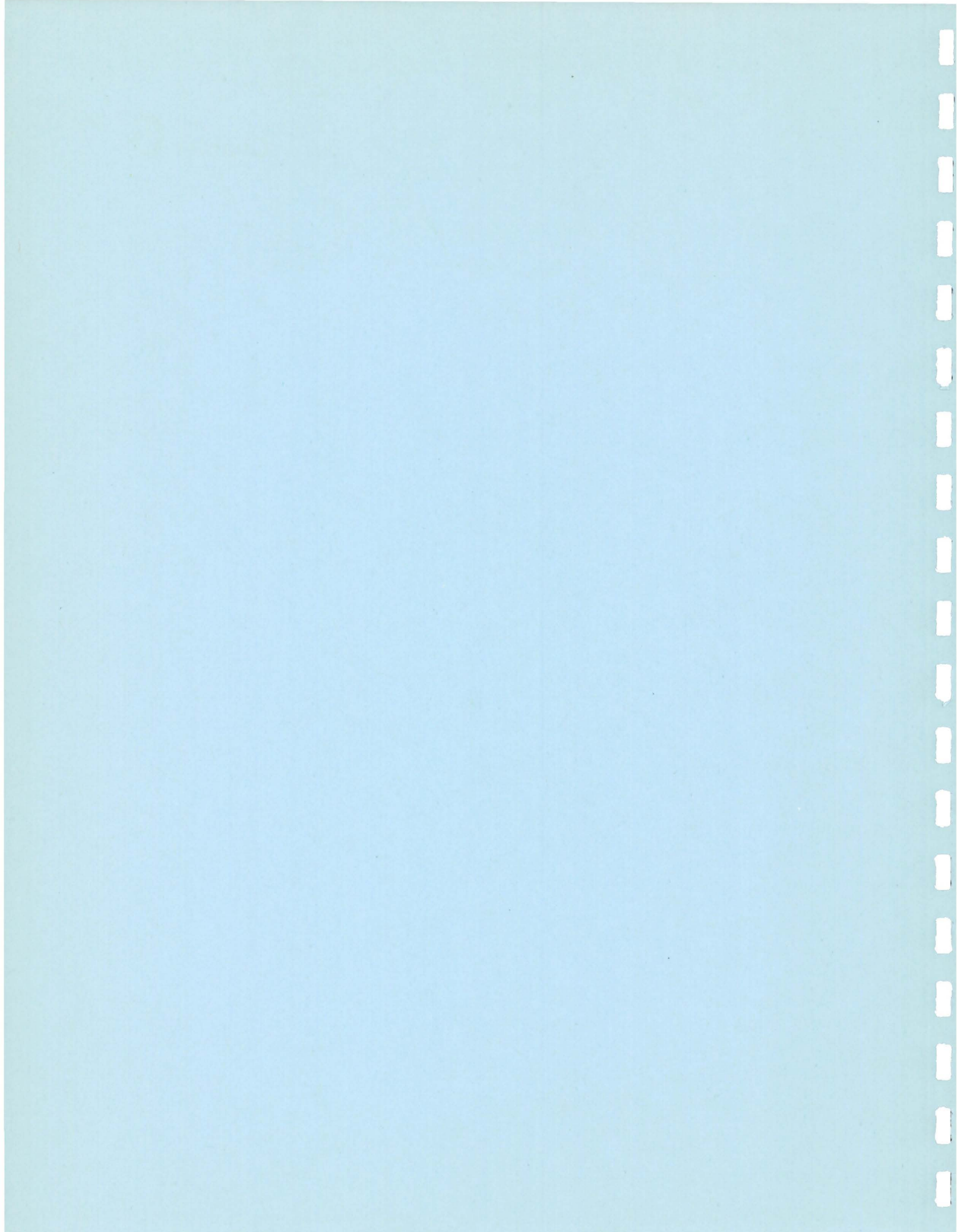
GENERAL REQUIREMENTS

- Provide adequate reservoir space for queuing at all stairs and moving stairs. The following are recommended minimum clearances for various conditions
- stair to turnstile 20ft.
- stair to wall, railing, etc. 10ft.
- stair to stair 25ft.
- stair to elevator 20ft.
- stair and/or moving stair to end of island platform 30ft.
- moving stair to turnstile 30ft.
- moving stair to wall, railing, etc. 20ft.
- moving stair to moving stair 40ft.
- moving stair to stair 30ft.
- moving stair to elevator 30ft.

NOTE: The above minimum distances are to be used as a guideline, it is anticipated that there will be many special conditions that will have to be considered on their own merits, however adequate reservoir space must be provided at all locations.



Chapter 6



Chapter 6

FINISHES

TABLE OF CONTENTS

1.	INTRODUCTION.....	SP-6-1
2.	PROPERTIES.....	SP-6-2
3.	LIST OF MATERIALS SUITABLE FOR STATION FINISHES.....	SP-6-2
4.	ACOUSTICAL MATERIALS.....	SP-6-5
5.	ENERGY CONSERVATION CRITERIA FOR ABOVE GROUND STRUCTURES.....	SP-6-5

Chapter 6

FINISHES

1 -INTRODUCTION

The intent of this section is to outline basic requirements and criteria for the finish materials to be used in all public spaces of the transit system. It is the task of the Project Architect to propose finishes which are most suitable for a transit environment without sacrificing attractiveness, quality or passenger comfort. The Project Architect should be aware that the proper selection of finishes and general aesthetic considerations will provide the passenger with pride for the facility and thereby reduce vandalism.

2- PROPERTIES

SAFETY

- Incombustible materials
- Adequate anchorage
- Non-slip Floors

DURABILITY

- Non-fading
- Weather resistant
- Strong
- Wear resistant
- Impact resistant

MAINTENANCE

- Dense, non-porous
- Acid & Alkali resistant
- Replaceable

3- LIST OF MATERIALS SUITABLE FOR STATION FINISHES

The following list should be used as a guide in the proposal of station finishes. It is intended that this list apply to all areas of public use.

NOTE The use of materials listed as "ACCEPTABLE" is subject to consideration of the location, use and environment of the particular installation and to the final performance standards and specifications.

Materials listed as "PROBABLY NOT ACCEPTABLE" may be considered if special conditions or further product development warrants their use.

FLOORS - All floor finishes are to meet Transit Authority Standards for non-slip qualities.

ACCEPTABLE MATERIALS

MONOLITHIC

- Concrete Toppings
heavy duty type
- Cement Terrazzo
special aggregate & installation control
- ** -Synthetic Resin Toppings
polyesters, epoxies, etc.
heavy commercial & industrial grades

UNIT MATERIALS

- Granite
- Quarry Tile
- Paver Brick
- Unglazed Ceramic Tile
- Cement Tile
- Terrazzo Tile
- ** -Synthetic Resin Tile

PROBABLY NOT ACCEPTABLE

MONOLITHIC MATERIALS

- Bituminous Toppings
- ** -Synthetic Resin Toppings
-residential & light commercial grade

UNIT MATERIALS

- ** -Resilient Tile & Sheet Products
further development of certain rubber products
may make them acceptable
- Wood Products
- Marble
- Carpeting

** See NOTE - FINISHES PAGE 4

WALLS

ACCEPTABLE MATERIALS

MONOLITHIC MATERIALS

- Smooth Concrete
using surface applied finish

UNIT MATERIALS

- Structural Glazed Facing Tile or Block
- Glazed Ceramic Tile
- Unglazed Ceramic Mosaic Tile
- Ceramic Facing Veneers
- Porcelain Enamel Panels
- ** -High Pressure Laminated Plastics
restricted locations
- Stainless Steel
- Bronze
- Granite
- Glazed Brick

NOTE ** It is recommended that to the greatest extent possible, the use of Plastics (including fiber-glass) be minimized wherever possible in the underground Rapid Transit System. Plastics, including vinyl and similar floor tiles are producers of smoke and/or fumes when in combustion, and often will fume at elevated temperatures lower than the temperature at which they themselves support combustion. These fumes are often toxic and are not desirable within an enclosed system.

Inclusion of fire retardant chemicals or other similar inhibitors in the Plastics will generally result in the production of even greater quantities of fumes often more toxic in nature. Fire retardant treatment for wood and other substances will similarly produce toxic fumes. Some newer and more expensive fire retardant plastics have been formulated to minimize toxicity or explosivity of gases evolved.

All fire retardant materials require laboratory evaluation for toxicity and flammability.

The proposal by the designer to use plastics, etc. shall be accompanied by samples with laboratory test results for submission to the Transit Authority Engineers for evaluation and approval. Strict control will be exercised as to the quantity of plastics permitted within a station.

4 - ACOUSTICAL MATERIALS

Acoustical materials in general are quite delicate and easily tampered with. Thus they should be located only on surfaces that are not accessible to the passenger (i.e. below the platform, ceilings, etc.).

ABSORBING MATERIALS

Acoustic absorbing materials shall be nonflammable durable and washable. Where possible, properly designed perforated panels shall be used to protect the absorbing materials.

SOUND INSULATING MATERIALS

Sound Insulating Materials shall be nonflammable, durable and washable.

ENERGY CONSERVATION CRITERIA

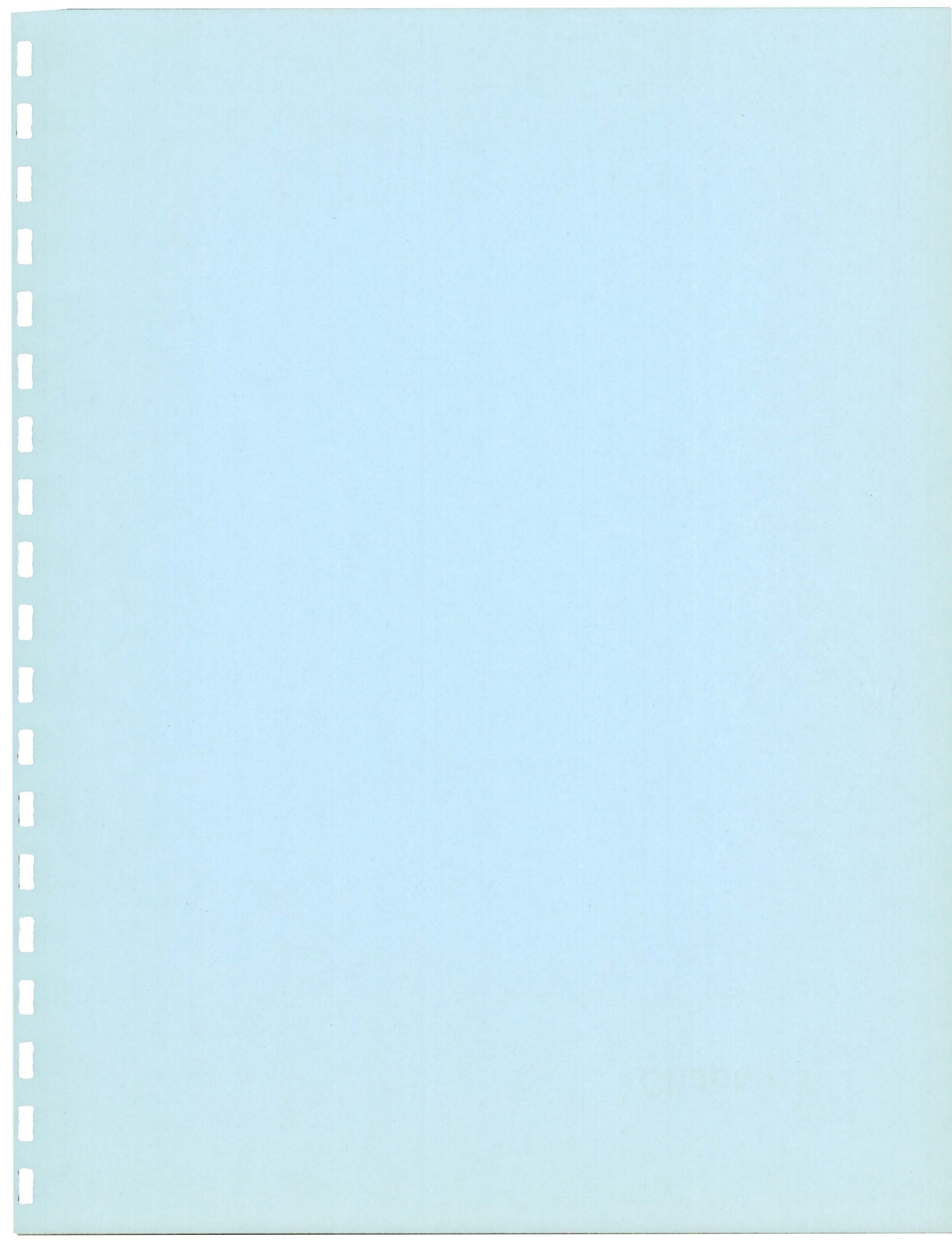
5- FOR ABOVE GROUND STRUCTURES

Walls shall have minimum "U" value of 0.12

Roofs shall have minimum "U" value of 0.12

Where more than 25% of the exposed exterior wall is glass at least one-fourth of all glass surfaces shall be insulating glass or storm sash.

Chapter 7

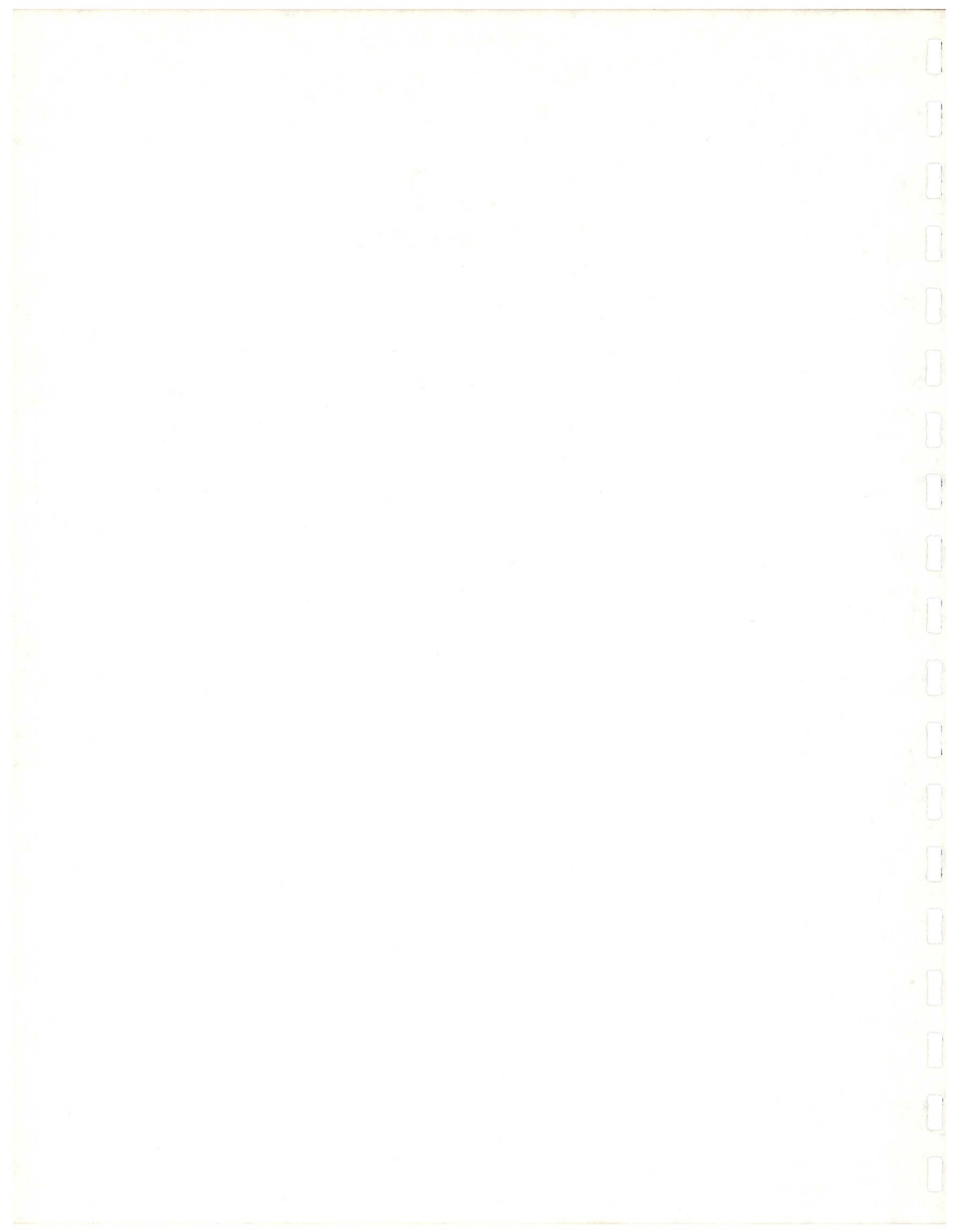


Chapter 7

REFUSE DISPOSAL

TABLE OF CONTENTS

1. REFUSE RECEPTACLES FOR PASSENGER USE....	SP-7-1
2. DISPOSAL SITES FOR COLLECTED REFUSE.....	SP-7-1
3. LOCATION.....	SP-7-1
4. SIZE OF DISPOSAL SITE.....	SP-7-2
5. EQUIPMENT & ACCESSORIES.....	SP-7-2
6. ENCLOSURE TREATMENT.....	SP-7-3
7. GENERAL REQUIREMENTS.....	SP-7-3



Chapter 7

REFUSE DISPOSAL

REFUSE RECEPTICALS FOR PASSENGER USE (STANDARD TA DESIGN)

- To be located in all station areas accessible to the passenger.

DISPOSAL SITES FOR COLLECTED REFUSE

TYPES

- Island Platform
- Side Platform
- Terminal Station

LOCATION

The disposal site is to be located in an extended area beyond one end of the passenger portion of the station platform.

ISLAND & TERMINAL PLATFORMS

- one per platform
- location to be designated

SIDE PLATFORMS

- one per platform
- located at outbound end

4- *SIZE OF DISPOSAL SITE*

- Clear Height: same as platform
- Length: 15'-0" minimum
- Width: platform width less clearance for tunnel walkway

5- *EQUIPMENT & ACCESSORIES*

BALING MACHINE

- one machine
- used only at sites generating a high volume of refuse

REFUSE CANS OR ROLL-ONS

- as required

VENTILATION

- positive system

SPRINKLER SYSTEM

- connect to domestic supply

FLOOR DRAINS

- provide sedimentation bucket
- connect to track drainage

HOSE BIBB

- one at each site

ELECTRIC CIRCUITRY

- include provision for baling machine at each site

SAND BOX

- one at each site

LIGHTING

6- ENCLOSURE TREATMENT

Platform End Wall:

- Horizontal closing door with side coiling box against or recessed into wall or suitable alternative.

Track Side:

- Overhead rolling shutter door operated manually from the duct bench.
- Alternate: 5'-0" high masonry wall with 5'-0" opening for access to disposal site.

Interior Finish:

- Concrete wall surfaces to receive epoxy paint to provide easy maintenance.
- Ceiling and floor surfaces to be dust proof.

7- GENERAL REQUIREMENTS

TOOL ROOM

- include a 12'x12' room at terminal stations for car cleaner tools.
- whenever battery charging is included, provide a mechanical exhaust system.

DISPOSAL OF REFUSE

- Collected refuse will be transferred onto work trains. These trains in turn will transfer the refuse at disposal yards to private collectors.

Chapter 8

8-11-10

Chapter 8

ACOUSTICS

TABLE OF CONTENTS

1. GLOSSARY.....SP-8-1
2. STATION LEVELS.....SP-8-2
3. COMMUNITY LEVELS NEAR STATIONS.....SP-8-3

Chapter 8

ACOUSTICS

1- GLOSSARY

N.C.:	Noise Criterion Curve, as defined in NOISE & VIBRATION CONTROL, by L. Beranek.
dBA:	Sound Level measured on the "A" scale of a General purpose sound level meter which meets ANSI Spec. S 1.4 - 1961.
Average Residential:	Range of expected ambient noise levels*: Day - 50 to 60 dBA. Night - 40 to 50 dBA.

Busy Residential: Range of expected ambient noise levels*:
Day - 70 to 80 dBA.
Night - 45 to 55 dBA.

Quiet Residential: Range of expected ambient noise levels*:
Day - 40 to 50 dBA.
Night - 35 to 45 dBA.

*The above noise levels are the general ambient noise levels of the community excluding major intrusive noises from aircraft, rapid transit and highways.

Reverberation Time: The time it takes for the sound to decay 60 decibels.

The following levels for acoustic standards are designed to provide increased comfort for passengers using transit facilities. These levels are to be achieved if practical.

2- STATION LEVELS

A. UNDERGROUND STATIONS

LOCATION	CRITERIA
-Platform Level trains entering & leaving	80 dBA
-Platform Level trains passing through	85 dBA
-Platform Level trains stationary	70 dBA
-Platform Level only station ventilation system operating	55 dBA
-Token Booth & Dispatcher interiors	45 dBA

-Maximum platform area reverberation time	1.6 to 2.0 seconds (at 250 to 2000 Hz)
--	---

B. ABOVE GROUND STATION

-Platform Level trains entering & leaving	75 dBA
--	--------

3- COMMUNITY LEVELS NEAR STATIONS

The impact of noise and vibration on the community adjacent to underground and aboveground stations is to be considered in the design of the station.

In general, it is desirable to hold the airborne noise and vibration induced noise to values below the following specified levels:

LOCATION	CRITERIA
----------	----------

A. Exterior Airborne Noise From Above Ground Stations

- Quiet Residential	70 dBA
- Average Residential	75 dBA
- Busy Residential/semi-commercial	80 dBA
- Commercial/open	85 dBA

B. Interior Groundborne Vibration Induced Noise

- Quiet Residential	NC 20 to 35
- Apartments	NC 25 to 40
- Hotels	NC 30 to 40
- Auditoriums	NC 20
- Churches and Theaters	NC 25
- Music Rooms and TV Studios	NC 25
- Hospital Sleeping Rooms	NC 30
- Courtrooms	NC 30
- Schools	NC 30
- Offices	NC 30
- Commercial Buildings	NC 40 to 45

C. Exterior Airborne Noise from Underground Stations

Quiet Residential

- Transient noise NC 40
- Steady noise NC 35

Average Residential

- Transient noise NC 45
- Steady noise NC 40

Busy Residential/semi
commercial

- Transient Noise NC 50
- Steady noise NC 45

Commercial, Daytime use only

- Transient noise NC 55
- Steady state noise NC 50

The aforementioned criteria can be met through the use of resilient track fasteners, welded rails, floating track slabs, acoustic barrier walls and judiciously placed acoustic absorbing materials. The exterior noise should be measured near the building in question.

Chapter 9

1000

1000



Chapter 9
HANDICAPPED
TABLE OF CONTENTS

1. DESIGN CRITERIA.....SP-9-1
2. DEFINITION.....SP-9-1
3. APPLICATION.....SP-9-2

Chapter 9

HANDICAPPED

1- DESIGN CRITERIA

Emphasis and consideration shall be given to those facilities which will make the transit system used by the public, accessible to, and usable by the physically handicapped, without sacrifice to the general public.

2- DEFINITION

For purposes of these Standards, the term "handicapped person" means any individual who, by reason of illness, injury, age, congenital malfunction, or other permanent or temporary incapacity or disability, is unable without special facilities or special planning or design to utilize mass transportation facilities and services as effectively as persons who are not so affected.

This definition is in accordance with the Mass Transportation Act of 1970.

APPLICATION

The needs of the handicapped have been incorporated into these station standards as follows:

	<u>Section</u>
Exit Gates	2
Graphics	2
Platform safety edge	2
Public address system	2
Street entrances	2
Telephones	2
Television surveillance	2
Toilets	2
Escalators	3 & 5
Handrails	3
Ramps & gradients	3 & 5
Snow melters	2
Stairs - raisers & treads	3 & 5
Elevators	3
Lighting	4
Non-slip floor finish	6

Chapter **10**

Of ...

Chapter 10

REFERENCE DATA

TABLE OF CONTENTS

1. INTRODUCTION.....SP-10-1
2. HANDBOOK OF STANDARDS.....SP-10-1
3. TYPICAL STANDARDS FOR STATION
AMENITIES.....SP-10-2
4. CODES & REGULATIONS.....SP-10-2

Chapter 10

REFERENCE DATA

1- *INTRODUCTION*

The following standards, codes and regulations are to be utilized and adhered to by the Project Architect.

2- *HANDBOOK OF STANDARDS*

- Structural standards
- Architectural & Planning Guidelines
- Construction methods
- Track & Power Rail Design
- Signal Systems
- Station & Car Equipment

- Materials Inspection
- Environmental Control
- Graphics Standards Manual

3- *TYPICAL STANDARDS FOR STATION AMENITIES*

- Exit Gates
- Turnstiles
- Advertising
- Concessions
- Railings & Handrails
- Telephones
- Utility Cabinets
- Conductor's Starting Light
- T.V. Surveillance
- Passenger Address System
- Refuse Receptacles
- Illuminated Entrance Post
- Token Booth

4- *CODES & REGULATIONS*

- The New York City Building Code is not applicable in transit station design, but can be used as a guide in areas not specifically covered by the Transit Authority Structural Design Standards or these Station Planning Standards.
- All plumbing work approvals and permits shall be obtained from the Department of Water Resources and Bureau of Water Pollution Control, subsidiaries of the Environmental Protection Administration.

- City, State and Federal Health Codes are applicable.
- American Standard Specifications for Making Buildings and Facilities Accessible to, and Usable by, the Physically Handicapped.
- Conditions not defined by these Station Planning Standards or by codes referred to should be brought to the attention of the Transit Authority, who will issue standards or guide lines for the specific condition.

STRUCTURAL DESIGN GUIDELINES



INTRODUCTION

INTRODUCTION

INTRODUCTION

These STRUCTURAL DESIGN GUIDELINES provide a general guide and standard for the design of subways, elevated lines and related structures of the New York City Transit Authority.

These guidelines are intended as an aid to, and not a replacement for, sound engineering judgement.

DIVISION ENGINEER

LEON ROSSUM

AUTHOR

NOEL MARKS

INDEX

INDEX

STRUCTURAL DESIGN GUIDELINES

INDEX

CHAPTER

1	DATUM TABLE - - - - -	SD-1-1
2	CLEARANCES - - - - -	SD-2-1
3	LOADS AND STRESSES TO BE USED IN DESIGNING SUBWAYS, TUNNELS AND ELEVATED STRUCTURES - - - - -	SD-3-1
4	DETAILS OF DESIGN FOR STRUCTURAL STEEL - - - - -	SD-4-1
5	DESIGN COLUMNS - - - - -	SD-5-1
6	DESIGN OF CONCRETE AND REINFORCED CONCRETE STRUCTURES - - - - -	SD-6-1
7	WATER PROOFING OF SUBWAYS - - - - -	SD-7-1
8	NATURAL VENTILATION DESIGN CRITERIA BETWEEN STATIONS - - - - -	SD-8-1

STANDARD FORM NO. 64

1-64

1. The purpose of this form is to provide a means for the collection and

dissemination of information on the activities of the

organization and its members, and to provide a means for the

collection and dissemination of information on the activities of

the organization and its members, and to provide a means for the

collection and dissemination of information on the activities of

the organization and its members, and to provide a means for the

collection and dissemination of information on the activities of

the organization and its members, and to provide a means for the

collection and dissemination of information on the activities of

the organization and its members, and to provide a means for the

collection and dissemination of information on the activities of

the organization and its members, and to provide a means for the

Chapter **1**

1000

Chapter **1**

DATUM TABLE

TABLE OF CONTENTS

I	DATUM TABLE - - - - -	SD-1-1
---	-----------------------	--------

Chapter 1

DATUM TABLE

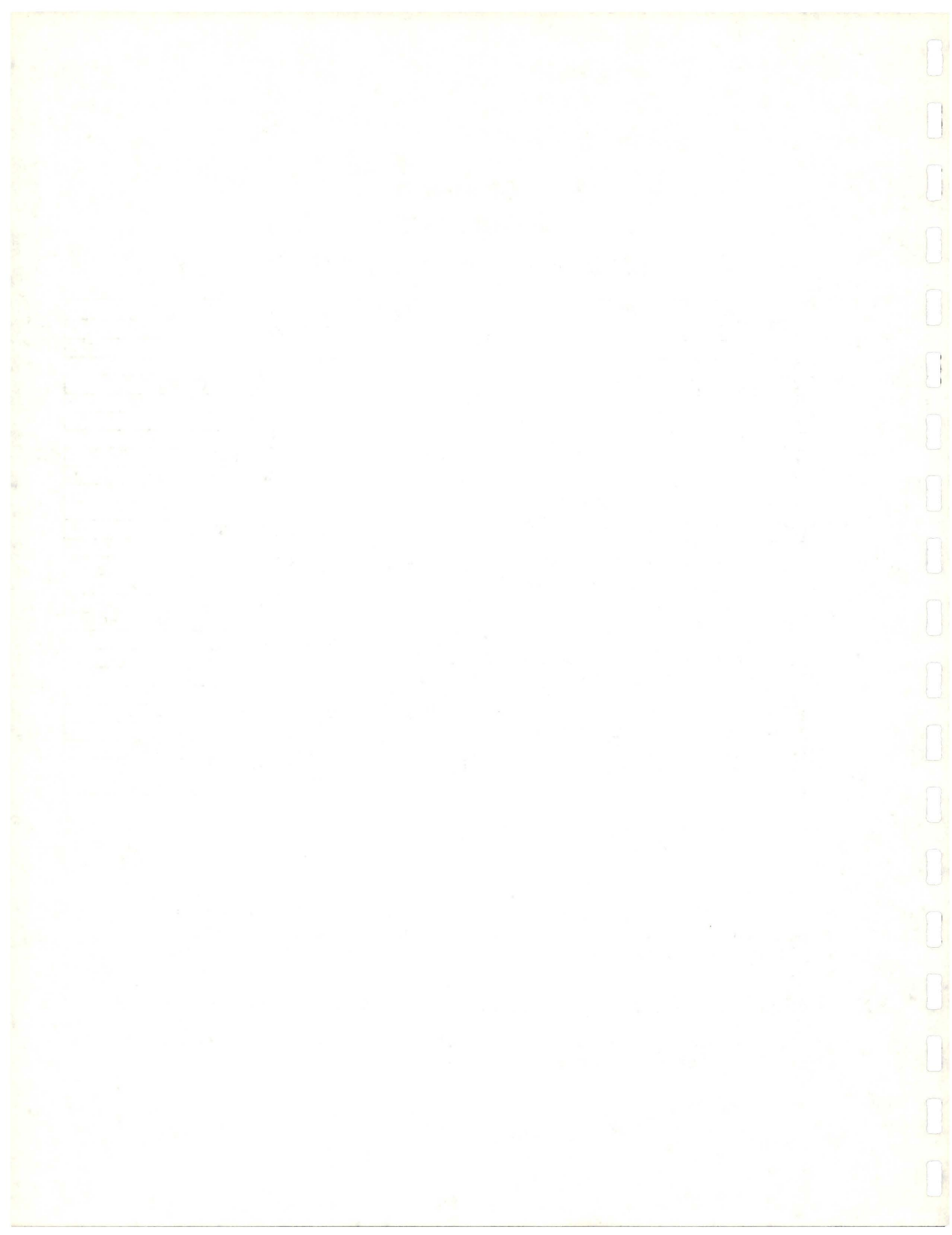
COMPARISON OF DATUM PLANES

	A	B	DESCRIPTION
1	100.539	+3.192	BOROUGH PRESIDENT OF RICHMOND
2	100.097	+2.750	N.Y. CENTRAL R.R.
3	100.097	+2.750	BOROUGH PRESIDENT OF MANHATTAN
4	100.072	+2.725	L.I.R.R. EXCEPT BAY RIDGE DIV. & TUNNELS
5	100.072	+2.725	BOROUGH PRESIDENT OF QUEENS
6	99.972	+2.625	WILLIAMSBURGH BRIDGE
7	99.955	+2.608	BOROUGH PRESIDENT OF BRONX
8	99.955	+2.608	NEW YORK, NEW HAVEN & HARTFORD R.R.
9	99.907	+2.560	BOROUGH PRESIDENT OF BROOKLYN - HIGHWAYS
10	99.646	+2.299	QUEENSBOROUGH BRIDGE
11	99.234	+1.877	BROOKLYN BRIDGE
12	99.067	+1.720	BOROUGH PRESIDENT OF BROOKLYN - SEWERS
13	99.027	+1.680	BROOKLYN WATER SUPPLY
14	99.025	+1.678	L.I.R.R.-BAY RIDGE DIVISION
15	99.024	+1.677	MANHATTAN BRIDGE
16	97.347	0	BOARD OF WATER SUPPLY
17	97.347	0	U.S.C. & G. SURVEY (MEAN SEA LEVEL, SANDY HOOK)
18	97.347	0	WESTCHESTER COUNTY PARK COMM.
19	96.561	-0.786	CROTON AQUEDUCT
20	95.244	-2.103	DEPT. OF MARINE & AVIATION
21	95.244	-2.103	NEW YORK CONNECTING R.R.
22	0	-97.347	N.Y.C. TRANSIT AUTHORITY*
23	-199.928	-297.275	PENN. TUNNELS (2.725 = 300)
24	-200.163	-297.275	L.I.TUNNELS OF THE PENN.R.R. (2.490 = 300)
25	-202.653	-300.000	PORT AUTHORITY TRANS. - HUDSON
26	-202.653	-300.000	NARROWS TUNNELS

To obtain from any given foreign elevation the corresponding elevation referred to the Transit Authority datum plane: add to the given elevation the figure shown in column A.

Column B shows datum in relation to U.S.C. & G. survey datum.

*Elevation 100 of Transit Authority is 2.653 ft. above Mean Sea Level at Sandy Hook.



Chapter 2

Sum

Chapter 2

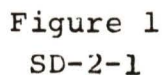
CLEARANCES

TABLE OF CONTENTS

I LATERAL CLEARANCES - - - - -	SD-2-1
II PERMISSIBLE ENCROACHMENTS	
ON LATERAL CLEARANCES - - - - -	SD-2-2
III VERTICAL CLEARANCES - - - - -	SD-2-6
IV FORMULAS FOR TURNOUTS	
AND CROSSOVERS - - - - -	SD-2-7
V CRANDALL'S TRANSITION CURVE - - - - -	SD-2-9
VI VERTICAL CURVES - - - - -	SD-2-12
VII EXCESSES - - - - -	SD-2-14

1 - LATERAL CLEARANCE

4. The standard distances from centerline of tangent track to ϕ of subway columns, benches and platform edge are shown in Figs. 1A to 1F. The distances are to be increased on curves to allow for superelevation, center and end excesses.



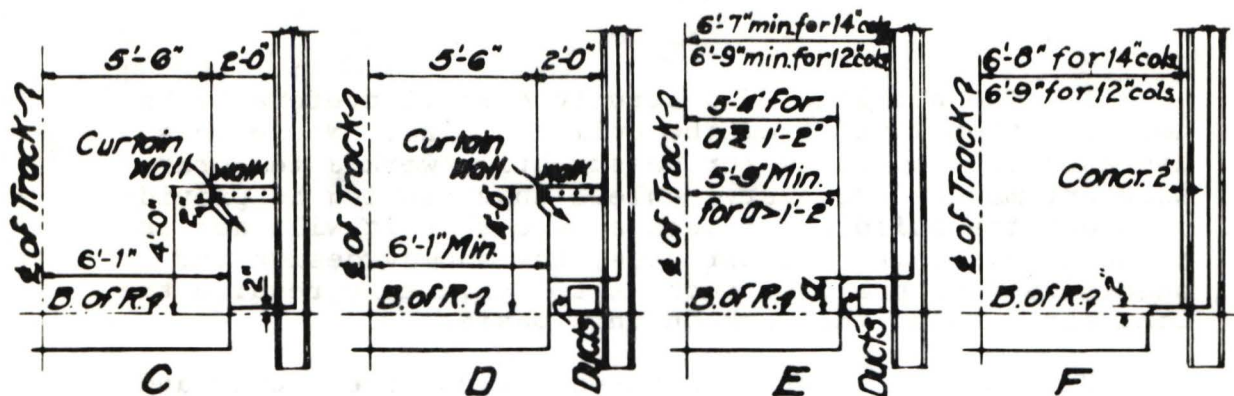
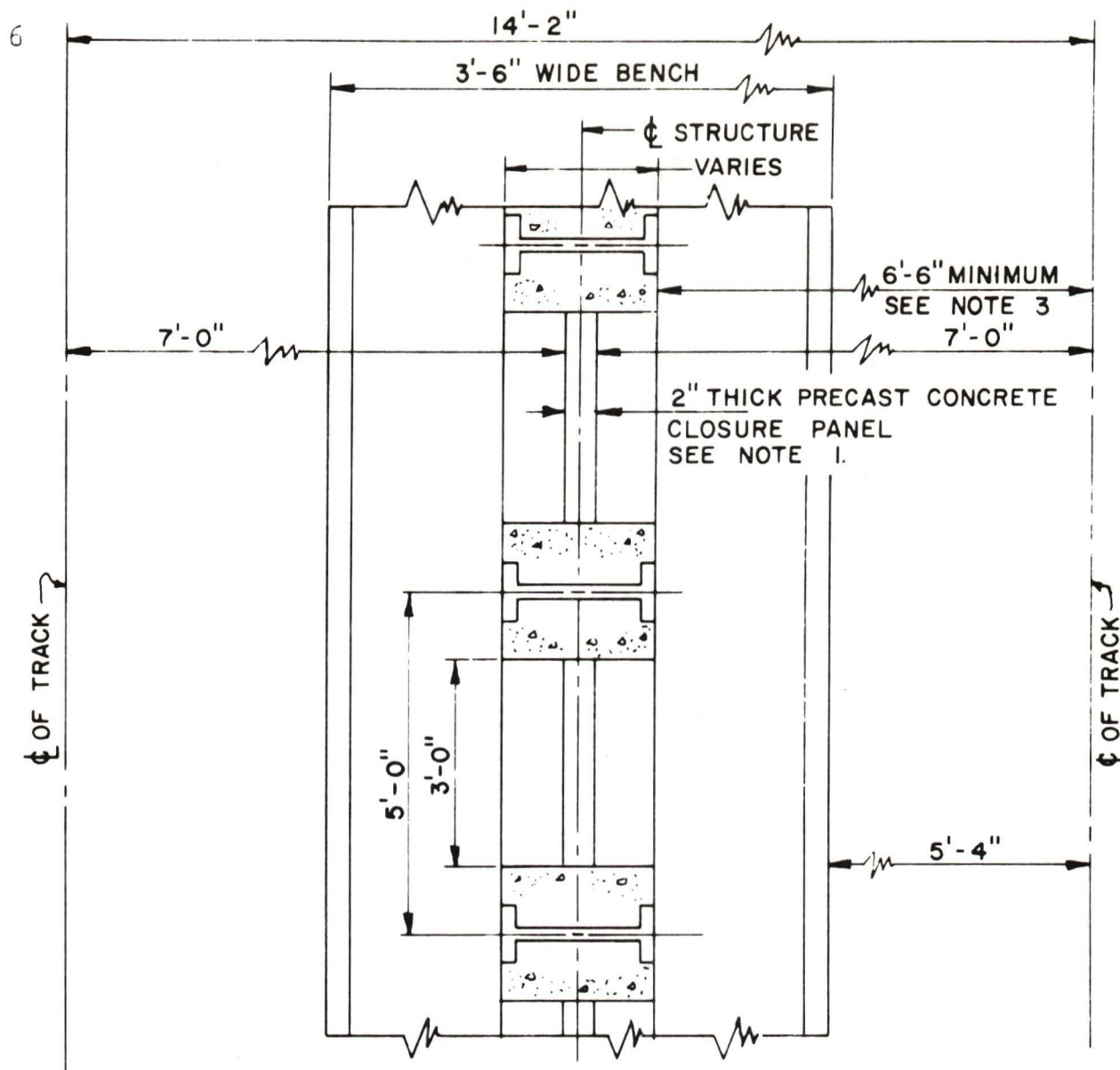


Figure 1 (Cont'd.)

5. Where safety niches cannot be provided in an interior wall for a length of more than three consecutive bays, or 15 ft., the minimum distance from centerline of track to face of wall shall be 7'-0" on tangent, to be increased by the required amounts on curves.



TYPICAL PART PLAN OF CENTER WALL

NOT TO SCALE

NOTES

1. ELIMINATE CLOSURE PANEL FOR ACCESS (APPROXIMATELY EVERY 300 FT.) AND AS REQUIRED FOR EQUIPMENT PURPOSES.
2. DISTANCES FROM CENTERLINE OF TANGENT TRACK ARE TO BE INCREASED ON CURVES TO ALLOW FOR SUPERELEVATION, CENTER AND END EXCESSES.
3. ALLOWANCE FOR ENCROACHMENT NOT INCLUDED. SEE SECTION II

**MODIFICATION TO CLEARANCES
BETWEEN CENTER WALL AND
CENTERLINE OF TANGENT
TRACK FOR IND-BMT
STRUCTURES**

II - PERMISSIBLE ENCROACHMENTS ON LATERAL CLEARANCE

7. The value given in Fig. 1A for the distance from centerline of track to of an interior column provides for a normal clearance of 1'-6" on tangent. This clearance shall generally be maintained on curves but may, in special cases, be encroached upon to the extent specified under Subsects. a to d below. Only where the encroachment would exceed the amounts therein given shall the distance between running tracks be increased.

Encroachment is permitted as follows:

a. At turnouts and crossovers, to the extent of 6 in. on the turnout or crossover track. Additional encroachment shall be taken care of by setting out the columns to encroach on the adjacent running track up to a maximum of 3 in. (See Fig. 2)

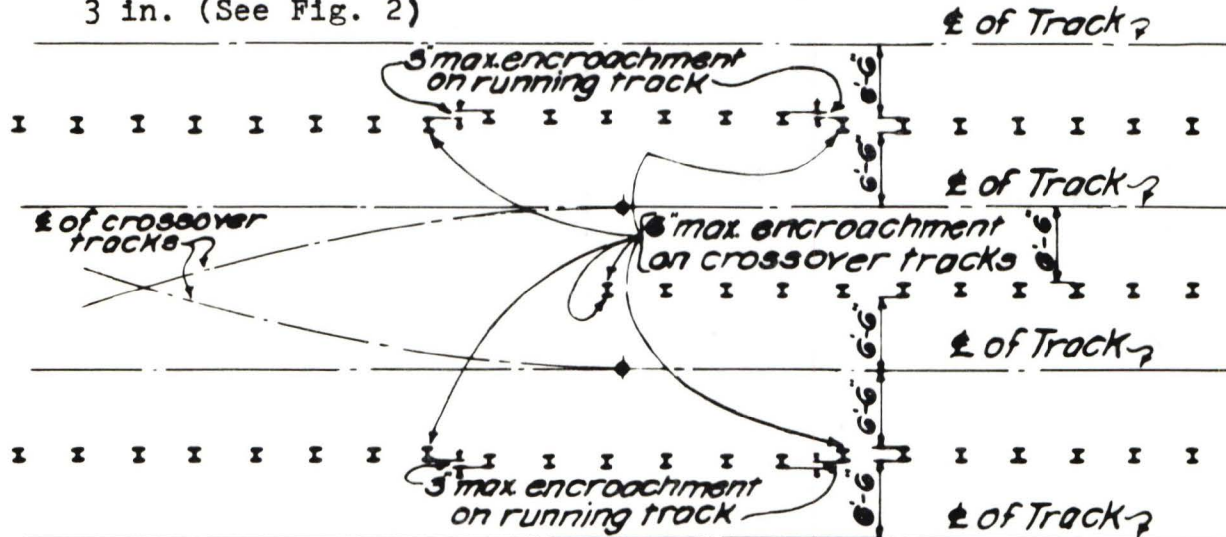


Figure 2

b. At turnouts back to back, to the extent of 9 in. on each turnout track (See Fig. 3). Encroachments exceeding 6 in. shall, however, be avoided wherever practicable by staggering the switch points and offsetting the columns, or by using higher frog numbers or long span roof beams.

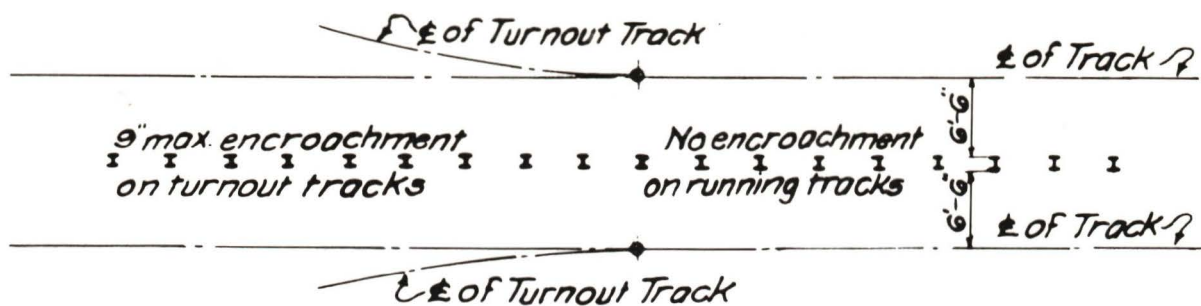


Figure 3

c. At the junctions of curved and tangent tracks, to the extent of 3 in. on each track (see Fig. 4)

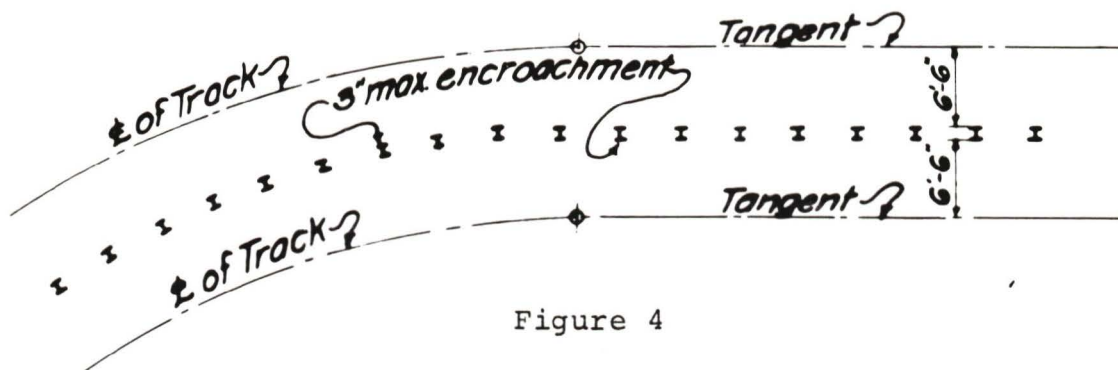
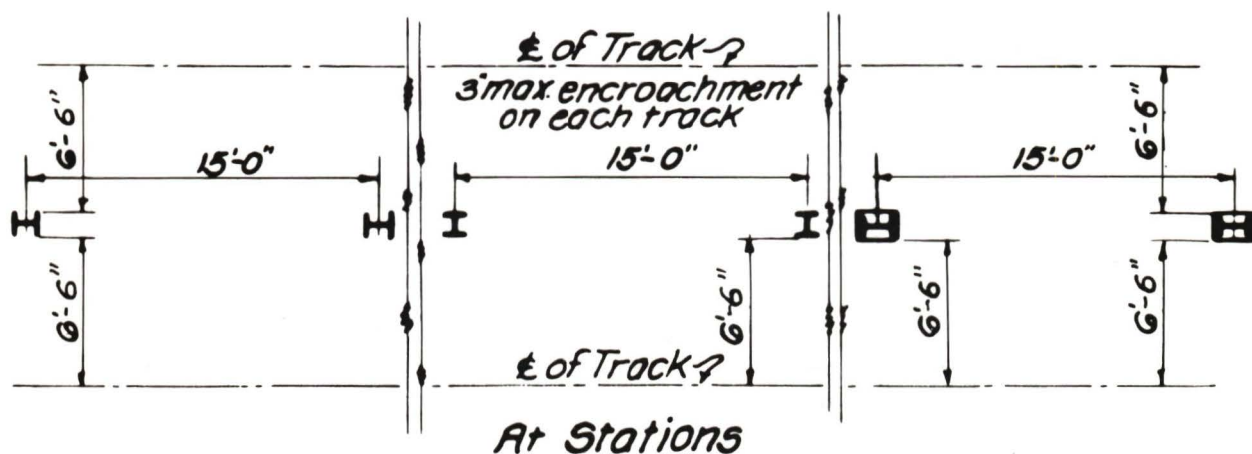


Figure 4

d. Where columns of increased depth are required between tracks, or where columns are encased in concrete, the encroachment may be 3 in. on each track (see Fig. 5), except as provided in Sect. 6



At Stations

Figure 5

8. No encroachment is permitted at sidewalls facing turnouts or crossovers. Such sidewalls shall be set out to allow for the full amount of clearance. (See Figs. 6 and 7)

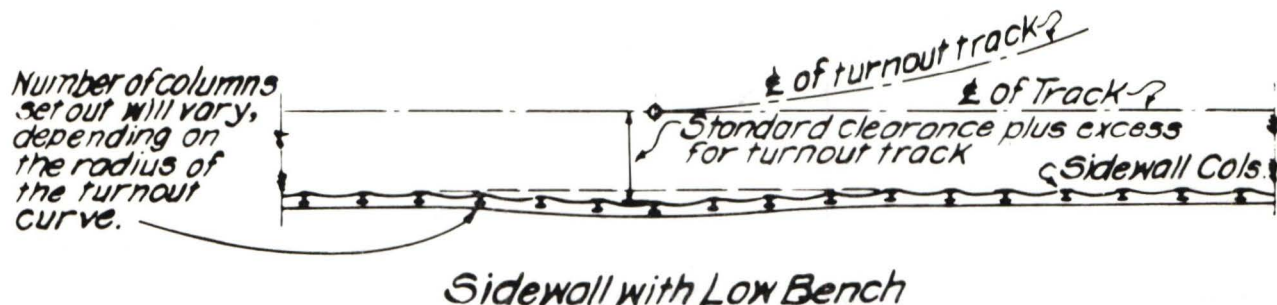


Figure 6

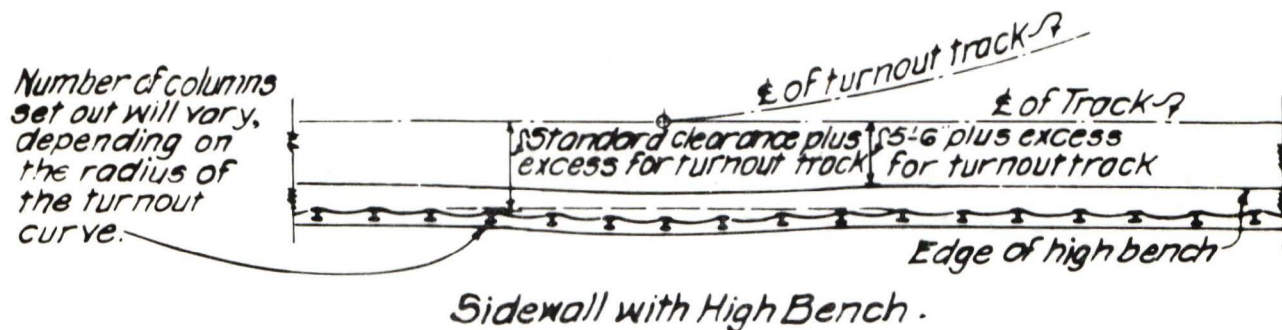


Figure 7

III - VERTICAL CLEARANCE

9. The minimum distance from street or ground surface to top of roof of main subway structure shall generally be 6 ft. over tracks and 5 ft. over mezzanines.

For special conditions, and under private property, these minima may be reduced as follows: Auxiliary structures, such as fan chambers, rectifier stations, entrances, passageways, etc., occupying relatively small areas of the roof surface, may have 2 ft. minimum cover, provided conditions are such as to permit a satisfactory relocation of subsurface structures. The minimum cover for auxiliary structures under sidewalks shall be 6 in.

The Supplementary drawings and the Construction Division shall be consulted to provide for additional clearance, where necessary, for sewers, street ducts and other subsurface structures. Raising the street or ground surface shall be considered as a possible economic measure.

10. In general, the depth of the Base of Rail below street or ground surface shall be about 21 ft. At mezzanine stations it shall be about 42 ft. The distance between Bases of Rail in double deck structures or at subway crossings shall be about 16 ft.

11. The distance from Base of Rail to underside of subway roof or mezzanine floor shall be not less than 13'-2". Where roof members have lower cover plates which are not embedded in concrete, the distance shall be not less than 13'-2 3/4" to underside of lowest cover plate so as to allow for rivet heads. At vertical curves, additional allowance shall be made for vertical center or end excess (See Sect. 21).

12. In elevated structures, the minimum vertical clearance for girders shall be 14 ft. over roadways.

For clearance to be provided over railroad tracks, the railroad company concerned shall be consulted.

IV - FORMULAS FOR TURNOUTS AND CROSSOVERS

13. Formulas for turnouts from tangent tracks, as well as for crossovers, are given in Fig. 8, and the corresponding values for standard frog numbers are given in Table 1, page SD-2-8

FROG		RADIUS		TANGENT	LEAD	LENGTH OF CROSSOVER "H" FOR M=			PS (STRUCT) TO
NO.	ANGLE					A-O	C-D	A-B	A-G
5	11°-25'-16"	235.417	46.617	23.542	47.083	113.909	116.384	118.859	1.067*
6	9°-31'-38"	339.000	56.110	28.250	56.500	136.938	139.917	142.896	3.872
7	8°-10'-16"	461.417	65.582	32.958	65.917	159.936	163.418	166.900	10.852
8	7°-09'-10"	602.667	75.040	37.667	75.333	182.910	186.894	190.878	16.626
9	6°-21'-35"	762.750	84.489	42.375	84.750	205.874	210.360	214.846	10.493
10	5°-43'-29"	941.667	93.932	47.083	94.167	228.831	233.819	238.806	14.972
12	4°-46'-19"	1356.000	112.804	56.500	113.000	274.717	280.706	286.696	25.072
15	3°-49'-06"	2118.750	141.093	70.625	141.250	343.523	351.015	358.507	19.133
16	3°-34'-37"	2410.667	150.520	75.333	150.667	366.462	374.454	382.447	23.921
18	3°-10'-56"	3051.000	169.369	84.750	169.500	412.317	421.310	430.303	33.940
20	2°-51'-51"	3766.667	188.216	94.167	188.333	458.167	468.161	478.155	48.417

TABLE I

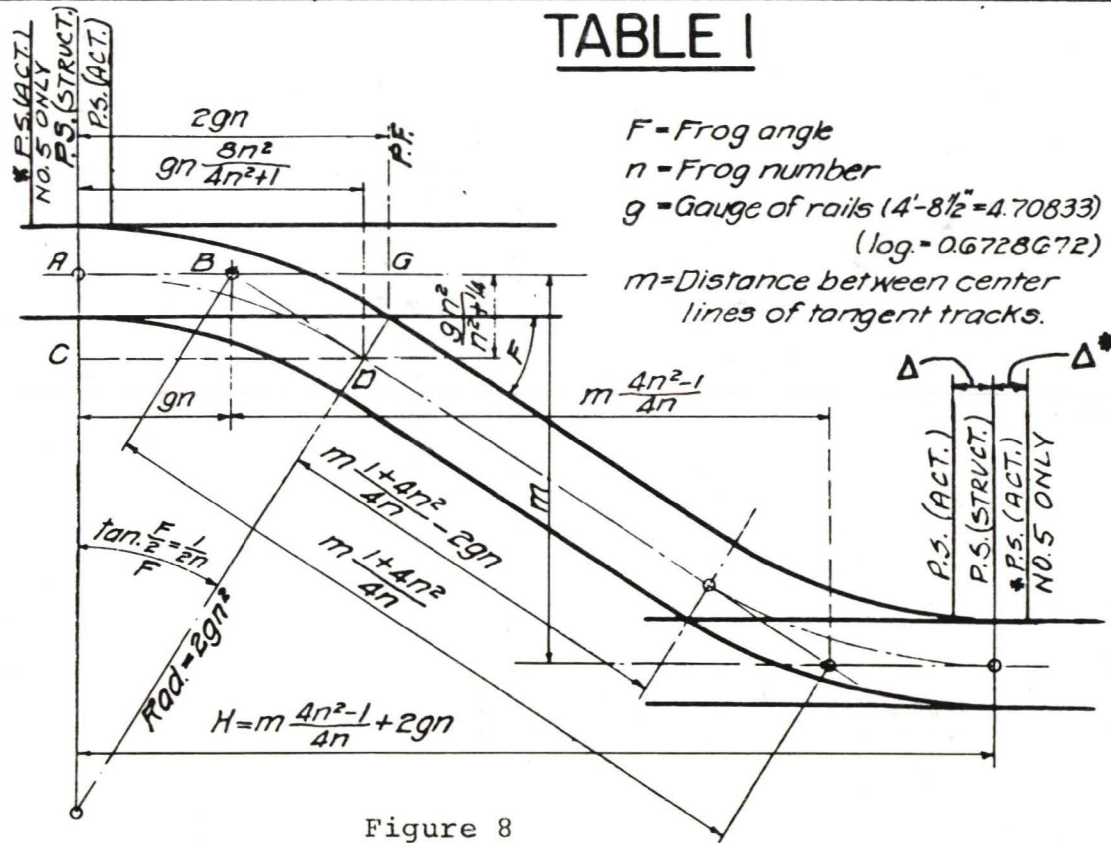


Figure 8

V - CRANDALL'S TRANSITION CURVE

14. Crandall's transition curve is a double spiral coiling in opposite directions, as shown in Fig. 9. Its curvature at any point is proportional to the distance from its point of zero curvature as measured along the curve. Transitions are used for effecting a gradual change in centrifugal force when trains are entering or leaving curves, and also for securing additional clearance between concentric circular tracks.

15. Notation (See Fig. 10)

P.T.C.	=	Junction between tangent and transition at beginning of curve.
P.C.C.	=	Junction between transition and circular curve.
P.T.T.	=	Junction between transition and tangent at end of curve.
x,y	=	Coordinates of a point on transition curve.
i,i°	=	Angle turned by curve at point x,y (in radians and degrees.)
ℓ	=	Length of curve from P.T.C. to point x,y.
r	=	Radius of curvature at point x,y.
X,Y,I,I°,L,R	=	Corresponding values at P.C.C.
F	=	Lateral throw of circular curve due to transition
D	=	Abscissa of center of circular curve.
T	=	Abscissa of point of intersection of tangents, P.I.
V	=	Angle formed by tangents.
k	=	$1/\ell r$ (a constant.)
n	=	ℓ/L (quotient of lengths ℓ and L.
Q	=	Value in degrees of one radian = 57.29578... (log. = 1.7581226.)

CRANDALL'S TRANSITION CURVE

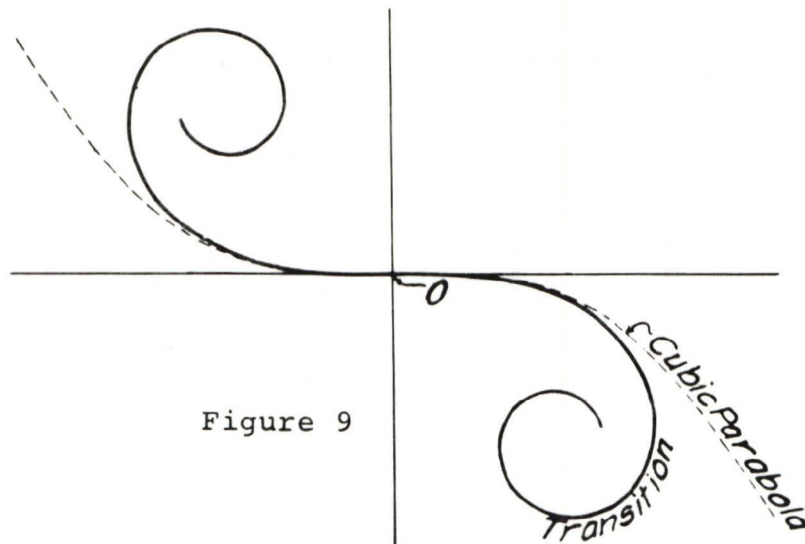


Figure 9

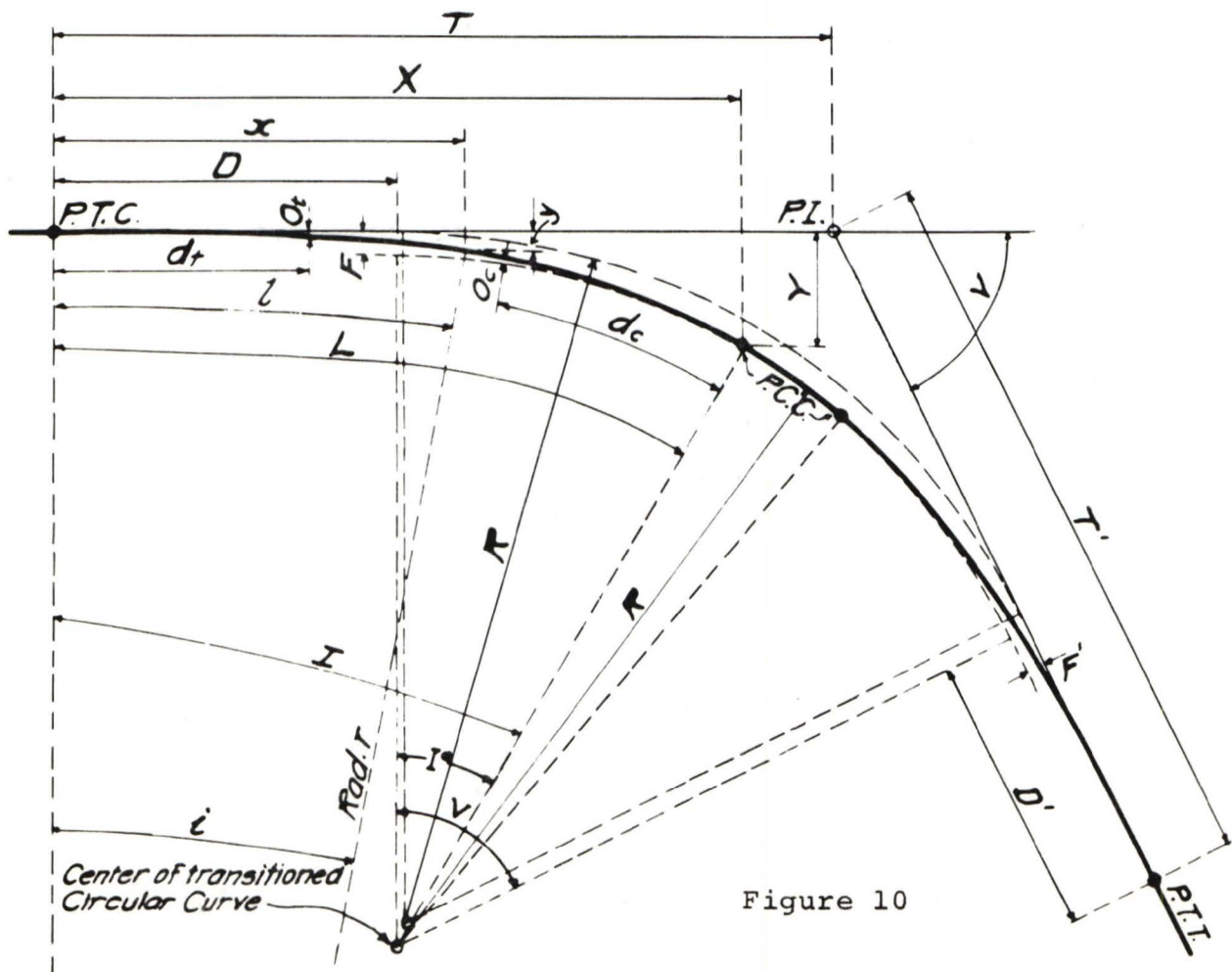


Figure 10

DERIVATION OF FORMULAS

16. By definition:

$$\frac{1}{T} = \frac{di}{d\ell} = K\ell \dots (1); \quad \frac{1}{R} = KL \dots (2); \quad K = \frac{1}{RL} \dots (3)$$

Substituting (3) in (1) and integrating; we have

$$i = \frac{\ell^2}{2RL} \dots (4) \quad I = \frac{L}{2R} \dots (5)$$

$$i^\circ = \frac{Q\ell^2}{2RL} \dots (6) \quad I^\circ = \frac{QL}{2R} \dots (7)$$

$$i^\circ = \frac{\ell^2}{L^2} I^\circ = n I^\circ \dots (8)$$

According to general theory:

$$dx = d\ell \cos i \quad \text{and} \quad dy = d\ell \sin i$$

or, substituting from (4):

$$dx = d\ell \cos \frac{\ell^2}{2RL} \quad \text{and} \quad dy = d\ell \sin \frac{\ell^2}{2RL} \dots (9)$$

By expanding the cosine and sine functions in (9) into series and integrating, we have, after substituting from (6):

$$\left. \begin{aligned} x &= \ell - \ell \left(\frac{i^{\circ 2}}{10 Q^2} - \frac{i^{\circ 4}}{216 Q^4} + \frac{i^{\circ 6}}{9360 Q^6} - \dots \right) \\ \text{and} \quad y &= \ell \left(\frac{i^{\circ}}{3 Q} - \frac{i^{\circ 3}}{42 Q^3} + \frac{i^{\circ 5}}{1320 Q^5} - \dots \right) \end{aligned} \right\} (10)$$

17. Lateral Throw, Length of Tangents. The transition causes the circular curve to be thrown off laterally from the tangent by an amount:

$$F = Y - R(1 - \cos I^\circ) \dots (11)$$

the abscissa of the center of the circular curve being:

$$D = X - R \sin I^\circ \dots (12)$$

For the tangent lengths T and T' (Fig. 10) of a curve transitioned at both ends we have:

$$\left. \begin{aligned} T &= D + (R + F) \tan \frac{V}{2} + \frac{F' - F}{\sin V} \\ T' &= D' + (R + F') \tan \frac{V}{2} + \frac{F - F'}{\sin V} \end{aligned} \right\} \dots (13)$$

VI - VERTICAL CURVES

18. Vertical curves are used in changing from one grade to another. They are parabolas with their axes vertical and are rated by the change r of grade effected in a distance of 100 ft., the change being expressed in per cent:

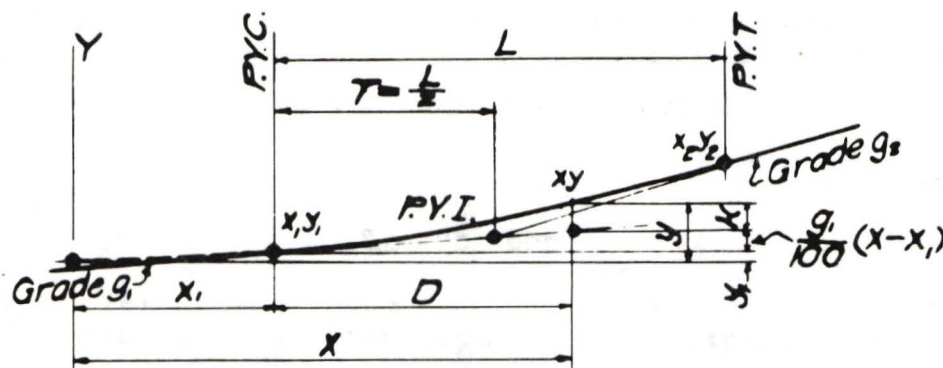


Figure 11

19. Notation (See Fig. 11)

- P.V.C. = Junction between tangent grade and V.C. at beginning of curve.
- P.V.T. = Junction between V.C. and tangent grade at end of curve.
- P.V.I. = Point of intersection of tangent grades, produced.
- r = Rate of vertical curve - in per cent per 100 ft.
- x, y = Coordinates of a point on vertical curve - in ft.
- x_1, y_1 = Coordinates of P.V.C. - in ft.
- g = Grade at point x, y - in per cent.
- g_1, g_2 = Tangent grades at P.V.C. and P.V.T., respectively - in per cent.
- D = Horizontal distance from P.V.C. to point x, y - in ft.
- T = Horizontal distance from P.V.C. to P.V.I. - in ft.

L = Horizontal length of vertical curve - in ft.
 K = Vertical offset of point x,y from tangent grade g, produced in ft.

20. The equation of a vertical curve, referred to its apex O as origin, is:

$$y = \frac{x^2}{2} \frac{r}{10000} \dots \dots \dots (1)$$

giving for the grade at any point on the curve:

$$\frac{g}{100} = \frac{dy}{dx} = x \frac{r}{10000} \dots \dots \dots (2)$$

At P.V.C., accordingly,

$$y_1 = \frac{x_1^2}{2} \frac{r}{10000} ; \frac{g_1}{100} = x_1 \frac{r}{10000} \dots \dots \dots (3)$$

Considering eqs. (1) and (3), we have for the vertical offset of point x,y from tangent grade g_1 (See Fig. 11)

$$\begin{aligned} K &= y - y_1 - \frac{g_1}{100} (x - x_1) \\ &= \frac{x^2}{2} \frac{r}{10000} - \frac{x_1^2}{2} \frac{r}{10000} - x_1 \frac{r}{10000} (x - x_1) \\ &= \frac{r}{10000} \frac{(x - x_1)^2}{2} \end{aligned}$$

$$\text{or } K = \frac{r}{2} \left(\frac{D}{100} \right)^2$$

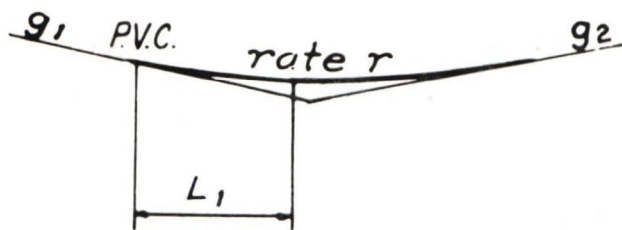
The length L of vertical curve required for joining grades g_1 and g_2 , Fig. 11, is equal to $x_2 - x_1$, or, according to Eq. (2),

$$L = \frac{g_1 - g_2}{r} 100 \text{ ft.}$$

Since in any parabola a diameter through the point of intersection P.V.I. of two tangents bisects the chord through their points of contact with the curve, we also have:

$$T = \frac{L}{2}$$

21. In figuring vertical center and end excess, the radius of the vertical curve shall be taken as $\frac{10000}{r}$ ft.



$L_1 = \frac{g_1}{r} 100$, where L_1 is distance from P.V.C. to low or high point of vertical curve when grades g_1 and g_2 reverse direction or one grade is level.

VII - EXCESSES

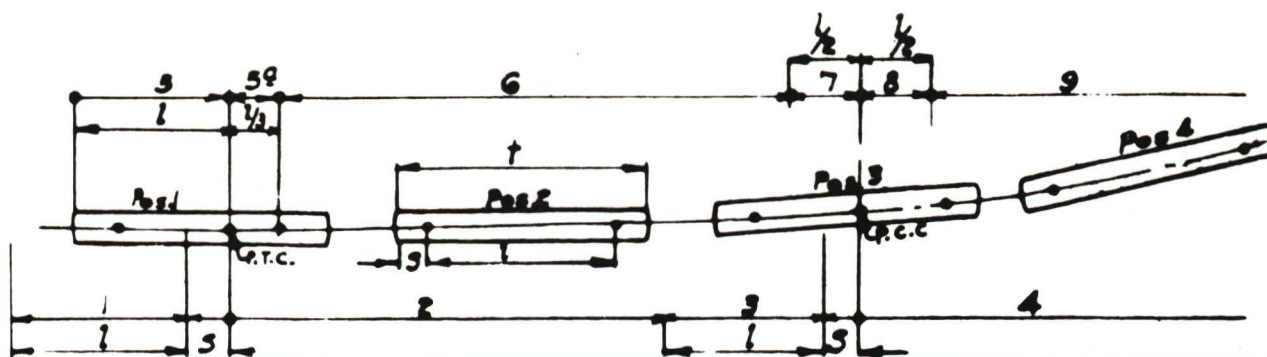
Superelevation excess on transition curves when superelevation at P.C.C. is known:-

$$E_s = S \left(1 - \frac{B - \Delta}{L_s} \right) \frac{h}{4.7083}$$

where:-

- E_s = Excess in ft. due to superelevation.
- S = Superelevation in ft. at P.C.C.
- B = Distance in ft. from P.C.C.
- L_s = Length of Track from 0 Superelevation to P.C.C.
- h = Height above B. of R. to be considered for excess.
- Δ = 20 for 51' (IRT) cars
- Δ = 25 for 67' (BMT-IND) cars
- Δ = 30 for 75' (BMT-IND) cars

FORMULAS FOR END & CENTER EXCESSES ON TRANSITION CURVES



$$1) \quad E.E. = \frac{(l+s+x)^3}{6LR} \frac{s}{l} \quad (\text{sign considered})$$

$$2) \quad E.E. = \frac{(l+s)s}{6LR} (3x+t)$$

$$3) \quad E.E. = \frac{s}{6LR} \left[(s+l)(3x+t) - \frac{(x-l+s+l)^3}{l} \right]$$

$$4) \quad E.E. = \frac{t^2 - l^2}{8R}$$

$$5) \quad C.E. = \frac{9}{312} \frac{(x+l)^4}{RLl} \quad (\text{sign considered})$$

$$5a) \quad C.E. = \frac{9}{312} \frac{(x+l)^4}{RLl} - \frac{x^3}{6RL}$$

$$6) \quad C.E. = \frac{1}{12RL} \left[x(l^2 - x^2) + (x^2 + \frac{l^2}{3})^{3/2} \right]$$

$$7) \quad C.E. = \frac{1}{24RL} \left[3l^2x + 2(L-x-\frac{l}{2})^3 \right]$$

$$8) \quad C.E. = \frac{1}{24RL} \left[3l^2L - 2(L-x+\frac{l}{2})^3 \right]$$

$$9) \quad C.E. = \frac{l^2}{8R}$$

E.E. = End Excess

C.E. = Center Excess

x = Distance from A.T.C. to point considered (Plus to right, minus to left).

t = Length of side of car.

l = Distance between Truck Pivots.

s = Overhang of end of Car.

L = Length of Transition.

R = Radius of Circular Curve.

NOTE:-

Above values expressed in ft.

EXCESS CLEARANCES FOR CARS ENTERING CIRCULAR CURVES—BMT-IND 67 FT. & 75 FT. CARS

I	II	III	IV	V	VI	VII	VIII		
End	Distance in ft. from P.C.	Center Excess		For 30 Miles per Hour		Speed of 40 Miles per Hour			
		High * Duct Bench	Wall	Local Tracks		Express Tracks			
				High * Duct Bench	Wall	High * Duct Bench	Wall		
Excess	B	Bench	Wall	High * Duct Bench	Wall	High * Duct Bench	Wall		
262	FRONT 9'-3" 47'-6" 7'-11 1/8" 54'-0" REAR 67 ft Car 75 ft Car	-30	365	282	605	913	792	1404	
262		-25	364	282	604	913	791	1404	
262		-20	356	279	596	910	783	1401	
262		-15	338	268	578	899	765	1390	
262		-10	310	246	550	877	737	1368	
262		-5	269	213	509	844	696	1335	
262		0	216	167	456	798	643	1289	
250		5	161	120	401	751	588	1242	
213		10	117	82	357	713	544	1204	
170		15	81	54	321	685	508	1176	
131		20	54	32	294	663	481	1154	
98		25	34	18	274	649	461	1140	
70		30	19	8	259	639-.02	446	1130-.02	
46		35	9	3	249-.01	634-.05	436-.01	1125-.05	
27		40	4	1	244-.02	632-.07	431-.02	1123-.07	
13		45	1	0	241-.03	631-.09	428-.03	1122-.09	
4	50	0		240-.04	631-.12	427-.04	1122-.12		
0	55			240-.04	631-.14	427-.04	1122-.14		
For any station not given, located B ft. from									
P.C., amounts to be subtracted are:									
		$\frac{B-30}{565}$		$\frac{B-25}{215}$		$\frac{B-30}{565}$		$\frac{B-25}{215}$	

To find End Excess or Center Excess at any station, divide corresponding figure in Col. I, III or IV by $\underline{R}$ (radius of curve in ft.).

To find Total Center Excess at Duct Bench or Wall, divide left-hand figure in Col. V or VI (VII or VIII) by $\underline{R}$ and subtract right-hand figure, where given.

Values thus obtained are expressed in ft.

Full superelevation assumed at P.C., tapering 1 in. in every 40 feet. This presupposes that a sufficient length of tangent track is available for the run-off. (Minimum radius=230 feet)

The entire car is assumed tilted same amount as front truck. The table does not apply to sharp curves, where transitions are required.

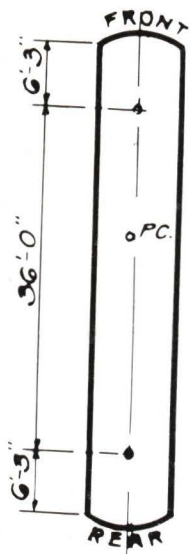
* Top of Duct Bench is 4'-0" above Base of Rail.

NOTE: Columns I, IV, VI and VIII refer to the 67 ft. car. Columns III, V, and VII refer to the 75 ft. car.

EXCESS CLEARANCES FOR CARS ENTERING CIRCULAR CURVES

IRT CAR (51'-4" CARS)

I	II	III	IV	V
End Excess	Distance in ft. from P.C. B	Center Excess	Total Center Excess High Duct Bench*	Wall
132	-25	162	402	793
132	-20	162	402	793
132	-15	160	400	791
132	-10	150	390	781
132	-5	129	369	760
132	0	96	336	727
120	5	61	301	692
90	10	36	276	667
64	15	18	259	650
43	20	8	248	639
26	25	3	243	634
13	30	0	240 - .03	631 - .05
5	35		240 - .03	631 - .07
1	40		240 - .04	631 - .09
0	45		240 - .04	631 - .12
	50		240 - .05	631 - .14
For any station not given, located B ft. from P.C., amounts to be subtracted in Columns IV and V are:			$\frac{B-20}{365}$	$\frac{B-20}{215}$



To find End Excess or Center Excess at any station, divide corresponding figure in Column I or III by R (radius of curve in ft.)

To find Total Center Excess at Duct Bench or Wall, divide left hand figure in Column IV or V by R and subtract right hand figure, where given.

Values thus obtained are expressed in ft.

Full superelevation assumed at P.C., tapering 1 in. in every 40 ft. This presupposes that a sufficient length of tangent track is available for the run-off.

The entire car is assumed tilted same amount as front truck. The table does not apply to sharp curves, where transitions are required.

* Top of Duct Bench is 4'-0" above Base of Rail.

DIAGRAM SHOWING NORMAL CLEARANCE FOR 67 ft CAR (BMT & IND DIVISIONS)

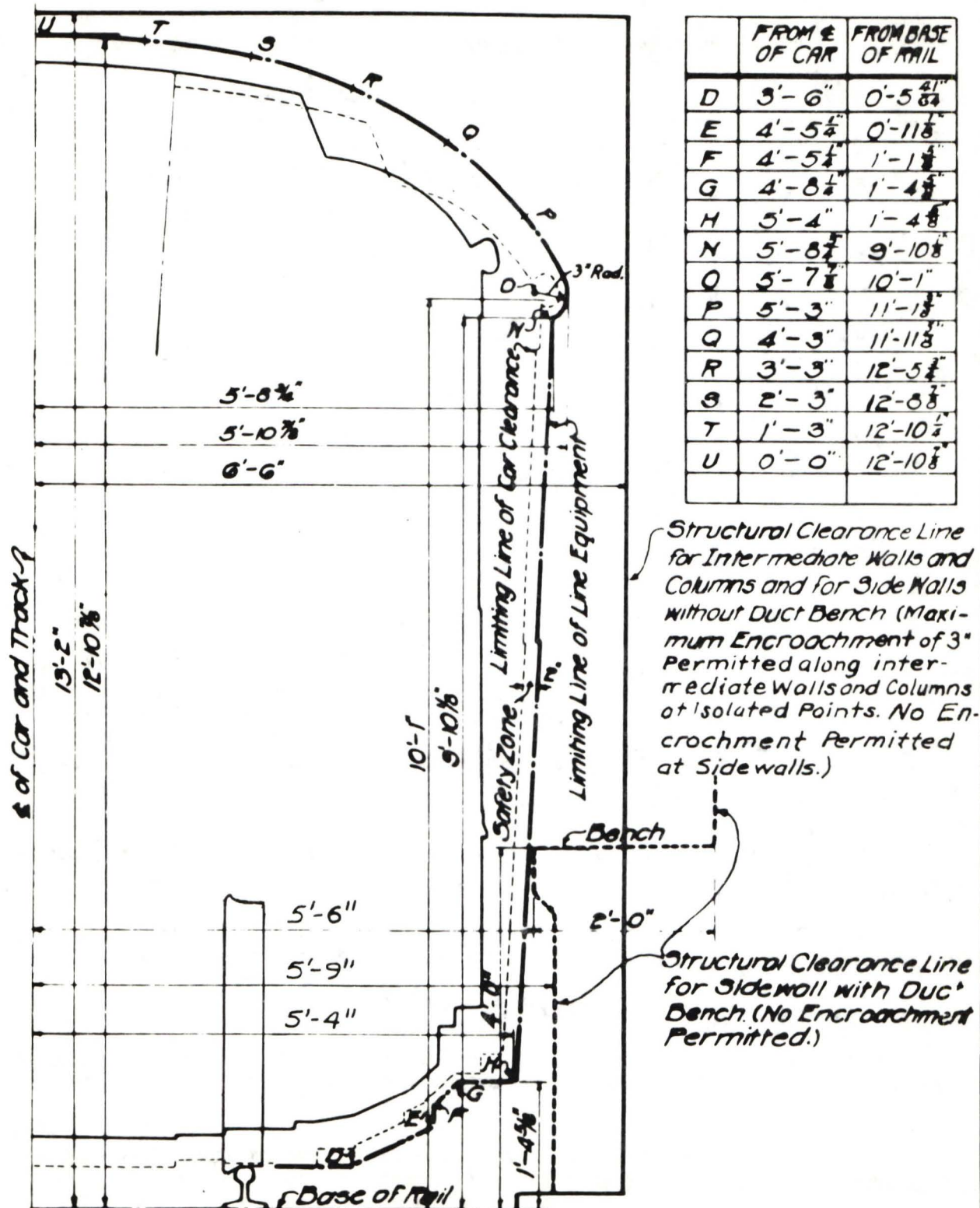
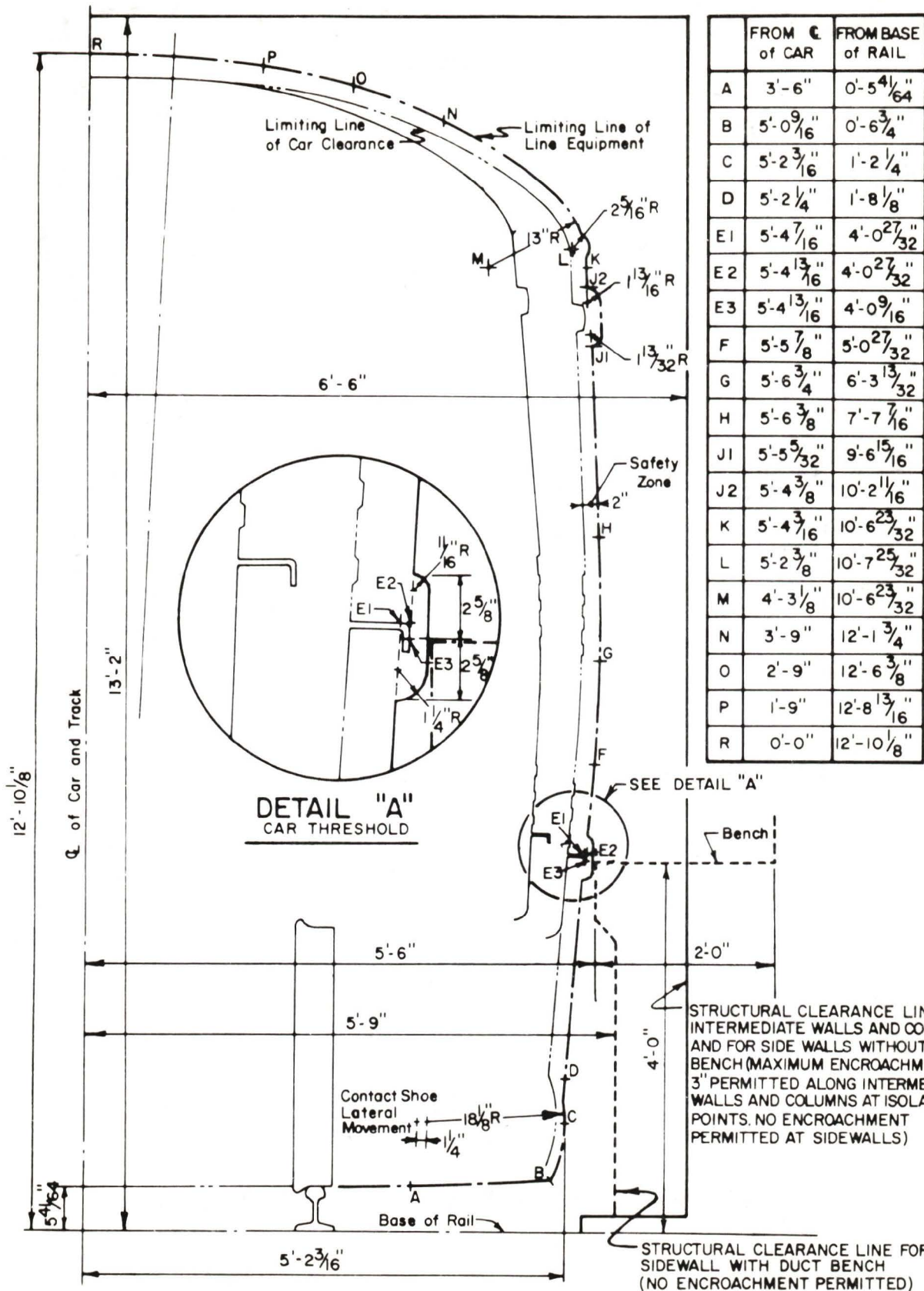


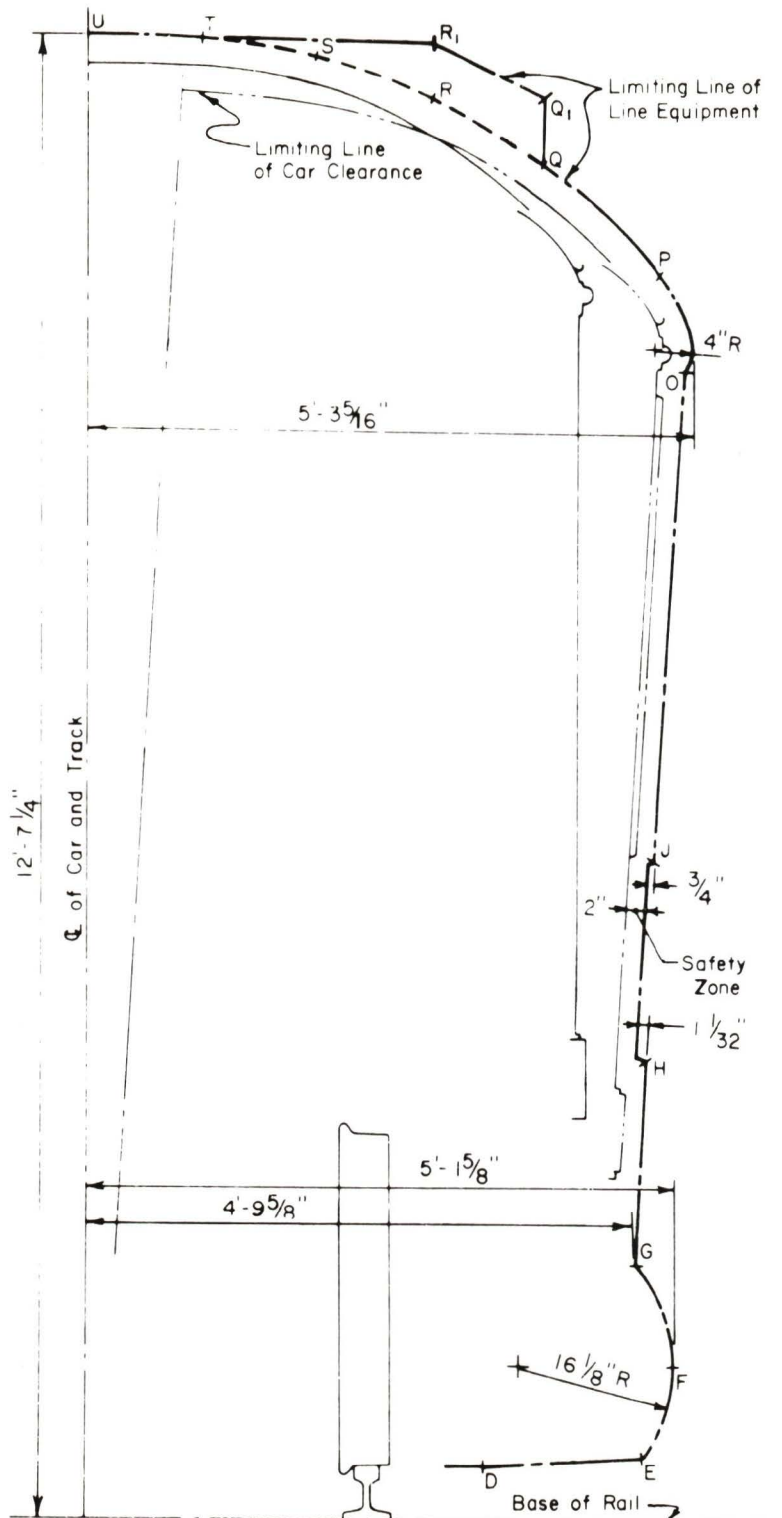
DIAGRAM SHOWING NORMAL CLEARANCE FOR 75 ft. CAR (BMT & IND DIVISIONS)





SD-2-20

DIAGRAM SHOWING NORMAL CLEARANCE FOR IRT DIVISION



Normal Clearance

	FROM $\mathbb{C}$ of CAR	FROM BASE of RAIL
D	3'-6"	0'-5 4/64"
E	4'-10 1/2"	0'-6 1/2"
F	5'-15/8"	1'-4"
G	4'-9 5/8"	2'-2 7/16"
H	4'-10 3/4"	3'-11 1/4"
J	4'-11 3/8"	5'-6 15/16"
O	5'-2 1/2"	9'-9 1/2"
P	5'-0"	10'-7"
Q	4'-0"	11'-6 1/8"
R	3'-0"	12'-0 3/4"
S	2'-0"	12'-5 5/16"
T	1'-0"	12'-6 15/16"
U	0'-0"	12'-7 1/4"

Clearance Modified
for 1938 and Earlier Cars

	FROM $\mathbb{C}$ of CAR	FROM BASE of RAIL
Q ₁	4'-0"	11'-11 1/4"
R ₁	3'-0"	12'-5 1/2"

Chapter **3**

1940

Chapter 3

LOADS AND STRESSES TO BE USED IN DESIGNING SUBWAYS, TUNNELS AND ELEVATED STRUCTURES

TABLE OF CONTENTS

I DEAD LOAD - - - - -	SD-3-1
II LIVE LOAD - - - - -	SD-3-2
III BUILDING LOAD - - - - -	SD-3-15
IV LATERAL FORCES ON ELEVATED STRUCTURES - - - - -	SD-3-21
V SIDE PRESSURES ON SUBWAYS - - - - -	SD-3-22
VI ECCENTRIC LOADING ON SIDEWALL COLUMNS - - - - -	SD-3-27
VII STRESSES - - - - -	SD-3-28
VIII COMBINED STRESSES - - - - -	SD-3-35

Chapter 3

LOADS AND STRESSES TO BE USED IN DESIGNING SUBWAYS, TUNNELS AND ELEVATED STRUCTURES

1 - DEAD LOAD

1. The dead load consists of the weight of the structure plus any stationary load it may have to carry.

2. Cover Load on subways is defined as the combined weight of the roof construction and the overlying earth and is considered equal to that of a layer of dry earth of a depth as from the underside of transverse roof members to the ground or street surface. If the top of the roof is below water level additional allowance shall be made for the greater weight of saturated earth. For roofs with ceiling approximately flush with underside of roof beam, add to cover load 75 lb. per sq. ft. of roof surface for every ft. of depth of roof slab.

3. Weight of Materials shall be estimated as follows:

<u>Material</u>	<u>Weight-lb./cu.ft.</u>
Steel - - - - -	490
Cast Iron - - - - -	450
White Oak, Yellow Pine - - - - -	48**
Fir, Spruce, White Pine - - - - -	30**
Timber, treated - - - - -	60
Stone Concrete, plain or reinf. - - - - -	150
Cinder Concrete - - - - -	100
Earth, dry - - - - -	100
Earth, saturated - - - - -	125
Rock - - - - -	150
Brick Masonry - - - - -	120
Stone Masonry - - - - -	150
Crushed Stone, Gravel - - - - -	110
Water - - - - -	62.5

**For green timber, add 25%.

4. Load on Tunnels. In designing subaqueous and rock tunnels, each case shall be considered on its own merits. In no case shall the load on top of rock tunnel* roofs be taken as less than that due to a 10 ft. layer of rock.
*18 ft. diameter

5. Miscellaneous, for Elevated Structures:

Canopy Roof - - - - - 20 lb./sq.ft.
Wooden Flooring for Platforms and
Mezzanines - - - - - 25 lb./sq.ft.
Ties, Rail and Service Walk in open
floor structures, for each rail - - - - 220 lb./lin.ft.

II - LIVE LOAD

6. The Train Load on subway and elevated tracks shall be taken as a continuous train of cars with axle loads of the amounts and spacings given in Figs. 1A to 1C. For maximum values of shear, moment or floor beam reaction produced by BMT or IND loadings, see Table 1. See also Sects. 16 to 18.

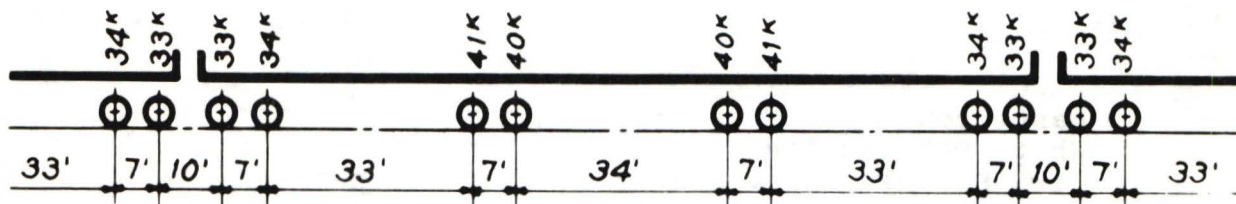


Figure 1A (BMT DIV. CAR LOADING)

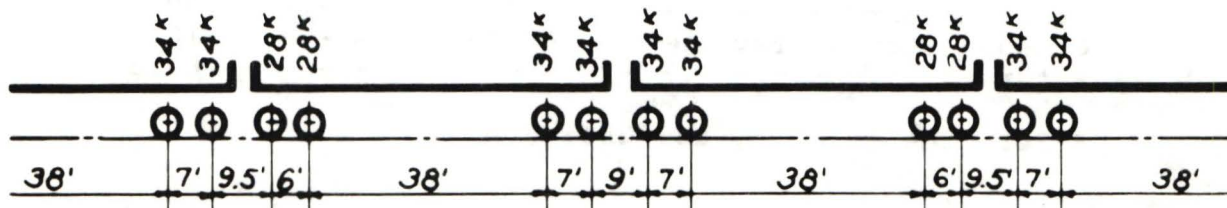


Figure 1B (IND DIV. CAR LOADING)

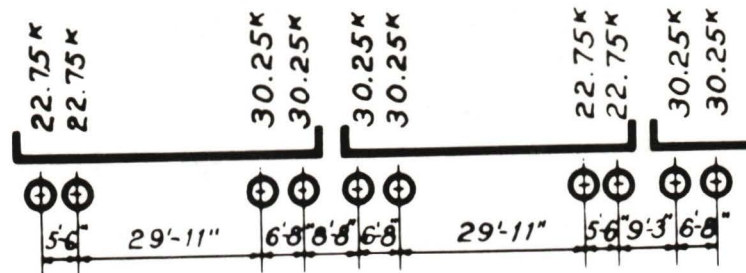


Figure 1C (IRT DIV. CAR LOADING)

7. Where the structure supports Railroad Trains, the design shall be made in accordance with the requirements of the railroad company concerned, provided those of the T.A. are not more severe.

8. Impact is considered for trains only. For subway and elevated trains, the loads specified in Sect. 6 shall be increased by a percentage I, as given by the following formula:

$$I = \frac{150 - \frac{L}{6}}{450 + L} 100 \text{ --- (1)}$$

where: I = Increase in percent of the live load on a single track.

L = Length of span in ft.

For members supporting several tracks, such as cross girders and columns, L = Length of adjacent spans for one track only. For values of I see Table 2.

TABLE 1

SHEARS, BENDING MOMENTS AND FLOOR BEAM
REACTIONS FOR STRINGERS ON STRAIGHT TRACK DUE
TO TRAIN LOAD ON ONE RAIL. IMPACT NOT INCLUDED
(FOR BMT & IND CAR LOADING)

Span Ft.	Shear Kip	Moment Ft. Kip	F.B.R. *Kip	Span Ft.	Shear Kip	Moment Ft. Kip	F.B.R. *Kip
6	20.50	30.75	20.50	46	51.00	517.48	57.92
8	23.00	41.00	23.00	48	51.71	551.17	59.99
10	26.50	51.25	26.50	50	52.36	584.89	61.89
12	28.83	61.58	28.83	52	52.96	618.62	63.64
14	30.50	80.39	31.57	54	53.52	652.37	65.81
16	31.75	99.56	34.00	56	54.04	686.15	68.04
18	32.72	118.97	37.78	58	54.52	719.94	70.45
20	33.50	138.55	40.80	60	54.97	753.74	73.03
22	34.14	158.25	43.27	62	55.69	787.55	75.45
24	35.42	178.04	45.33	64	56.68	821.38	77.72
26	37.92	197.90	47.08	66	58.22	855.22	79.85
28	40.07	221.20	48.57	68	59.67	889.06	81.85
30	41.93	249.48	49.87	70	61.04	922.92	83.74
32	43.56	282.76	51.00	75	64.13	1007.59	88.03
34	45.00	316.13	52.00	80	66.84	1092.30	91.78
36	46.28	349.56	52.89	85	69.24	1177.05	96.21
38	47.42	383.06	53.68	90	71.36	1304.72	101.53
40	48.45	416.61	54.40	95	74.27	1436.33	106.29
42	49.38	450.20	55.05	100	77.06	1568.22	111.49
44	50.23	483.82	55.84				

*For two adjacent spans of equal length.

Adj. Spans Ft.	F.B.R. Kip
30 & 35	51.89
" " 40	53.41
" " 45	54.59
" " 50	55.53
" " 55	58.20
" " 60	61.05
" " 65	63.46
" " 70	66.12
" " 75	68.61
" " 80	70.80
" " 85	73.06
" " 90	76.00
" " 95	78.63
30 & 100	81.00

Adj. Spans Ft.	F.B.R. Kip
35 & 35	52.46
" " 40	53.98
" " 45	55.16
" " 50	56.95
" " 55	60.37
" " 60	63.21
" " 65	65.62
" " 70	67.69
" " 75	69.48
" " 80	72.37
" " 85	75.04
" " 90	77.42
" " 95	79.55
35 & 100	82.00

In designing sections, the effect of dead load and impact shall be added. Where stringers are spliced for moment at supports, shears and floor beam reactions shall be increased 25 per cent.

TABLE 2

IMPACT INCREASES FOR SUBWAY AND ELEVATED
TRAINS AS DETERMINED FROM FORMULA (1) *

L	I	L	I	L	I	L	I
5	33	40	29	100	24	400	10
10	32	50	28	150	21	500	7
15	32	60	28	200	18	600	5
20	31	70	27	250	16	700	3
25	31	80	26	300	14	800	2
30	30	90	25	350	12	900	0

*For railroad trains, use three times these values, except as provided in Sect. 7 and 11.

9. Where a member supports more than one track the number of tracks assumed loaded shall be such as will produce the maximum stress in the member, but the impact increase shall be applied only to that track which, when loaded, contributes most to the live load stress.

10. In designing steel members of structures supporting elevated columns, use actual computed loads and apply T.A. impact formulas and stresses as specified in "Loads and Stresses."

11. The live load and impact on Highway Bridges shall be assumed as per specifications of the Dept. of Public Works.

12. Live Load from Sidewalks and Roadways The sidewalk live load over subways shall be taken at 600 lb. per sq. ft. This value also applies to sidewalk gratings.

The roadway live load over subways shall be computed in either of the following ways, whichever gives the more severe condition:

(a) For uniform load as given in Table 3. This live load shall always be assumed for the design of interior columns and longitudinal roof members in subways, as it always governs where area supported is large.

(b) As a local concentration of 200 Kip on four wheels, 12 ft. between axles and 6 ft. gauge. Each of these wheel loads shall be considered distributed over an area of 2 ft. by 2 ft. on the pavement and thence through the soil and roof at a slope of 1 horizontal to 2 vertical.

Table 3 gives the uniform live load, together with the corresponding dead load, for various covers of dry earth.

Table 4 gives the equivalent total load per sq. ft. which for various covers, spans and spacings of roof beams produces in the latter the same moment or shear as does the local concentration specified in Subsection (b) above, together with the corresponding dead load, for various covers of dry earth.

TABLE 3

SIDEWALK AND ROADWAY LOAD OVER SUBWAYS IN KIP PER SQ. FT.

Cover in Ft.	Dead Load (Cover Load)	Live Load		Total Load	
		Sidewalk	Roadway	Sidewalk	Roadway
2	0.2	0.6	1.3	0.8	(1.5)
3	0.3	0.6	1.2	0.9	(1.5)
4	0.4	0.6	1.1	1.0	(1.5)
5	0.5	0.6	1.0	1.1	1.5
6	0.6	0.6	0.9	1.2	1.5
7	0.7	0.6	0.8	1.3	1.5
8	0.8	0.6	0.7	1.4	1.5
9	0.9	0.6	0.6	1.5	1.5
10	1.0	0.6	0.6	1.6	1.6
11	1.1	0.6		1.7	
12	1.2	0.6		1.8	
13	1.3	0.6		1.9	
14	1.4	0.6		2.0	
15	1.5	0.5		2.0	
16	1.6	0.4		2.0	
17	1.7	0.3		2.0	
18	1.8	0.2		2.0	
19	1.9	0.1		2.0	
20	2.0	0.0		2.0	

For each additional ft. of cover, increase total load by 0.1 kip per sq. ft.

Values in brackets are minimum values and shall be compared to those given in Table 4.

For roofs below water or with depressed ceiling, increase load as specified in Sec. 2.

13. Subway Roofs supporting no other structures shall be designed for the loads specified in Tables 3 or 4 of Sect. 12. For spans to be considered, see "Details of Design for Structural Steel".

14. In determining roof load carried by a Column, the portion directly over the column shall be included.

15. In double deck structures, where the upper and lower sidewall columns are vertically aligned, one-half the total load on the upper column shall be considered given over to the lower column, except where total exceeds 200 kip or bond value of column, in which case all of it shall be considered given over. To this shall be added the intermediate floor load. Both columns shall be designed as per "Design of Sidewall Columns," pg. SD-5-1 where Sects. 39 to 41 apply. In no case, however, shall the lower column be of less strength than the upper one.

16. Intermediate Track Floors in subways, with beams placed transversely, shall be designed for a live load of 1100 lb. per sq. ft. static equivalent, applied over a width of 10 ft. symmetrical to the centerline of track, in addition to dead load, as shown in Fig. 2. The direct compression due to side pressure shall be considered in designing track floor beams (see Sect. 55.)

Special track floor construction at crossings, with rail supports placed longitudinally, shall be designed in accordance with Tables 1 and 2.

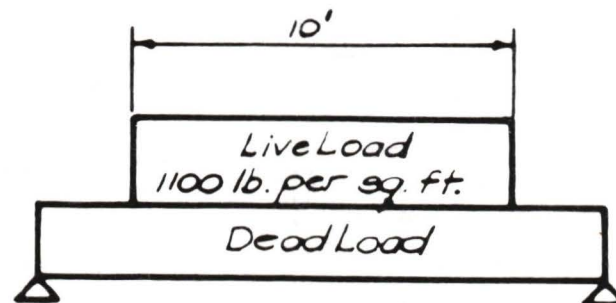


Figure 2

TABLE 4

LOCAL CONCENTRATION AS PER SECTION 12b
EQUIVALENT LOAD (INCL. COVER LOAD)
IN KIP PER SQ. FT.

		Span in Ft.	Spacing of Beams					
			1 Ft.	2 Ft.	3 Ft.	4 Ft.	5 Ft.	
2 FT. COVER	VALUES TO BE USED FOR SHEAR	5	3.20	3.20	2.85	2.45	2.20	
		6	3.00	3.00	2.65	2.30	2.05	
		7	2.75	2.75	2.45	2.10	1.90	
		8	2.75	2.75	2.45	2.10	1.85	
		9	2.70	2.70	2.45	2.10	1.80	
		10	2.70	2.70	2.40	2.05	1.80	
		11	2.70	2.70	2.40	2.05	1.80	
		12	2.65	2.65	2.35	2.00	1.75	
		13	2.55	2.55	2.30	2.00	1.70	
		14	2.50	2.50	2.25	1.95	1.70	
		15	2.45	2.45	2.15	1.85	1.65	
		16	2.35	2.35	2.10	1.80	1.60	
		17	2.30	2.30	2.05	1.75	1.55	
		18	2.20	2.20	2.00	1.70	1.50	
		19	2.15	2.15	1.95	1.65	1.50	
		20	2.10	2.10	1.90	1.60	1.50	
		VALUES TO BE USED FOR MOMENT	5	3.20	3.20	2.85	2.45	2.20
			6	3.00	3.00	2.65	2.30	2.05
			7	2.75	2.75	2.45	2.10	1.90
			8	2.55	2.55	2.30	1.95	1.75
	9		2.35	2.35	2.10	1.80	1.65	
	10		2.35	2.35	2.10	1.80	1.60	
	11		2.30	2.30	2.05	1.75	1.55	
	12		2.25	2.25	2.05	1.75	1.50	
	13		2.20	2.20	2.00	1.70	1.50	
	14		2.20	2.20	1.95	1.70	1.50	
	15		2.15	2.15	1.95	1.65	1.50	
	16		2.10	2.10	1.90	1.65	1.50	
	17		2.05	2.05	1.85	1.60	1.50	
	18		2.00	2.00	1.80	1.55	1.50	
	19		1.95	1.95	1.75	1.55	1.50	
	20		1.95	1.95	1.75	1.50	1.50	

TABLE 4 (CONTINUED)

LOCAL CONCENTRATION AS PER SECTION 12b
EQUIVALENT LOAD (INCL. COVER LOAD)
IN KIP PER SQ. FT.

	Span in Ft.	Spacing of Beams				
		1 Ft.	2 Ft.	3 Ft.	4 Ft.	5 Ft.
3 FT. COVER VALUES TO BE USED FOR MOMENT & SHEAR	5	2.30	2.30	2.25	2.05	1.95
	6	2.25	2.25	2.20	2.00	1.90
	7	2.20	2.20	2.15	1.90	1.80
	8	2.15	2.15	2.10	1.90	1.75
	9	2.10	2.10	2.10	1.85	1.70
	10	2.10	2.10	2.10	1.85	1.70
	11	2.10	2.10	2.10	1.85	1.70
	12	2.10	2.10	2.05	1.85	1.65
	13	2.10	2.10	2.05	1.85	1.65
	14	2.05	2.05	2.00	1.80	1.60
	15	2.00	2.00	1.95	1.75	1.60
	16	1.95	1.95	1.90	1.75	1.55
	17	1.90	1.90	1.85	1.70	1.50
	18	1.85	1.85	1.80	1.65	1.50
4 FT. COVER VALUES TO BE USED FOR MOMENT & SHEAR	19	1.80	1.80	1.75	1.60	1.50
	20	1.75	1.75	1.70	1.55	1.50
	5	1.80	1.80	1.80	1.80	1.80
	6	1.80	1.80	1.80	1.80	1.80
	7	1.80	1.80	1.80	1.75	1.75
	8	1.80	1.80	1.80	1.70	1.70
	9	1.80	1.80	1.80	1.70	1.65
	10	1.80	1.80	1.80	1.70	1.55
	11	1.80	1.80	1.80	1.70	1.55
	12	1.80	1.80	1.80	1.70	1.55
	13	1.80	1.80	1.80	1.70	1.55
	14	1.80	1.80	1.80	1.70	1.55
	15	1.75	1.75	1.75	1.65	1.55
	16	1.70	1.70	1.70	1.60	1.50
	17	1.65	1.65	1.65	1.60	1.50
	18	1.65	1.65	1.65	1.55	1.50
	19	1.60	1.60	1.60	1.55	1.50
	20	1.55	1.55	1.55	1.50	1.50

For Covers between 4 ft. and 9 ft. use 1500 lb. per sq. ft. total load irrespective of span and spacing of beams.

TABLE 4 (CONTINUED)

LOCAL CONCENTRATION AS PER SECTION 12b
EQUIVALENT LOAD (INCL. COVER LOAD)
IN KIP PER SQ. FT.



Table 4 shall not be used in designing a beam A (see diagram) supporting a number of other beams B. In such cases, where cover is less than 9 ft., beam A shall be designed for a uniform load of 1.5 kip per sq. ft. of area supported.

17. Column Footings, Grillages, longitudinal invert Distributing Girders and Interior Subway Columns shall be designed for the Total Load given in Table 3, to which shall be added platform and mezzanine floor live load at 150 lb. per sq. ft. and intermediate track floor live load as specified in Sect. 16, together with their respective dead loads. In considering loads transmitted from sidewall columns to steel footings no deduction shall be made for load carried by the wall concrete.

18. Subway Inverts distributing loads over the entire subgrade shall be designed for the "Dead Load" given in Table 3, together with the weight of walls and floors, not including invert, to which loads shall be added the live load from platform, mezzanine and upper tracks at one-half the values specified in Sects. 16 and 17, but in no case shall inverts of this type be designed for a total load of less than 900 lb. per sq. ft.

In computing the shearing and bearing stresses in steel or concrete at column supports, however, the loads to be provided for shall be those specified in Sect. 17.

19. The Design Live Load on other surfaces of subway and elevated structures are tabulated below.

NOTE:

The Designing Engineer must check with the appropriate Department or Division whether there have been any major changes in the equipment design, with respect to size, weight, method of support and vibration or shock loading characteristics subsequent to the derivation of these design live loads (January 1974.)

See DESIGN AIDS for equipment used as a basis for these design live loads.

TABLE OF DESIGN LIVE LOAD

No.	Area Description	Uniformly Distributed + Load (PSF)	Concen- trated Load (Kips)	See Note No.
1	Canopy Roofs	30	0	1
2	Service Walks	150	0	1
3	Stairs, on horizont- al projection	150	0	1
4	Floors of Platforms & Mezzanines			
(a)	Elevated	100	0	1
(b)	Subways	150	0	-
5	Floors of Chiller Rooms	150	15.0	2
6	Floors of Air Cooling Unit Rooms	150	1.0	2
7(a)	Floors of Fan Areas	150	5.0	2,3
(b)	Floors of Control Rooms	150	0	-
8(a)	Floors of Elevator Machinery Rooms	-	-	4
(b)	Floors of Elevator Pits	-	-	4
9(a)	Floors of Escalator Machinery Rooms	150	2.0	2,5
(b)	Floors of Escalator Pits	150	0	5
10	Floors of Ejector Rooms	150	1.0	2
11(a)	Floors of Pump Chambers	250	2.0	2
(b)	Floors of Sumps	-	-	6

TABLE OF DESIGN LIVE LOAD (CONT'D.)

No.	Area Description	Uniformly Distributed + Load (PSF)	Concen- trated Load (Kips)	See Note No.
12	Floors of Circuit Breaker Houses	200	2.0	2
13	Floors of Electrical Distribution Rooms	250	5.0	2
14	Floors of Electrical Panel Rooms	150	0	-
15(a)	Floors of Relay Rooms	150	1.0	2
(b)	Floors of Central Instrument Rooms	150	1.0	2
16	Floors of Signal Tower Control Rooms	150	1.0	2
17	Floors of Communica- tions Rooms	150	0	2
18	Floors of Telephone Compartment Rooms	150	0	-
19	Floors of Compressor Rooms	150	0	-
20	Floors of Substation			
(a)	Transformer Areas	300	15.0	2
(b)	Circuit Breaker Platforms	300	6.0	2
21	Floors of Track Lubrication Rooms	150	0	-
22	Floors of Various Quarters	150	0	7

TABLE OF DESIGN LIVE LOAD (CONT'D.)

No.	Area Description	Uniformly Distributed + Load (PSF)	Concen- trated Load (Kips)	See Note No.
23	Floors of Storage Spaces in Subways	400	0	-
24	Floors of Mainten- ance, Service Rooms & Duct Manholes	150	0	-
25	Floors of Passageways	150	0	8

NOTES:

1. In designing elevated columns, use one-half of the uniformly distributed live load.
- 2a. In designing floor slabs (one-way or two-way) or floor beams use the uniformly distributed live load over the entire floor area plus the concentrated live load* located so as to produce (1) maximum shear, and (2) maximum moment. (*For one-way slabs, apply the distributed live load plus the concentrated live load to a slab whose width is twice the effective depth.)
- 2b. In designing columns, use the uniformly distributed live load, only.
3. This loading is to be used for Under Platform Exhaust Fan Rooms, Fan Chambers, Fan Work Areas and any other areas supporting similar size fans.
- 4a. Design live loads must be determined for each location by consultation with the Equipment Division.
- 4b. A minimum uniformly distributed live load of 150 psf shall be used on all floors.
- 4c. The equipment live load shall be increased sufficiently to provide for impact. If not otherwise specified, this increase shall be taken as 100 percent.

5. Design live loads given are for escalators with a maximum rise of 33 feet. For longer escalators, Note 4, above, applies.
6. Design live loads must be determined on the basis of maximum hydrostatic pressure (and external earth pressure, where applicable.)
7. This design live load applies to quarters of the following personnel, including tool rooms, work shops and "light" storage rooms.
 - a. foreman
 - b. dispatchers
 - c. trainmen
 - d. motormen
 - e. 3rd railmen
 - f. trackmen
8. Passageways and other areas on which equipment is to be temporarily supported must be designed for the design live loads of the appropriated rooms.

III - BUILDING LOAD

20. When the subway passes under private property it shall be designed for Building load. The question as to height and character of building to be provided for in each case, as well as the location of walls of lot lines where the same has not already been determined, shall be discussed by the Designs Subdivision with the Real Estate Bureau and the Architectural Subdivision, and the Designing Engineer shall file an office memorandum of the data agreed upon during such discussion and transmit copies of the same to the Real Estate Agent and Appraiser, the Designing Architect, and the Division Engineer of the Designs Division.

21. Building loads on subways shall be computed from the following values which are given in lb. per sq. ft., the dead loads including the weight of partitions:

	Live Load	Dead Load
Roof, all types of buildings	40	60
<u>Floors:</u>		
Apartment Houses, Hotels	40*	100
Office Buildings	50*	100
Theatres, Concert Halls	75*	100
Other Places of Assembly, Schools	60*	100
Light Manufacturing Buildings	75*	100
Factory Buildings, Storage Houses, Garages	120*	100
Heavy Manufacturing Buildings	250*	130
Cellar, all types of buildings	300	
<u>Walls, (12 in. Brick):</u>		
Without Openings	120 lb./vert.sq.ft.	
With Openings	100 lb./vert.sq.ft.	

*Live load on the top floor shall be taken at 85% of the values given above, that on succeeding floors below at 80%, 75% ... down to a minimum of 50% of the same values. This reduction does not, however, apply to storage houses where the full live load shall be assumed for all the floors.

The above loads are substantially in agreement with the Building Code.

22. In designing the subway for uniform building load, the footings supporting piers and columns are generally assumed to be spread over an area equal to one-half that of the corresponding panels. The load per sq. ft. of subway roof shall then be assumed equal to twice the total from roof and floors as determined from Sect. 21. On this load, which is assumed to be applied to every sq. ft. of subway roof within the easement, shall be superimposed the following additional loads:

a) Dead weight of front wall. This weight shall be considered distributed over a strip 4 ft. wide of which 1 ft. is outside the building line, except where top of subway roof is less than 10 ft. below street surface when a strip of 3 ft. wide flush with the building line shall be considered. Exception is also made as per Subsect. c, below.

b) Dead weight of lot line walls, distributed over strips 3 ft. wide flush with lot lines, except as provided in Subsect. c, below.

c) For buildings more than 6 stories high, the width of the strips referred to under Subsects. a, and b, above shall be increased by being extended to the middle of the end panels.

d) Live load on cellar floor as per Sect. 21.

e) Weight of subway roof and overlying soil, to be taken at 100 lb. per sq. ft. for every ft. between cellar floor level (usually 10 ft. below street level) and underside of transverse roof members. Where top of subway roof is below water, 25 lb. per sq. ft. shall be added for every ft. of ground water head above.

Table 5 gives values of uniform building load for various heights of buildings in accordance with the above rules.

TABLE 5

VALUES FOR BUILDING AND WALL LOADS
WHEN UNIFORMLY DISTRIBUTED OVER SUBWAY ROOF*

Number of Stories	A	B	C	D	E	F	G	H	I
	Apt. Houses, Hotels	Office Buildings	Theatres, Concert Halls, Light, Mfg. Bldgs.	Other Places of Assembly, Schools	Factory Bldgs. Garages	Storage Houses	Heavy Mfg. Bldgs.	Front Wall	Lot Line Wall
25	6.60	6.90	7.60	7.20	8.85	11.50	13.95	For buildings more than 6 stories high, the wall loads given in Table 6 under Cols. Q and R respectively, shall be considered distributed over strips as specified in Sect. 22c.	
24	6.40	6.65	7.30	6.90	8.55	11.05	13.45		
23	6.15	6.40	7.05	6.65	8.20	10.65	12.95		
22	5.90	6.15	6.75	6.40	7.50	10.20	12.45		
21	5.65	5.90	6.50	6.15	7.55	9.75	11.90		
20	5.40	5.65	6.20	5.90	7.25	9.30	11.40		
19	5.20	5.40	5.95	5.60	6.95	8.85	10.90		
18	4.95	5.15	5.65	5.35	6.60	8.45	10.40		
17	4.70	4.90	5.40	5.10	6.30	8.00	9.90		
16	4.45	4.65	5.10	4.85	5.95	7.55	9.35		
15	4.20	4.40	4.85	4.60	5.65	7.10	8.85		
14	4.00	4.15	4.55	4.30	5.35	6.65	8.35		
13	3.75	3.90	4.30	4.05	5.00	6.25	7.85		
12	3.50	3.65	4.00	3.80	4.70	5.80	7.35		
11	3.25	3.40	3.75	3.55	4.35	5.35	6.80		
10	3.00	3.15	3.45	3.30	4.05	4.90	6.30		
9	2.80	2.90	3.20	3.00	3.75	4.45	5.80		
8	2.55	2.65	2.90	2.75	3.40	4.05	5.30		
7	2.30	2.40	2.65	2.50	3.10	3.60	4.80		
6	2.05	2.15	2.35	2.25	2.75	3.15	4.25	2.10	3.35
5	1.80	1.90	2.05	1.55	2.40	2.70	3.70	1.80	2.90
4	1.55	1.60	1.80	1.70	2.05	2.25	3.10	1.50	2.40

* Columns A to G give loads in kip per sq. ft. to be used in designing subway for uniform building load as per Sect. 22. These include twice the total from roof and floors plus live load on cellar, but shall be increased by weight of subway roof and overlying soil as per Sect. 22e.

Figures in Cols. H and I give the additional loads in kip per sq. ft. due to building walls distributed over strips 4 ft. and 3 ft. wide as specified in Sect. 22a and b respectively, assuming each story height at 12 ft.

Where front wall is assumed to be distributed over a strip 3 ft. wide as per Sect. 22a, the values given in Col. H shall be increased by one-third.

23. Where provisions are to be made for specific column locations, the columns shall be placed a uniform distance apart, as close to 20 ft. by 20 ft. as conditions permit, odd inches to be taken up in the end panels. The wall columns shall be set back on a centerline which is 1'-8" from the building line and 1'-4" from lot lines, and the column loads shall be computed in accordance with Sect. 21. The subway, in this case, shall be designed for the column loads and for the additional loads specified in Sect. 22d and e. No base plate or grillage to be provided by the building owner shall project beyond lot lines, or more than 1 ft. beyond the building line, as provided by the Building Code, but where grillages for building column support are included in the subway construction no such limit is imposed.

Table 6 gives values for determining column concentrations for various heights of buildings, together with the corresponding weights of walls per lin. ft. of length.

TABLE 6

VALUES FOR BUILDING COLUMN CONCENTRATIONS
AND WEIGHT OF BUILDING WALLS*

Number of Stories	J Apt. Houses, Hotels	K Office Buildings	L Theatres, Concert Halls, Light, Mfg. Bldgs.	M Other Places of Assembly, Schools	N Factory Bldgs. Garages	O Storage Houses	P Heavy Mfg. Bldgs.	Q Front Wall	R Lot Line Wall
25	3.15	3.30	3.65	3.45	4.30	5.60	6.85	31.20	37.45
24	3.05	3.20	3.50	3.30	4.10	5.40	6.60	30.00	36.00
23	2.95	3.05	3.40	3.20	3.95	5.15	6.35	28.80	34.55
22	2.80	2.95	3.25	3.05	3.80	4.95	6.05	27.60	33.15
21	2.70	2.80	3.10	2.95	3.65	4.75	5.80	26.40	31.70
20	2.55	2.70	2.95	2.80	3.50	4.50	5.55	25.20	30.25
19	2.45	2.55	2.85	2.65	3.30	4.30	5.30	24.00	28.80
18	2.35	2.45	2.70	2.55	3.15	4.05	5.05	22.80	27.35
17	2.20	2.30	2.55	2.40	3.00	3.85	4.80	21.60	25.95
16	2.10	2.20	2.40	2.50	2.85	3.65	4.55	20.40	24.50
15	1.95	2.05	2.30	2.15	2.70	3.40	4.30	19.20	23.05
14	1.85	1.95	2.15	2.00	2.50	3.20	4.05	18.00	21.60
13	1.75	1.80	2.00	1.90	2.35	2.95	3.80	16.80	20.15
12	1.60	1.70	1.85	1.75	2.20	2.75	3.50	15.60	18.75
11	1.50	1.55	1.75	1.65	2.05	2.55	3.25	14.40	17.30
10	1.35	1.45	1.60	1.50	1.90	2.30	3.00	13.20	15.85
9	1.25	1.30	1.45	1.35	1.70	2.10	2.75	12.00	14.40
8	1.15	1.20	1.30	1.25	1.55	1.85	2.50	10.80	12.95
7	1.00	1.05	1.20	1.10	1.40	1.65	2.25	9.60	11.55
6	0.90	0.95	1.05	0.95	1.25	1.45	2.00	8.40	10.10
5	0.75	0.80	0.90	0.85	1.05	1.20	1.70	7.20	8.65
4	0.65	0.65	0.75	0.70	0.90	1.00	1.40	6.00	7.20

* Columns J to P give building loads in kip per sq. ft. of area supported by columns resting on subway as per Sect.23, while Cols. Q and R give additional loads in kip per lin. ft. for building walls supported by such exterior columns. In addition to these column concentrations, the subway shall be designed for the uniform loads specified in Sect.22 d and e). Height of each story assumed at 12 ft.

IV - LATERAL FORCES ON ELEVATED STRUCTURES

24. Wind Force shall be computed at 30 lb. per sq. ft. of vertical projection of exposed surface. For two and three track structures the exposed surface of 1 train, for four track structures that of 1-1/4 trains and for five track structures that of 1-1/2 trains shall be included. The wind force on trains shall be considered as applied 6 ft. above B. of R. Where wind screens at platforms are considered as part of the exposed surface, the wind force on one train shall be disregarded.

25. Tractive Force shall be taken at 200 lb. per lin. ft. of track for a length equal to the distance between expansion joints and shall be assumed to stress the columns resisting such tractive force in bending only. In structures supporting several tracks, the tractive force due to all the tracks shall be considered at express stations only. At local stations and between stations, consider force due to 1-2/3 track for a two track line, 2 tracks for a 3 track line and 2-1/3 track for a four track line. The force per column shall be taken as the total tractive force divided by the number of columns resisting it, except that where there is a considerable difference in the stiffness of columns, the force resisted by each column shall be assumed to be in proportion to its stiffness which is defined as moment of inertia divided by length.

26. Centrifugal Force. With proper superelevation, the centrifugal force shall be considered as stressing columns (in bending only), bracing and steel column bases, being assumed to act at the level of B.of R. In this case, only its horizontal effects need be considered.

Where no superelevation is provided, the centrifugal force shall be assumed to act 5 ft. above B. of R. and the resulting vertical forces shall be taken into account in designing stringers and columns.

In computing stresses, assume trains on all tracks and use the following formula:

$$F = CW \quad (2)$$

where: F = Centrifugal Force
C = Coefficient depending on degree of curvature, as per Table 7.
W = Weight of Train, assumed as 2 kip per lin.ft. of each track measured between centerlines of spans.

TABLE 7

Degree of Curvature	Radius in ft.	C	Degree of Curvature	Radius in ft.	C	Degree of Curvature	Radius in ft.	C
1	5730	.020	8	717	.120	15	383	.120
2	2865	.040	9	637	.126	16	359	.112
3	1910	.060	10	574	.130	17	338	.102
4	1433	.076	11	522	.132	18	320	.090
5	1146	.090	12	478	.132	19	303	.076
6	955	.102	13	442	.130	20	288	.060
7	819	.112	14	410	.126			

Centrifugal force shall be neglected for curves of less than 1 degree, while for curves exceeding 20 degrees, value of C shall be taken at .060.

27. Temperature. Provision shall be made in designing steel structures for a variation in temperature from -10 to +110 degrees Fahr., and in designing masonry structures, such as viaduct arches, for a variation from +20 to +80 degrees Fahr.

V - SIDE PRESSURE ON SUBWAYS

28. Side pressure, as considered in designing subway walls, is generally due to one or more of the following conditions:

- 1) Earth abutting against a vertical plane flush with back of wall.
- 2) Loads resting on abutting earth.
- 3) Water producing hydrostatic pressure.

The side pressure from the abutting earth per lin. ft. of wall is taken as that due to the earth contained within the triangular prism ABC (Fig. 3) one ft. long and bordered by the wall plane AB, a horizontal plane of loading BC, and a plane of rupture AC passing through the bottom of the wall span.

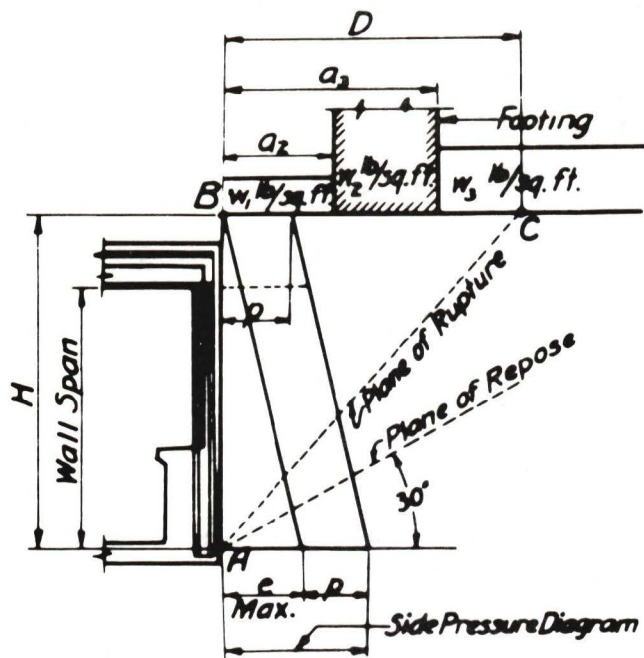


Figure 3

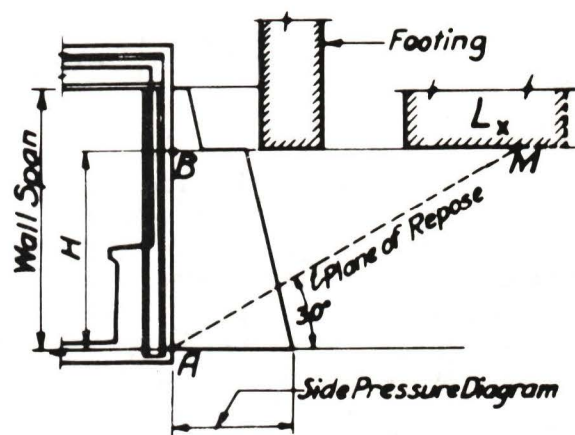


Figure 4

29. Notation (See Fig. 3)

- H = Height of prism - in ft.
- D = Width at top of prism - in ft.
- w = Any loading intensity ($w_1, w_2, \dots$) applied to top of prism - in lb. per sq. ft.
- a = Distance ($a_1, a_2, \dots$) from wall plane to corresponding loading intensity w - in ft.
- ΣP = Surcharge on prism (overlying earth, footings and other loads) - in lb.
- ΣQ = Surcharge within distance a - in lb.

e= Unit side pressure due to weight of prism (zero at top, maximum at bottom of prism) - in lb. per sq. ft.

p= Unit side pressure due to ΣP - in lb. per sq. ft.

30. The width D is a function of the properties of the soil and the amount and distribution of the surcharge. For the usual angle of repose of 30° with the horizontal:

$$D = .58H + \frac{wa - \Sigma Q}{w + 50H} \dots \dots \dots (3)$$

In doubtful cases, D shall be determined for each loading intensity within the plane of repose, the critical value of D being the one which gives the greatest side pressure as determined from Formulas (4) & (5). Where Formula (3) gives a value less than a , the corresponding D shall be taken as equal to a ; where it gives a value extending beyond the outer limit of the loading intensity w used, such value shall be disregarded.

$$e_{\max} = 100D \frac{H - .58D}{D + .58H} = 100DK \dots \dots \dots (4)$$

$$p = \frac{\Sigma P}{H} \frac{H - .58D}{D + .58H} = \frac{\Sigma P}{H} K \dots \dots \dots (5)$$

TABLE OF VALUES OF K

D/H	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.1	1.2	1.3
K	1.13	.94	.78	.66	.55	.46	.39	.32	.27	.22	.17	.13

31. The plane of loading BC (Fig. 3) shall be taken at the top of wall when the surcharge is uniform at this level, or where a footing is less than 1 ft. above or below it, the bottom of such footing being considered level with the top of wall. In this case, the values obtained from Formulas (4) and (5) represent the pressures against the wall.

In the cases where footings are higher or lower, the pressures against the wall are determined from the trapezoidal loading diagrams obtained for the plane of loading used. Where such plane is below the top of wall (Fig. 4) the pressure against the upper portion of the wall shall be de-

terminated from the loading conditions existing between the wall and the footing only.

Where a load L_x (Fig. 4), is intersected by the plane of repose AM , only the portion within the plane need be considered.

32. Some simple rules for the more frequent cases follow:

1) For a uniform surcharge, D shall be taken as $.58H$, giving for the side pressure the usual value of one-third the vertical pressure.

2) Where an upper wall or column is resting on a cantilevered roof beam (Fig. 5), Formula (3) is sufficiently approximated by:

$$D = a + .58H \dots \dots \dots (6)$$

3) Where the far face of an upper sidewall footing resting on soil is within a distance of $.58H$ of the lower wall (Fig. 6), D shall be determined from Formula (3).

4) Where the near face of an upper sidewall footing is more than $.58H$ from the lower wall (Fig. 7), the side pressure shall be computed for the two conditions, $D = a$ and $D = .58H$, and the larger pressure used.

5) Where an upper interior wall or column footing is resting on soil (Fig. 8), the side pressure shall generally be computed for $D = a$ only. However, when a exceeds H , the side pressure corresponding to $D = .58H$ shall also be determined and the larger pressure used.

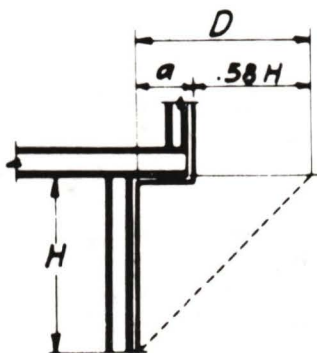


Figure 5

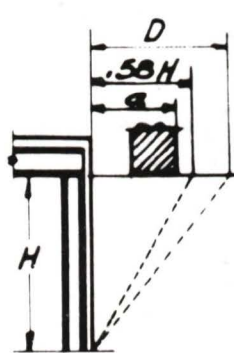


Figure 6

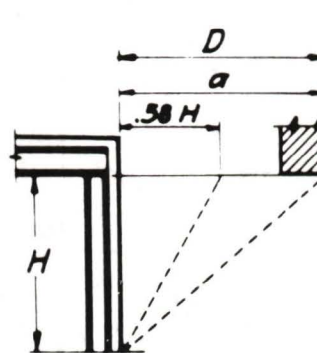


Figure 7

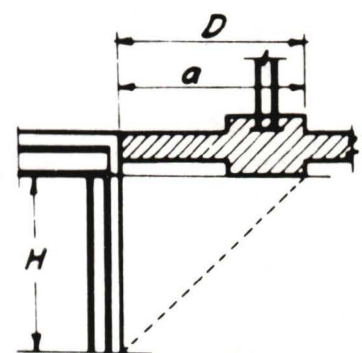


Figure 8

33. Overlying loads, when considered for side pressure, shall be treated as follows:

1) In computing loads from footings or earth, street live load shall not be included.

2) Loads from floors shall include live load. In the case of track floors, the live load shall be taken at 450 lb. per sq. ft. For other floors, see Sect. 19.

3) Where an overlying foundation is not continuous longitudinally, the load shall be considered distributed over a length of earth prism equal to the length of the foundation plus twice the transverse distance from net line of lower wall to the near edge of the foundation and treated as above. In no case, however, shall the increased length exceed the longitudinal distance between the centers of adjacent foundations.

34. For subway walls under or adjacent to buildings, the side pressure shall be computed from the ground or street surface, unless side pressure due to the buildings has to be provided for and is more severe.

35. For walls in earth near street surface, the side pressure shall at no point be taken at less than 200 lb. per sq. ft.

36. Side pressure due to water, if any, shall be added to that produced by earth and superimposed loads.

See also "Design of Sidewall Columns," pg. SD-5-1

37. In earth, where adjacent tracks are at different levels, the full thrust due to side pressure shall be considered transmitted through the roof and invert, except that where an invert includes one or more footings of intervening columns, the thrust at the invert is assumed to be taken up by the soil in friction.

In earth, where the active side pressures against opposite sides of a structure are unequal, the greater pressure shall be considered for both sides.

38. In rock, where an upper track floor projects beyond a lower wall, the side pressure shall be computed in accordance with the rules given in "Design of Sidewall Col." pg. SD-5-1, when track floor is sealed. When weep holes are provided in the track floor, the water level shall be taken at the upper Base of Rail.

VI - ECCENTRIC LOADING ON SIDEWALL COLUMNS

39. Sidewall columns designed in accordance with "Design of Sidewall Columns" shall also be investigated for the effects of eccentric loading as per Sects. 40 and 41.

40. In earth, with roof member bearing on inside flange of column, the sum of the stresses in the flange due to load and moment shall not exceed 20 kip per sq. in. (T.A. or Bldg. Code) the load to be taken as the end reaction including roof load directly over the column. The moment due to eccentricity shall be computed as load times:

- .5 column depth when roof member is a girder;
- .4 column depth when roof member is a beam with stiffeners;
- .3 column depth when roof member is a beam without stiffeners.

41. In earth, where eccentric steel cantilever footings are used, the sum of the stresses in the inside column flange due to direct load and eccentricity shall not exceed 25 or 20 kip per sq. in. (22 or 20 kip for Bldg. Code), according to whether or not the inside flange is embedded as per Sect. 47, 1, for a height of at least one-fourth the column span, the load to be taken as the full load carried by the column and wall. The moment shall be computed as load times the distance between centerline of column and center of footing.

VII - STRESSES

TABLE 8

42. ALLOWABLE UNIT STRESSES (T.A.) FOR STRUCTURAL STEEL
IN KIPS PER SQ. IN., EXCEPT AS NOTED

Nature of Stress	Subway Structures & Transit Buildings	Elevated Structures
(a) <u>Tension</u> , net section:	20	20
(b) <u>Compression</u> :		
Members in which $L/r \leq 3$	20	20
Columns	$17 - .000485 \frac{L^2}{r^2}$	$18.5 - 0.09 \frac{L}{r}$ (not to exceed 15)
Secondary Members	$1 + \frac{18000}{L^2}$	
Webs of Rolled Sections at	$1 + \frac{18000}{r^2}$	
Toe of Fillet	24	
(Beams not imbedded in concrete shall be investigated for crippling.)		
(c) <u>Bending</u> , extreme fibre:		
Compression or Tension,		
gross area	20	
Tension, net area		20
For composite construction, see Sect. 47.		
Pins & Turned Bolts	30	30
(d) <u>Shearing</u> :		
Webs, gross section	13	12.5
Rivets (By Direct-acting Riveting)	15	15
Rivets (By Power Hammer Riveting)	12.5	12.5
Pins & Turned Bolts	15	15
Unfinished Bolts	10	

TABLE 8 (CONTINUED)

Nature of Stress	Subway Structures & Transit Buildings	Elevated Structures
(e) <u>Bearing:</u>		
Contact area of rolled surfaces	24	20
Contact area of milled surfaces	30	20
Contact area of rolled & milled surfaces	27	20
Pins		30
Rivets (By Direct-acting Riveting) & Turned Bolts:		
Double Shear	40	30
Single Shear	32	30
Rivets (By Power Hammer Riveting)	27	25
Unfinished Bolts:		
Double Shear	25	
Single Shear	20	
Rollers, kips per lin. in.: . . .		0.75d

The value of L/r shall not exceed the following:

In Subway Structures 120 for main members and 150 for secondary members.

In Elevated Structures 100 for main members and 150 for secondary members.

L = Unbraced length of member in inches.

r = Governing radius of gyration of member in inches.

d = Diameter of roller in inches.

TABLE 9

ALLOWABLE UNIT STRESS (TA) FOR COMPRESSION
MEMBERS IN KIP PER SQ. IN. (SEE SECT. 42)

$\frac{L}{r}$	$17.000485 \frac{L^2}{r^2}$	$18.5-.09 \frac{L}{r}$	$\frac{L}{r}$	$17.000485 \frac{L^2}{r^2}$	$18.5-.09 \frac{L}{r}$
3 or less	20.00	20.00	68	14.76	12.38
4	16.99	15.00	70	14.62	12.20
6	16.98	15.00	72	14.49	12.02
8	16.97	15.00	74	14.34	11.84
10	16.95	15.00	76	14.20	11.66
12	16.93	15.00	78	14.05	11.48
14	16.91	15.00	80	13.90	11.30
16	16.88	15.00	82	13.74	11.12
18	16.84	15.00	84	13.58	10.94
20	16.81	15.00	86	13.41	10.76
22	16.77	15.00	88	13.24	10.58
24	16.72	15.00	90	13.07	10.40
26	16.67	15.00	92	12.90	10.22
28	16.62	15.00	94	12.72	10.04
30	16.56	15.00	96	12.53	9.86
32	16.50	15.00	98	12.34	9.68
34	16.44	15.00	100	12.15	9.50
36	16.37	15.00	102	11.95	9.32
38	16.30	15.00	104	11.75	9.14
40	16.22	14.90	106	11.55	8.96
42	16.14	14.72	108	11.34	8.78
44	16.06	14.54	110	11.13	8.60
46	15.97	14.36	112	10.92	8.42
48	15.88	14.18	114	10.70	8.24
50	15.79	14.00	116	10.47	8.06
52	15.69	13.82	118	10.25	7.88
54	15.59	13.64	120	10.02	7.70
56	15.48	13.46	125		7.25
58	15.37	13.28	130		6.80
60	15.25	13.10	135		6.35
62	15.14	12.92	140		5.90
64	15.01	12.74	145		5.45
66	14.99	12.56	150		5.00

TABLE 10

ALLOWABLE UNIT BENDING STRESS (TA)
IN COMPRESSION FLANGES FOR BEAMS AND GIRDERS
IN KIP PER SQ. IN. (SEE SECT. 48)

$\frac{L}{W}$	$f_c^I = 25 - .31 \frac{L}{W}$
16	20.00
18	19.42
20	18.80
22	18.18
24	17.56
26	16.94
28	16.32

$\frac{L}{W}$	$f_c^I = 25 - .31 \frac{L}{W}$
30	15.70
32	15.08
34	14.46
36	13.84
38	13.22
40	12.60
42	11.98

43. For temporary work, use stresses given in "Field Design Stds."

44. Holes filled with rivets as well as isolated holes up to 1 in. in diameter for tie rods and the like, are not considered as reducing the web section for resisting shear.

45. At copings and re-entrant cuts, the allowable stress per sq. in. is reduced to 10 kip for shear on net section and 15 kip for bending, but such details shall not be resorted to unless unavoidable.

46. Where the subway structure takes building load, it shall be designed in accordance with Building Code stresses, unless those of the T.A. are lower.

47. Composite Construction. Where concrete may be counted on to act integrally with the steel, an equivalent design bending stress for Structural Steel may be taken as 25 kip per sq. in., in lieu of an analysis of the composite section. Except as noted in (a) to (d) below this applies to:

(1) Beams and girders having their compression flange embedded in a flat slab which extends in depth at least $1/3$ the distance to the extreme tension fibre, and in width at least $1/2$ of the depth of the member beyond both flange edges.

(2) Beams and girders encased between subway roof arches.

(3) Longitudinal mezzanine and platform roof members with other members framed into them on both sides and having their compression flange embedded in concrete for a width as specified in Subsect. (1) above.

No increase in bending stress beyond 20 kip per sq. in. shall be allowed for:

- (a) Roof members located between building lines of intersecting streets where top of subway roof is less than 7 ft. below street surface, so as to provide for present or future depressed bay construction.
- (b) Members placed closer center to center than the sum of depth and flange width.
- (c) Members having a nominal depth exceeding 36 in.
- (d) Rectangular sections stressed in shear and bending, such as web plates extended longitudinally beyond flanges of girders.

When special steels are substituted for structural steel, an analysis of the composite section shall be made.

48. Where the unbraced length of the compression flange of beams and girders stressed in bending exceeds 16 times its width, the allowable compressive stress (T.A.) shall be reduced in accordance with the formula:

$$f'_c = 25 - .3L/w \quad (7)$$

where: f'_c = Allowable unit stress in kip per sq.in. (See Table 10.)

L = Unbraced length of flange in inches.

w = Width of flange in inches.

49. For beams and girders, where the ratio of span to depth exceeds the value k , as given below, the allowable bending stress shall be reduced in accordance with the following formula: $f' = fk \frac{d}{L}$ (8)

where: f' = Reduced bending stress.
 f = Bending stress as given in Sects. 42, 47 or 48.
 k = Constant, having the value 12 for members supporting tracks, and the value 20 for other members.
 d = Depth of the member in in.
 L = Length of span in in.

TABLE 11

50.
ALLOWABLE UNIT STRESSES FOR TIMBER IN LB. PER SQ. INCH

Nature of Stress	Long Leaf Pine, Fir	Short Leaf Pine	White Pine, Spruce	White Oak
Bending, extreme fibre	1600	1250	1250	1400
Compression:				
Parallel to grain				
for $L/d > 15$	$1600(1 - \frac{L}{60d})$	$1250(1 - \frac{L}{60d})$	$1250(1 - \frac{L}{60d})$	$1600(1 - \frac{L}{60d})$
for $L/d \leq 15$	1200	940	940	1200
Perpendicular to grain	320	200	200	560
Shear	150	150	90	140
Modulus of Elasticity*	1500000	1500000	1200000	1200000

where: L = Length of member in in.

d = Least side or diameter in in.

*For long continued loading, the Modulus of Elasticity decreases to one-half the values given above.

The stresses given are for green timber and shall be used without increase of live load stresses for impact.

When members are designed to take shear with the grain, selected timber shall be used. Shearing stresses given above apply also in this case.

For buildings and similar structures in which the timber is protected from weather and practically free from impact, the stresses given above shall be increased 25 per cent.

For railroad bridges and trestles, the unit stresses shall conform to the requirements of the railroad company concerned, provided those of the T.A. are not more severe.

51.

TABLE 12

ALLOWABLE BEARING VALUES (T.A.) FOR MASONRY

Material	Kip per sq.ft.	lb. per sq. in.
Stone Concrete, 1:2:4 mix	108 (70)	750 (500)
Granite, single block centrally loaded	100 (70)	700 (500)
Granite cut stone masonry	80 (57)	550 (400)
Limestone cut stone masonry	60 (43)	420 (300)
Brick or Sandstone cut stone masonry	40 (30)	280 (200)

For bearing under steel slabs, bed plates and wide flange beams, use figures shown in brackets.

52.

TABLE 13

ALLOWABLE BEARING VALUES (T.A.) FOR SOILS

Nature of Soil	Kip per sq. ft.
Sound Ledge Rock	60 to 150
Hardpan or Compact Gravel	20
Coarse Sand or Gravel	12
Clean Sand or Dry Clay	8
Clay, moist (Value subject to test)	Up to 4

These values are for most favorable conditions; for questionable soils they shall be reduced.

VIII - COMBINED STRESSES

53. Interior subway columns, where compression and bending due to side thrust are combined, the allowable bending stress shall be determined by the formula:

$$f'_b = 20 - \frac{P}{A} \frac{20}{f'_d} \dots \dots \dots (9)$$

where: f'_b = Allowable bending stress in kip per sq. in.
 f'_d = Allowable direct load stress in kip per sq. in. as per column formula Sect. 42b.

P = Direct load in kip. A = Area of column section in sq. in.

Effects of eccentric loading on interior columns may be disregarded.

54. For subway sidewall columns stressed in bending and compression, see "Design of Sidewall Columns," and Sects. 39 to 41.

55. Compression due to side pressure shall be neglected in designing subway roof and invert members, but shall be considered for intermediate floor beams which shall be designed as follows:

When the requirements of Sect. 47, 1 or 2, are fulfilled, assume one-half the direct side pressure as being taken by the beams and allow a combined bending and direct stress of 25 kip per sq. in. In all other cases, assume beams to take full side pressure and allow a combined stress of 20 kip per sq. in. (See also Sect. 49.)

Chapter 4

Chapter 4

Chapter 4

DETAILS OF DESIGN FOR STRUCTURAL STEEL

TABLE OF CONTENTS

I DETERMINATE DESIGN - - - - -	SD-4-1
II MINIMUM THICKNESS OF METAL - - - - -	SD-4-1
III OPEN DETAILS - - - - -	SD-4-1
IV STRENGTH OF DETAILS - - - - -	SD-4-1
V SPANS FOR CALCULATION - - - - -	SD-4-1
VI DEPTH RATIOS FOR BEAMS AND GIRDERS - - - - -	SD-4-2
VII PLATE GIRDERS - - - - -	SD-4-2
VIII BUILT-UP SECTIONS OTHER THAN PLATE GIRDERS ---	SD-4-6
IX LATTICING AND STAY PLATES - - - - -	SD-4-6
X NET SECTIONS - - - - -	SD-4-7
XI EFFECTIVE SECTIONS OF ANGLES IN TENSION - - - - -	SD-4-7
XII ECCENTRIC CONNECTIONS - - - - -	SD-4-7
XIII ABUTTING COMPRESSION MEMBERS - - - - -	SD-4-8
XIV DIMENSIONS AND PLACING OF RIVETS - - - - -	SD-4-8
XV WELDING - - - - -	SD-4-9
XVI BEARING AT SUPPORTS - - - - -	SD-4-10

XVII STIFFENERS ON BEAMS - - - - -	SD-4-13
XVIII STIFFENERS ON PLATE GIRDERS - - - - -	SD-4-14
XIX SUBWAY COLUMN DETAILS - - - - -	SD-4-15
XX MISCELLANEOUS - - - - -	SD-4-17

Chapter 4

DETAILS OF DESIGN FOR STRUCTURAL STEEL

I DETERMINATE DESIGN

1. The structure shall preferably be so designed that stresses may be calculated directly.

II MINIMUM THICKNESS OF METAL

2. In general, no material of less than $3/8$ in. thickness shall be used in main members, except as fillers. This limitation does not apply to rolled beams and channels, nor to canopies of elevated stations, for which the minimum thickness of material shall be $1/4$ in.

III OPEN DETAILS

3. Details shall be designed so as to give free access for inspection and painting. Waterpockets shall be avoided.

IV STRENGTH OF DETAILS

4. The connections and other details of a member shall be of at least sufficient strength to resist the forces acting thereon.

V SPANS FOR CALCULATION

5. The spans assumed for calculation shall be as follows:

Subway Structures:

For beams and girders with framed end connections, clear distance between supports.

For beams and girders with bearing ends, clear distance between supports plus 3 in.

For beams on bed plates, distance between centers of plates.

Elevated Structures:

For cross girders, distance between centers of columns.

For stringers, distance between centers of cross girders.

For floor beams, distance between centers of stringers.

VI DEPTH RATIOS FOR BEAMS AND GIRDERS

6. The depth of beams and girders shall generally be not less than $1/12$ of the span for members supporting tracks, and not less than $1/20$ of the span for other members. See "Loads and Stresses", Sect. 49.

VII PLATE GIRDERS

7. Make-up of Flange Cover plates shall not be used unless angles of more than $7/8$ in. thickness would be required. When cover plates are used the thickness of flange angles shall preferably not exceed $5/8$ in., except when the gross section of the cover plates would exceed one-half the gross section of the flange. The gross section of the compression flange shall be not less than that of the tension flange.

8. SECTION MODULUS OF GIRDERS
WITH OR WITHOUT COVER PLATES

Notation:

A	=	Area of two angles, with one or two rivet holes per angle deducted (See Sect. 21), - in sq. in.
a	=	Area of top or bottom cover plate, with two rivet holes per plate deducted, - in sq. in.
h	=	Depth of web - Nominal depth of girder, - in inches.
d	=	Distance between centers of gravity of angles, - in inches.

d_1 = Distance from back to back of angles - nominal depth of girder plus 1/2 in. - in inches.
 S_a = Section Modulus of four angles - in in.³
 S_c = Section Modulus of cover plates (top and bottom), - in in.³
 S_w = Equivalent Section Modulus of web, - in in.³
 t = Thickness of web in inches.

Values: $S_a = \frac{Ad^2}{d_1} \quad (1)$

$S_c = ad_1 \quad (2)$

$S_w = \frac{th}{8}(h-3) \dots (See Sect. 10) \quad (3)$

9. Splicing of Flange Flange members, when spliced, shall be covered by extra material at least equal in section to the member spliced. There shall be enough rivets on each side of the splice to develop the strength of the member.

Flange angles shall generally be spliced with angles.

Splices shall preferably be located at points where there is an excess of material. Where practicable, no two component parts of a girder shall be spliced at the same cross section.

10. Web for Flange Area In computing the bending strength of plate girders, one-eighth of the gross web section shall be counted as additional flange area, as per Sect. , when the web is in one piece or is spliced for bending. No such allowance shall be made when web is spliced for shear only.

11. Splicing of Web Web splices shall consist of one or more plates riveted on each side of the girder, the strength of plates and rivets to be sufficient to resist the shear and generally also the moment acting at the splice.

12. Length of Cover Plates Cover plates shall be extended beyond their theoretical ends to permit placing of additional rivets in accordance with Sect. 16 .

Where cover plates are used, at least one upper cover plate shall extend from end to end of girder except when encased in concrete or protected against moisture.

In open track floors of elevated structures where cover plates are required on track stringers, the upper cover plates shall all extend the full length of the stringer, and the uppermost cover plate shall be set the required distance below the Base of Rail. The thickness of this cover plate shall be not less than $5/8$ in., and the rivets passing through it shall be countersunk at the top.

13. Thickness of Cover Plates Cover plates shall be of equal thickness or shall diminish in thickness from the flange angles outward, but no one plate shall have a thickness greater than that of the flange angles, except as noted in Sect. 12.

14. The Cross Section of the Cover Plates in each flange shall preferably form not more than one-half and in no case more than two-thirds of the gross section of the flange.

15. Flange Rivets through Web The flanges shall be connected to the web with enough rivets to transfer the stress due to longitudinal shear as well as that due to loads supported by the flanges. When ties rest directly on the upper flange of elevated railway stringers, each wheel load, properly increased for impact, shall be considered distributed over a track length of 5 ft.

Load transmitted through arch action is not considered as producing vertical stress in the flange rivets of plate girders.

16. Spacing of Flange Rivets (See also Sect. 27).

Notation: n = Number of rivets required between theoretical and actual end of cover plate (not to be less than four.)
 A = Net area of one entire flange at section considered, not including web, - in sq. in.
 A_1 = Net area of one flange (generally including $1/8$ web) inside of the cover plate for which n is desired, - in sq. in.
 a = Net area of all the cover plates of one flange at section considered, - in sq. in.

- α = Net area of the cover plate for which n is desired, - in sq. in.
 Δ = $1/8$ of web area if counted on to resist bending, - in sq. in.
 d = Distance between centers of gravity of angles, - in inches.
 f = Allowable unit bending stress, - in kip per sq. in.
 r = Bearing or shearing value of one rivet (single shear in case of cover plates), - in kip.
 V = Total transverse shear at section considered, - in kip.
 w = Load applied directly to flange, - in kip per lin. ft.
 p = Distance between rivets, assuming single gage lines in legs of angles, - in inches.

Values:

Rivets Connecting Flange Angles to Web

For longitudinal shear only:

$$p = \frac{rd}{V} \left(\frac{A + \Delta}{A} \right) \quad (4)$$

For longitudinal shear and load w applied directly to flange (See Sect. 15):

$$p = \frac{r}{\sqrt{\left(\frac{V}{d} \cdot \frac{A}{A + \Delta} \right)^2 + \left(\frac{W}{12} \right)^2}} \quad (5)$$

Rivets Connecting Cover Plates to Flange Angles

Within theoretical length of cover plates

$$p = \frac{rd}{V} \left(\frac{A + \Delta}{a} \right) \quad (6)$$

Between theoretical and actual length of cover plates:

$$n = \frac{f A_1 \alpha}{r(A_1 + \alpha)} \quad (7)$$

17. Stiffeners Rules for stiffeners on plate girders are given in Sects. 42 to 47.

VIII BUILT-UP SECTIONS OTHER THAN PLATE GIRDERS

18. The Section Modulus of beams with cover plates and of other built-up sections, not including plate girders, shall be computed from the Moments of Inertia of the component parts. Cover plates for beams shall be designed in accordance with Sects.

IX LATTICING AND STAY PLATES

19. Lattice-bars of compression members shall be so spaced that the L/r of the portion of the flange included between the lattice-bar connections will not be greater than two-thirds of the L/r of the member, and in no case more than 40.

Single lattice-bars shall generally be inclined at an angle of sixty degrees to the axis of the member, and double lattice-bars at an angle of forty-five degrees, with a rivet at their intersection.

The latticing of compression members shall be proportioned to resist a shearing force normal to the member equal to 2 percent of the direct load.

Single lattice-bars shall have a thickness of not less than one-fortieth and double lattice-bars a thickness of not less than one-sixtieth of the distance between the rivets connecting them to the compression member, and their minimum width and end connections shall be as follows:

For	8" C's	rolled or built-up, use 2" bars with 1-5/8" rivet at each end
For	9" C's	rolled or built-up, use 2 1/2" bars with 1-3/4" rivet at each end
For	10" & 12" C's	rolled or built-up, use 3" bars with 1-3/4" rivet at each end
For	15" & 18" C's	rolled or built-up, use 3 1/2" bars with 1-7/8" rivet at each end

For types of latticed sections, see Fig. 1.



Figure 1

20. The latticed sides of main compression members shall be provided with stay-plates at the ends and at any intermediate point where the latticing is interrupted.

The length of end stay-plates shall be not less than $1 \frac{1}{4}$ times the distance between the lines of rivets connecting them to the outer flanges, and the length of intermediate stay-plates shall be not less than $\frac{3}{4}$ times that distance.

In tension members composed of shapes, the latter shall be connected by stay-plates, or by stay-plates and lattice-bars.

Stay-plates are generally not required in secondary members.

X NET SECTIONS

21. Tension members shall be designed for their net section, except as noted in Sect. 22, rivet holes being taken as $\frac{1}{8}$ in. larger than the nominal diameter of the rivet.

Where rivets are staggered the net section of tension members shall be the smallest area which can be obtained in a straight or zig-zag line across the member, the net area of diagonal sections between rivet holes being counted at $\frac{3}{4}$ their value.

In no case shall a deduction be made for more than one hole in each leg of plate girder flange angles, tests having shown that plate girders usually fail by buckling of the compression flange.

XI EFFECTIVE SECTIONS OF ANGLES IN TENSION

22. In tension members, the effective section of an angle when connected at its end by one leg only, shall be assumed as the net section of the connected leg plus one-half that of the unconnected leg.

When the angle is connected by both legs, the effective section shall be assumed as the next section of the angle.

XII ECCENTRIC CONNECTIONS

23. Where eccentric connections are used, provision shall be made for the additional stresses produced in the member and its details.

Exception is made for standard stiffener and connection angles on beams and girders, where eccentricity shall not be considered.

XIII ABUTTING COMPRESSION MEMBERS

24. Abutting members subject to compression only, when faced for bearing and supported against lateral deflection within 18 in. of abutting ends, shall be connected with four or more rivets to hold the abutting parts securely in place. When faced for bearing and not thus supported against lateral deflection, such members shall be spliced on four sides for 50 percent of full strength. Abutting members not faced for bearing shall be spliced for full strength.

XIV DIMENSIONS AND PLACING OF RIVETS

25. Rivet Diameter In proportioning rivets, the nominal diameter of the rivet shall be used. Rivets shall generally be $7/8$ in. in diameter.

26. Rivet Grip If the grip of rivets carrying calculated stress exceeds 5 times the diameter of the rivet, the number of rivets shall be increased at least one percent for each additional $1/16$ in. of grip. Where the grip would exceed 6 times the diameter, rivets of larger size shall be used.

27. Rivet Spacing The distance center to center of rivets shall be not less than three diameters when holes are sub-punched and reamed or drilled from the solid, and not less than three diameters plus $1/4$ in. when holes are punched full size, except that when $7/8$ in. rivets are used with 6 in. stiffener or connection angles, the gage may be made $2\ 1/4$ in. from back of angle and $2\ 1/2$ in. between rivet lines and the rivets placed $2\ 1/2$ in. center to center both between and in the flange angles. (See General Contract Provisions.)

In the direction of stress, rivets shall be spaced not farther apart than 16 times the thickness of the thinnest plate connected, nor more than 30 times that thickness at right angles to the direction of stress. However, in no case shall the spacing of rivets in the direction of stress exceed 6 in.

When two or more plates are in contact and riveted for compactness, the stitch rivets shall be not farther apart in any direction than 24 times the thickness of the thinnest plate connected.

At the ends of compression members, the spacing of rivets in the direction of stress shall not exceed 4 times the diameter of rivet for a distance equal to the width of the member.

28. Edge Distance of Rivets The minimum distance from center of rivet to a rolled or finished edge shall be $1\frac{1}{2}$ times the diameter of the rivet, and to a sheared edge $\frac{1}{8}$ in. more, except that in flanges of beams and channels the gages given in the steel handbooks shall be used.

The distance from center of rivet to the edge of a plate shall not exceed 8 times the thickness of the plate.

29. Rivets through Fillers shall be considered only 75 percent effective in shear, unless each filler is extended for direct riveting by at least one-third the number of such rivets. (See Sect. 56.)

30. Use of Field Rivets The number of field rivets shall be reduced to a minimum.

31. Use of Unfinished Bolts Unfinished bolts may be used for connecting base plates to grillages where difficulty in riveting is encountered, provided the bolts will not be subject to calculated stresses.

32. Bearing Area of Pins, Bolts and Rivets The effective bearing area of pins, turned bolts and rivets shall be taken as their diameter multiplied by the length in bearing. For countersunk rivets, the length in bearing shall be considered reduced by one-fourth the rivet diameter if countersunk on one side, and by one-half the rivet diameter if countersunk on both sides.

XV WELDING

33. (a) Shop welding is permitted except for:

- (1) Members or connections for elevated structures.
- (2) Members or connections subjected to impact or fatigue loading, e.g., subway track floor.

(b) Field welding of buildings is permitted, e.g., bus garages and above ground substations. (Design to be based on the structural specifics and economics of each situation.)

- (c) Field welding of subway or below ground structures is not permitted unless approved by the Civil Engineering and Architectural Division, and is prohibited where shop welding is not permitted.

34. The welding portions of the following Specifications are to be used:

- (a) Subway and Below Ground Structures

American Railway Engineering Association (AREA) Specifications, 1970, for subway and below ground structures.

- (b) Buildings

American Institute of Steel Construction Specifications (AISC), 1963, for buildings.

XVI BEARING AT SUPPORTS

35. Only such part of bearing area shall be considered effective as is located within lines drawn at forty-five degrees through the edges of the supports (see pp. SD-4-11 and SD-4-12.) At sidewall columns supporting beams, the inner 6 in. of the column depth shall be considered in contact with the beam; at interior columns, the full depth under the beam shall be thus considered.

36. At sidewall columns supporting beams, if the bearing area as determined from Sect. 35 is deficient, stiffeners shall be provided on the beam. Where sidewall columns support plate girders, cap plates 3/4 in. in thickness shall be used.

37. At interior columns, where a welded cap plate is used for connecting column to roof members, the plate shall have a thickness of 3/4 in. when supporting a plate girder and at least 1/2 in. when supporting a beam. In the latter case the thickness may be varied up to 2 1/2 in. as required for bearing. If sufficient bearing area cannot be thus obtained, stiffeners shall be used on the beam, with cap plate 1/2 in. thick.

Where the reaction from one span is more than twice that from the other span, the beam or plate girder producing the heavier reaction shall extend over the full depth of the column section.

**DISTRIBUTION OF LOADING AT SUBWAY ROOF SUPPORTS
AND FORMULAS FOR BEARING AND SHEAR VALUES.**
Dimensions in in. Bearing and Shear Values in kip.

FIG. 2 	BEAM	Bearing = $24 t_b (6+2k)$ Shear = $13 \frac{t_b}{2}$
	COL.	Bearing = $27 [(6-t_f) t_c + (2+0.0145 W_b) t_f]$ W_b = Weight of beam-in lb. per lin. ft.
FIG. 3 	BEAM	Bearing = $24 t_b (6+2k)$ + value of stiff's, (but not to exceed beam shear). Shear = $13 t_b D_b$
	COL.	Bearing = $27 [F t_f + (6-t_f) t_c]$
	2-STIFF.	Bearing = $2 \times 27 A \frac{t_s}{2}$ or value of rivets, whichever is less
FIG. 4 	BEAM	Bearing = $24 t_b (e+cp+k)$ Shear = $13 t_b D_b$
	COL.	Bearing = $27 [(e-t_f) t_c + (2cp+2+0.0145 W_b) t_f]$
FIG. 5 	BEAM	Bearing = $24 t_b (e+\frac{1}{2}+k)$ + value of stiff's, (but not to exceed beam shear). Shear = $13 t_b D_b$
	COL.	Bearing = $3.97 W_c = 27 (\frac{1}{2} \text{ Area of column})$ W_c = Weight of column-in lb. per lin. ft.
	2-STIFF.	Bearing = $2 \times 27 A \frac{t_s}{2}$ or value of rivets, whichever is less.
FIG. 6 	BEAM	Bearing = $24 t_b (D_c+\frac{1}{2}+k)$ + $1 \frac{1}{2} \times$ Value of Inside Stiff's. Shear = $13 t_b D_b$
	COL.	Bearing = $4.85 W_c$ (for $16.5 \times$ area of column) but not to exceed column formula value.
	2-STIFF.	Bearing = $2 \times 27 A \frac{t_s}{2}$ or value of rivets, whichever is less.

ROOF GIRDER ON SIDEWALL COLUMN.

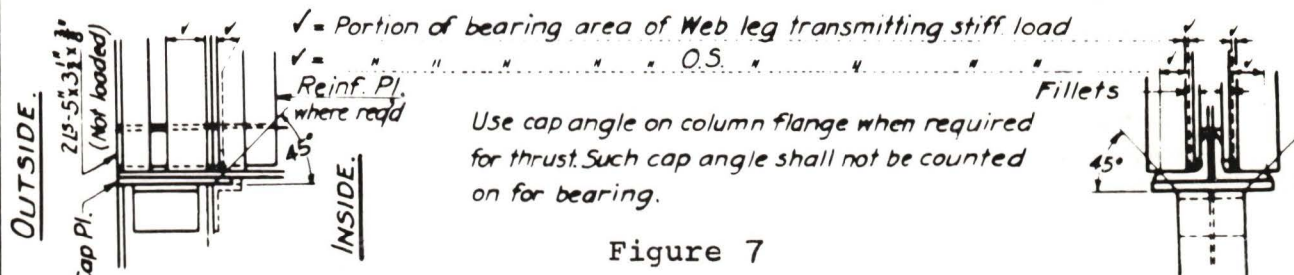


Figure 7

GIRDER EXTENDING OVER INTERIOR COLUMN.

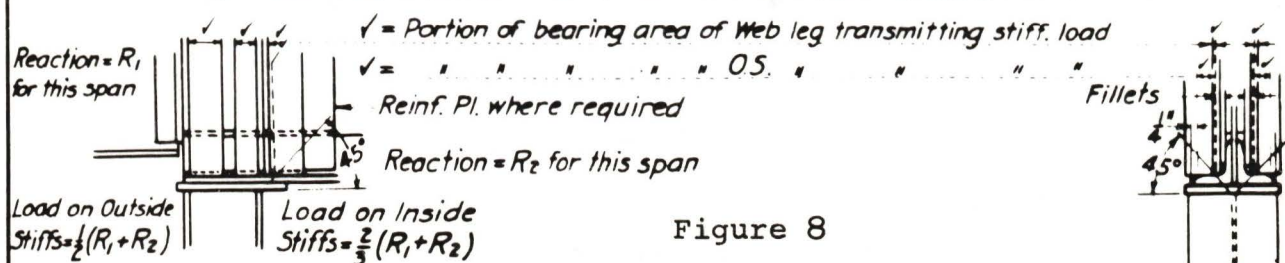


Figure 8

**DISTRIBUTION OF LOADING AT INTERMEDIATE FLOOR AND
INVERT SUPPORTS, AND FORMULAS FOR BEARING VALUES OF
BEAMS AT TRANSVERSE BEAM SUPPORTS.**

Dimensions in in. Loads and Bearing Values in kip.

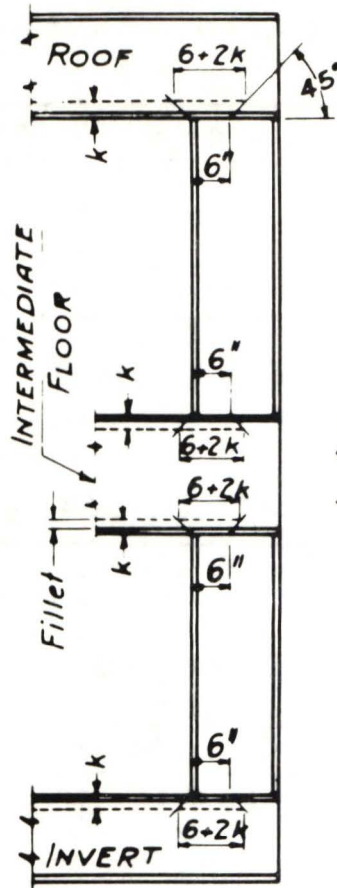


Figure 9

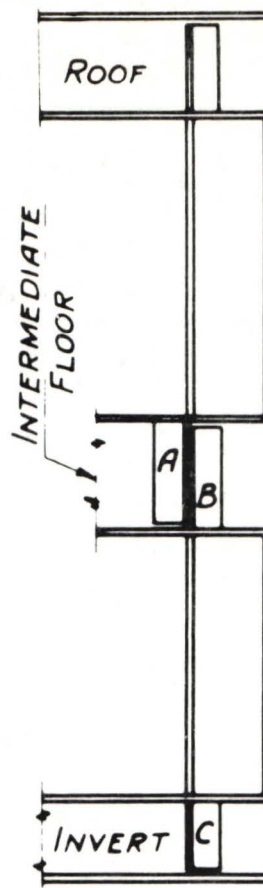


Figure 10

STIFFENER LOADS
(Use the larger value)

$$\text{Stiff. A} = \begin{cases} (R - B_b) \\ (R - B_c) \end{cases}$$

$$\text{Stiff. B} = \begin{cases} (P - B_b) \\ (P - B_c) \end{cases}$$

$$\text{Stiff. C} = \begin{cases} (P - B_b) \\ (P - B_c) \end{cases}$$

NOTES.

R = Load on upper column = Reaction of roof beam, considering load to back of column.

P = Load on lower column = R + Reaction from intermediate floor.

B_b = Bearing value of beam.

B_c = Bearing value of column (No stiffeners on beam).

Formulas for B_b and B_c are given on page D9

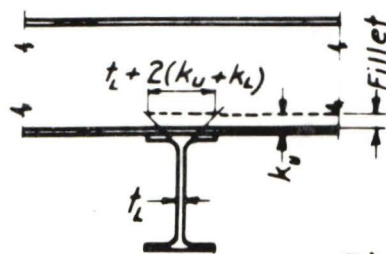
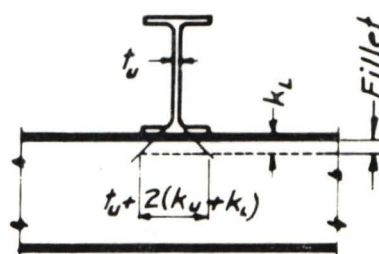


Figure 11



$$\text{Bearing Value of upper beam} = 24 t_u [t_l + 2(k_u + k_l)]$$

$$\text{Bearing Value of lower beam} = 24 t_l [t_u + 2(k_u + k_l)]$$

38. In considering bearing of columns on invert beams or plate girders, rules similar to those for columns supporting beams or plate girders shall apply.

39. For intermediate floor beams, the distribution of load to be assumed at sidewall columns is shown on page SD-4-12.

XVII STIFFENERS ON BEAMS

40. Stiffeners on beams shall be designed for the difference between the load transmitted (see "Loads and Stresses," Sect.14) and the bearing value of the beam web or column, whichever is less.

Where a beam is extended over the full depth of an interior column to support a beam from an adjacent span (Fig. 6, pg. SD-4-11), the inside and outside stiffeners, if such are required on the supporting beam, shall be proportioned, respectively, for two-thirds and one-half of the column load after deducting bearing value of beam web or column, whichever is less.

41. Stiffeners on beams shall be finished at bearing end. The non-bearing end may be cut back 1 in. from inside of flange to allow space for drift pin. On account of minor variations in the distance between flanges, it is impracticable to fabricate stiffeners on beams so that they will bear at both ends. To meet this condition, two stiffeners may be used as shown in Fig.10 , page SD-4-12.

The outstanding leg of stiffener angles, when exposed, shall extend as nearly as practicable to the edge of the flange. When encased in concrete, it shall be at least 1/2 in. inside of the flange edge. The web leg shall generally be not less than 3 1/2 in.

The thickness of stiffener angles shall be in multiples of 1/8 in., with a minimum of 3/8 in.

Rivets in web leg of stiffener angles shall be computed for vertical shear only (See Sec.23). For rivet spacing in 6 in. web leg, see Sect. 27.

Where interior columns are less than 8 in. deep or where splice plates are used on roof beams over a column, the web legs of stiffener angles shall point toward the center of span.

XVIII STIFFENERS ON PLATE GIRDERS

42. Stiffeners shall be provided at points of concentrated loading, including reaction points, at web splices and at free end or ends of girders.

When the web thickness of a girder is less than $1/50$ of the unsupported distance between flange angles, intermediate stiffeners, usually $5 \times 3 \frac{1}{2} \times 3/8$ angles, shall be riveted on both sides of the web. The distance center to center of such stiffeners shall generally not exceed the full depth of the web but shall in no case be less than 4 ft. nor more than 6 ft.

43. At sidewall columns the inside stiffeners on the girder shall be designed for the full girder reaction. End stiffeners shall be $5 \times 3 \frac{1}{2} \times 3/8$ angles.

44. At interior columns, where each girder is extended over one-half the column depth, stiffeners shall be provided on each girder to transmit its full end reaction.

Where a girder is extended over the full depth of an interior column to support a beam or girder from the adjacent span, the inside and outside stiffeners shall be proportioned, respectively, for two-thirds and one-half of the total column load.

45. At intermediate floor girders, the stiffeners over the lower columns shall be designed in accordance with Sects. 43 and 44.

Where an upper column rests on the top flange of the girder and is vertically aligned with the lower column, the stiffeners shall be designed for the combined column and intermediate floor load in bearing, web rivets, however, being provided only for the intermediate floor load.

The load of an upper sidewall column resting on a girder is assumed to be taken by the inside stiffeners (see page SD-4-12), that of an upper interior column is assumed to be equally divided between the supporting stiffeners.

46. Bearing stiffeners on girders shall be finished at bearing ends and connected to the web by enough rivets to transmit the calculated load and shall not be crimped.

The outstanding leg of stiffener angles, when exposed, shall extend as nearly as practicable to the edge of the flange. When encased in concrete, it shall be at least $1/2$

inch inside of the flange edge. The web leg shall generally be not less than 3 1/2 inches.

The thickness of stiffener angles shall be in multiples of 1/8 inch, with a minimum of 3/8 in., and shall generally not exceed 5/8 in. Where two stiffeners of 5/8 in. thickness are insufficient, four angles may be used or, if this is impracticable, two angles with plates riveted to the outstanding legs. The thickness of stiffeners may be greater than 5/8 in. when the thickness of flange angles or web of a girder is such as to require sub-punching and reaming.

47. Stiffener rivets through fillers shall be considered only 75 percent effective in shear, except where fillers are extended for direct riveting (see Sec. 29), or where stiffeners are placed on top of web reinforcing plates, in which cases the full shearing value may be allowed. When the web is less than 9/16 in. thick, the bearing value of the rivets may govern, 9/16 in. being the bearing thickness which is equivalent to 75 percent of double rivet shear.

Stiffener rivets through flange angles shall not be counted on as transmitting load to web, except where stiffeners are placed on top of web reinforcing plates, in which case the full shearing value of the rivets may be allowed. Short web reinforcing plates may be added under stiffeners where space available for stiffener rivets would otherwise be insufficient. (See Fig. 8 pg. SD-4-11).

XIX SUBWAY COLUMN DETAILS

48. For built-up columns, the distance back to back of angles shall be 1/4 in. greater than the nominal depth (width of web plate,) except for 6 in. columns when it shall be 1/2 in. greater.

49. In double deck structures, where an upper and lower interior column are vertically aligned, the lower column shall preferably be run through to the roof, or else be spliced to the upper column at the intermediate floor framing as shown in Fig. 12 (a, b & c).

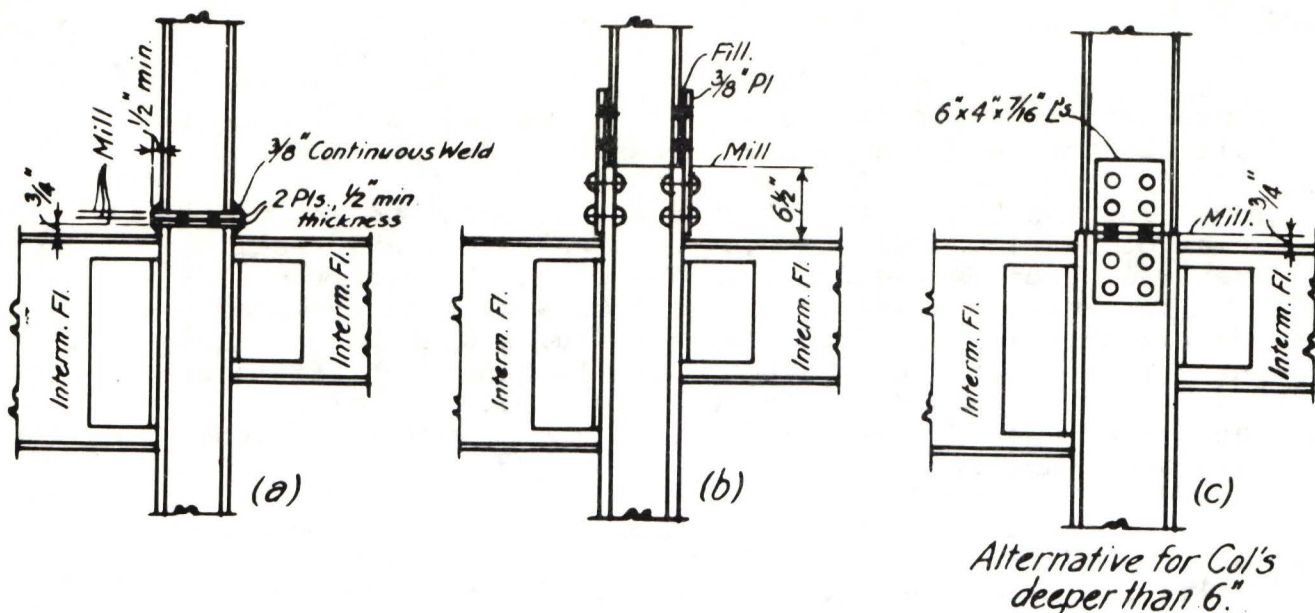


Figure 12

In the case of sidewall columns vertically aligned, where it is impracticable to transmit the load of the upper column through the intermediate floor beam, the columns may be spliced above the intermediate floor, the beam being connected to the lower column as shown in Fig. 13

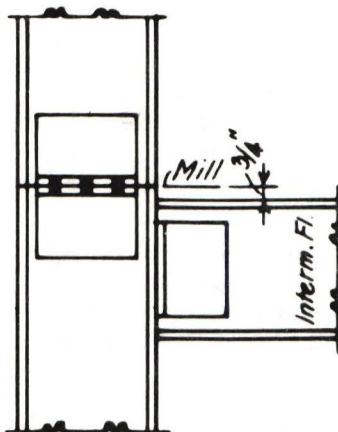


Figure 13

50. Where the track grade is 1/2 percent or less, longitudinal members shall be made level and stepped up at columns, except at mezzanine floors where the members shall follow the track grade.

Where the track grade exceeds 1/2 percent, longitudinal members shall always follow the track grade. Beveled cap plates may be used where it would otherwise be necessary to bevel the top of columns, or the columns may be run through and the longitudinal members shear-connected to them.

51. Cap and base angles, if used on columns shall generally be 7/16 in. thick.

Cap angles shall generally not be used on the web of an interior column 8 in. or less in depth where the superimposed beams are spliced at the center of column, nor on the flange of such column under a beam supported by a member extending across the column from an adjacent span.

Cap angles on web of sidewall columns shall connect roof member by at least four rivets for 8 in. and 10 in. columns, and by at least six rivets for 12 in. columns and over. Such angles shall not be counted on for bearing.

Cap angles on inside flange of sidewall columns shall be used only where required to provide additional rivets for resisting side pressure. Where a sufficient number of 7/8 in. rivets cannot be provided in the angles connecting a column web to a beam, 1 in. rivets shall be tried before resorting to a cap angle on the column flange.

The length of cap angles on column flanges shall, if possible, not exceed the width of beam or column flange, whichever is less. Base angles on column flanges may extend beyond the flange if embedded in concrete.

52. Bearing plates shall not be riveted to the flanges of interior columns supporting beams or girders for the purpose of increasing the bearing area at the support, such plates being either uneconomical or ineffective.

XX MISCELLANEOUS

53. Universal Mill Plates shall be used for cover plates and for cap and base plates where feasible, to eliminate shop planing of edges and to insure full bearing where required.

54. Copings and Re-entrant Cuts shall not be resorted to unless unavoidable (See "Loads & Stresses," Sect. 45). In any case they shall be rounded.

55. Web Reinforcing Plates on Beams are not permitted.

56. In Plate Girders, the total number of rivets through fillers or web reinforcing plates shall be at least equal to the reaction divided by the web bearing value of one rivet. (Sections 29 & 47).

57. Specifications for Drilling, Subpunching & Reaming If the thickness of the material is not greater than the nominal diameter of the rivet or bolts plus 1/8 in., the holes may be punched. If the thickness of the material is greater than the nominal diameter of the rivet or bolt plus 1/8 in., the holes shall either be drilled from the solid or subpunched and reamed.

58. Specification for Remodeling Existing Steel When necessary to use flame cutting, it shall be done by approved method as directed by the Engineer. When permitted, the edge of the cut member shall be straight and the distance from the center of rivets to the cut edge shall not be less than 1 1/2 times the diameter of rivet plus 3/8 inch.

Chapter **5**

2. *Chrysomelidae* (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chrysomelidae (see also p. 10)

Chapter 5

DESIGN OF SIDEWALL COLUMNS SUBJECTED TO BENDING FROM EXTERNAL SIDE PRESSURE

TABLE OF CONTENTS

I DESIGN OF SIDEWALL COLUMNS SUBJECTED TO BENDING FROM EXTERNAL SIDE PRESSURE - - - - -	SD-5-1
II INTERIOR COLUMNS - - - - -	SD-5-2
III GRILLAGES, BASE SLABS AND FOOTINGS - - - - -	SD-5-3

Chapter 5

DESIGN OF SIDEWALL COLUMNS SUBJECTED TO BENDING FROM EXTERNAL SIDE PRESSURE

1 - NOTATION :

- A = Area of column section in sq. in.
L = Unbraced length of column in inches,
generally 168 for 13'-2" headroom.
M = Bending moment in in. kip.
P = Total direct load in kip.
r = Radius of gyration of column in inches.
S = Section modulus of column in in.³.
 f_D' = Maximum allowable direct stress in kip per
sq. in.
 f_B' = Maximum allowable bending stress in kip per
sq. in. (For steel embedded in concrete and
carrying no direct load.)
 f_{B1} = Allowable bending stress in kip per sq. in.
for P = 150 kip.
 f_{B2} = Allowable bending stress in kip per sq. in.
for P = $f_D' A$
 f_B = Allowable bending stress in kip per sq. in.
for any other load.

Water Level = Ground water level, or T.A.datum
(El. 100.0), whichever is higher.

RULES FOR DESIGN: (See also "Loads & Stresses," Sects. 39
to 41)

2. Under ordinary conditions, only dead load is to be considered in determining side pressure, which shall be computed as follows:

- a) In earth above water level, as one-third the vertical pressure, assuming weight of earth as 100 lb. per cu.ft.
- b) In earth below water level, same as above, and, in addition, full water pressure from water level.
- c) In sound rock, where concrete can be rammed into it and produce a seal for at least one-half the area exposed, as one-half water pressure from water level, top of rock or top of subway roof, whichever is highest. In unsound rock, where no such seal can be obtained, full water pressure shall be assumed instead.

- d) With rock line within the span of a sidewall column, as full water pressure from water level or top of subway roof, whichever is higher, and in addition earth pressure on portion above rock, except that where rock line is less than 3 ft. below top of column the water pressure may be reduced to one-half below rock surface if in sound rock.

The above rules are for general guidance only, as drainage conditions depend on position of subway relative to rock surface over a considerable area; also, field conditions may call for subsequent changes in design.

3. f'_D and f_B may be determined from the following formulas, which apply to any column length:

For T.A. Stresses:

$$f'_D = 17 - 0.000485 \frac{L^2}{r^2} \quad \text{--- (1)}$$

$$\text{For } P \leq 150: f_B = 25 \frac{P}{2A} \quad \text{--- (2)}$$

$$\text{For } P > 150: f_B = (20 - f'_D) + (5 + f'_D - \frac{150}{2A}) \frac{f'_D A - P}{f'_D A - 150} \quad \text{--- (3)}$$

For Bldg. Code Stresses:

$$f'_D = 17 - 0.000485 \frac{L^2}{r^2} \quad \text{--- (4)}$$

$$\text{For } P \leq 150: f_B = 22 - \frac{P}{2A} \quad \text{--- (5)}$$

$$\text{For } P > 150: f_B = (20 - f'_D) + (2 + f'_D - \frac{150}{2A}) \frac{f'_D A - P}{f'_D A - 150} \quad \text{--- (6)}$$

4. In general, sidewall columns shall extend 6 in. below the bottom of track trough or rough floor line, unless riveted to a transverse grillage or invert beam; at side platforms, mezzanines and station entrances, this distance shall be 4 in. min.

II - INTERIOR COLUMNS

5. Formula to be used for the design of interior columns:

$$U = 17 - 0.000485 \frac{L^2}{r^2}$$

where U = Allowable Unit Stress in kips psi.
L = Unbraced length of column in in.
r = Governing Radius of Gyration in in.

Formulas for combined stresses due to direct load and bending are given in "Loads & Stresses," Sect. 53.

III- GRILLAGES, BASE SLABS AND FOOTINGS

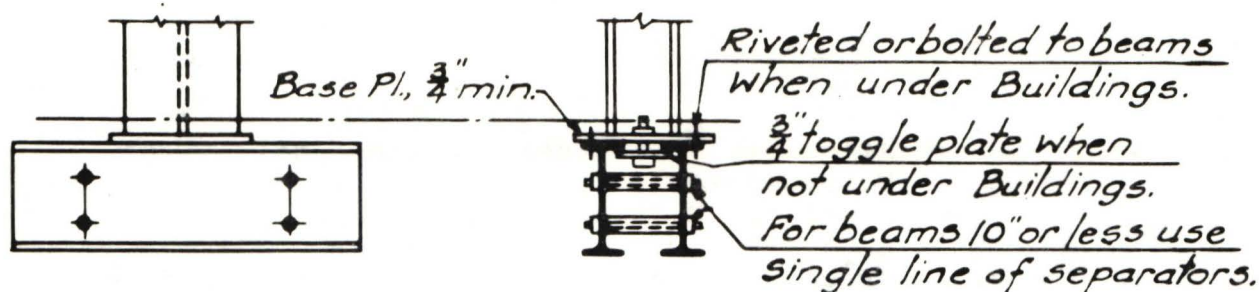
6. Grillage beams shall have sufficient flange bearing area, considering both flanges, to transmit safely the superimposed load to the concrete at the allowable unit bearing stress. The total width of bearing on concrete shall be taken as $A+2B$, where "A" is the distance center to center of outer grillage beams, not to exceed the number of beams less one multiplied by twice the flange width of one beam, and "B" is the distance from center of outer beam to adjacent face of concrete footing, not to exceed the flange width of one beam. The clear distance between flanges of grillage beams shall be not less than 2 1/2 inches.

7. For grillages made up of standard beam sections, the load shall be considered uniformly distributed on the concrete at a bearing value not exceeding 750 lb. per sq. in. (500 lb. for Bldg. Code.)

8. For grillages made up of wide flange beam sections and for column base slabs, the load shall be considered uniformly distributed on the concrete at a bearing value not exceeding 500 lb. per sq. in. (Same for Bldg. Code.)

The lower bearing value for the concrete under wide flanges and slabs in T.A. design is due to their greater flexibility causing a substantial variation in pressure, from a maximum at the center of beam flange or slab to a minimum at the edges.

The legs of wide flange beam sections, considered as cantilevers from end of fillet, shall not be stressed in bending beyond 20 kip per sq.in. (18 kip for Bldg. Code.)



TYPICAL GRILLAGE BEAMS.

Figure 1

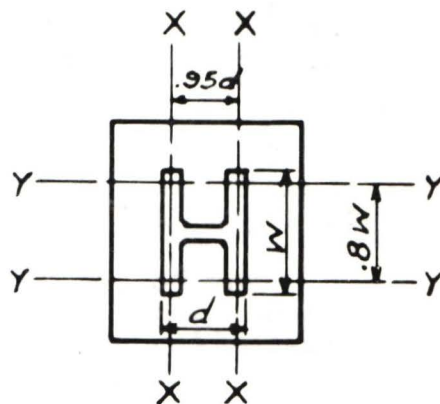
9. Grillage beams shall be designed to resist moment, shear and full bearing under the column. Stiffeners on grillage beams, where required, shall be designed for the difference between the reaction and the bearing value of the beam webs or column, whichever is less.

The allowable bearing value for steel shall be taken at 24 kip per sq. in. (18 kip for Bldg. Code.)

Web buckling shall not be considered when the beams are encased in concrete and the load is applied after the concrete has set.

10. Base slabs shall be designed for bending about axes X-X and Y-Y, Fig. 2 whichever governs, considering the total load spread uniformly over the entire slab area.

11. For grillages consisting of two or more beams, the column load shall be considered equally distributed among the several beams.



TYPICAL BASE SLAB.

Figure 2

12. Grillage beams shall have a depth of not less than 6 in. and a length of not less than 1'-6".

13. Beams or base slabs supporting columns spaced about 5 ft. on centers, shall be considered as distributing the load to the soil longitudinally for a distance equal to the column spacing, owing to the arching effect of the concrete. For grillages spaced further apart, such as those under platform columns, the load shall be considered uniformly spread to the soil longitudinally on 30° planes passing through the upper flange ends as indicated in Fig. 3 the arching effect of the concrete being in this case disregarded. The transverse reinforcement, if any, shall be designed for the load carried over the full length L and longitudinal bars 12 in. center to center shall be provided, the same size bars being used for both sets of reinforcement, with an upper limit of No. 6 for the longitudinal bars. See also "Design of Concrete and Reinforced Concrete Structures."

The grillage shall be designed for the total load uniformly distributed over the length of beam. Double tier grillages may be used if economical.

14. The weight of the concrete footing shall be disregarded in the design and in determining bearing on soil.

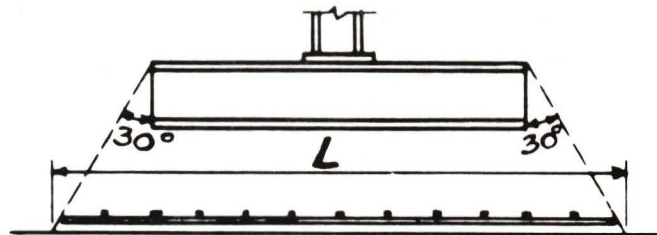


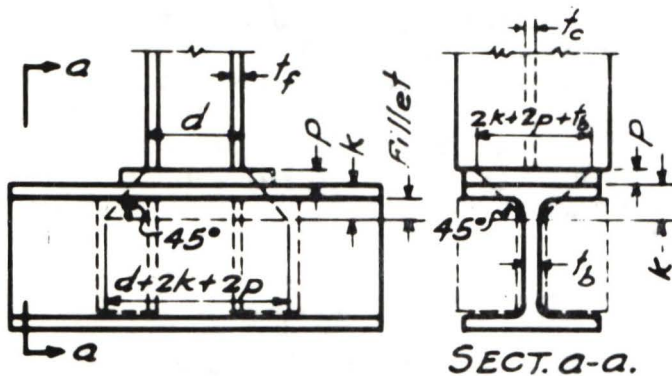
Figure 3

15. Figs. 4 to 6 show details of columns supported on one or two grillage beams, together with corresponding formulas for determining the effective steel bearing area of columns and beams, and the design of base plates. The following notation is used:

- A_b = Effective steel bearing area of beam or beams
- in sq. in.
- A_c = Effective steel bearing area of column - in sq. in.
- P = Total column load - in kip.
- $d, e, k, p, t_b, t_c, t_f$ and w = Dimensions as indicated in Figs. 4 to 6 in inches.

ONE-BEAM GRILLAGES

16. In computing bearing area, Formula 7 or 8 shall be used, whichever gives the smaller value. The thickness p of base plate for one-beam grillages may be varied as required for bearing from 1/2 in. to 2 1/2 in. If the required bearing area cannot be thus obtained, stiffeners shall be used as shown dotted in Fig. 4, with base plate generally 1/2 in. thick.



$$A_b = (d + 2k + 2p) t_b \dots \dots (7)$$

$$A_c = d t_c + (4k + 4p + 2t_b - 2t_c) t_f \dots (8)$$

Figure 4

Bending shall not be considered in designing base plates for one-beam grillages.

One-beam grillages shall generally be avoided in cases where column web and beam web would be normal to each other.

TWO-BEAM GRILLAGES

17. In computing bearing area of grillage beam web, Formulas 9 & 10 shall be used. The thickness p of base plate for two-beam grillages may be varied as required for bearing from 3/4 in. to 2 1/2 in. If sufficient bearing length cannot be thus obtained, stiffeners shall be used on beams as shown dotted in Figs. 5 & 6, with base plate of the required thickness.

The base plate is considered to have sufficient bending strength when its thickness p is equal to e (Figs. 5 & 6), except that when the latter exceeds 2 1/2 in. the plate shall be designed for a bending moment of $Pe/2$ and its thickness may be increased beyond 2 1/2 in., if necessary.

The base plate, being much more flexible than the grillage, shall not be designed for bending about an axis normal to the length of the beams, but shall be assumed to spread the column load to the beam webs at an angle of 45°.

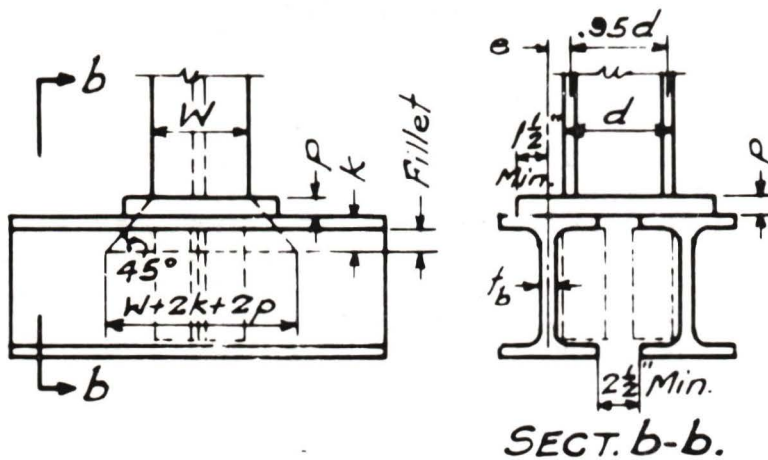


Figure 5

For two beams
normal to col. web:
 $A_b = 2(W + 2k + 2p)t_b \dots (9)$
 $A_c = \text{Total col. area.}$

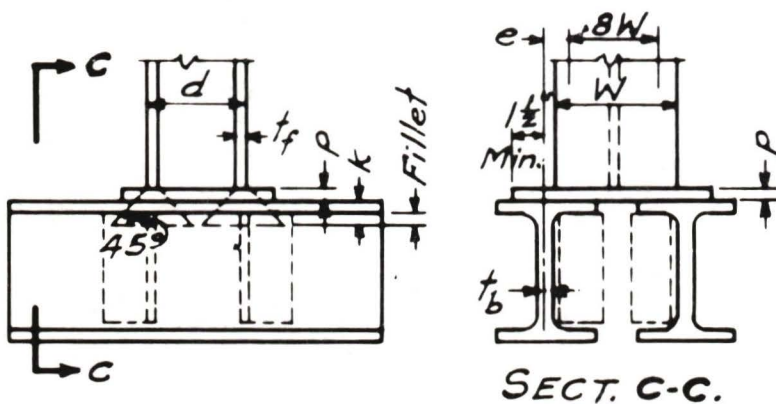


Figure 6

For two beams
parallel to col. web:
 $A_b = 2(2t_f + 4k + 4p)t_b$
not to exceed $2(d + 2k + 2p)t_b$ } (10)
 $A_c = \text{Total col. area.}$

PLATE GIRDER GRILLAGES

18. Where heavy column loads or other conditions necessitate the use of plate girder grillages, the following rules shall be observed:

Where the flanges of plate girders transmit the load directly to the concrete, stiffeners shall not be used for the purpose of strengthening the lower flange, and the concrete and outstanding legs of flange angles shall not be stressed beyond the values given for rolled beam grillages in Sect. 8.

Both upper and lower flanges may be counted on for bearing, but as the load from the upper flange spreads through the concrete to the level of and beyond the lower flange the amount of this load will depend on the available width of concrete to spread it.

Where the flanges are insufficient for spreading the load to the concrete, or where enough flange rivets to transfer the stress due to longitudinal shear as well as that due to vertical pressure cannot be provided, a tier of grillage beams (Fig. 7) having sufficient bearing area to transmit the load to the concrete as per Sect. 6 shall be placed under such girder, and the bearing of the girder flanges on the concrete shall be disregarded.

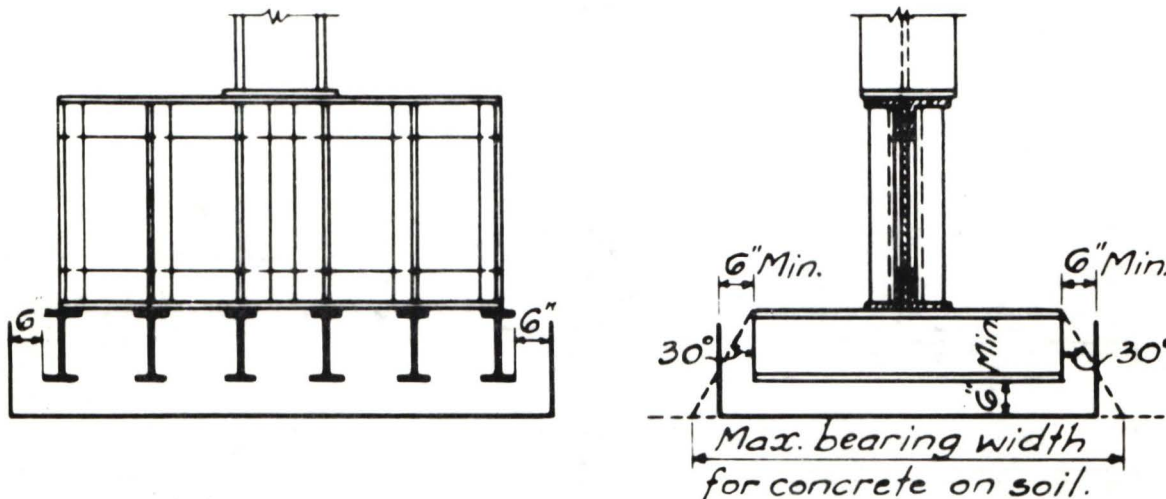


Figure 7

Stiffeners shall be provided above grillage beams where latter are used, and otherwise as indicated in "Details of Design for Structural Steel," Sect. 42.

Base plates, when resting on a grillage girder, shall have a thickness of not less than $3/4$ inch.

SIDEWALL COLUMN FOOTINGS IN EARTH

19. In earth above water level, for the usual soil bearing value of 8 kip per sq. ft., the type of sidewall footing to be used shall be determined as follows:

When the load carried by column and wall, including their own weight, is 90 kip or less, the concrete at sub-grade shall be considered sufficient as a footing.

When the load exceeds 90 kip, one of the following designs may be used, depending on economy and adaptability:

- a) Steel cantilever footings, as given on page SD-5-12 (Reinforced concrete cantilever footings shall not be used.)
- b) Steel footings projecting beyond the net line of sidewall, as shown in Fig. 8. Double tier grillages (Fig. 9) may be used where single beam footings are insufficient for the load. The weight of the backfill above the projection shall be disregarded in designing these footings because of the confinement of the soil at the projecting end.
- c) Invert beams spanning between interior and sidewall columns.

Bevel, if necessary,
in order to avoid
encroachment on
track trough.

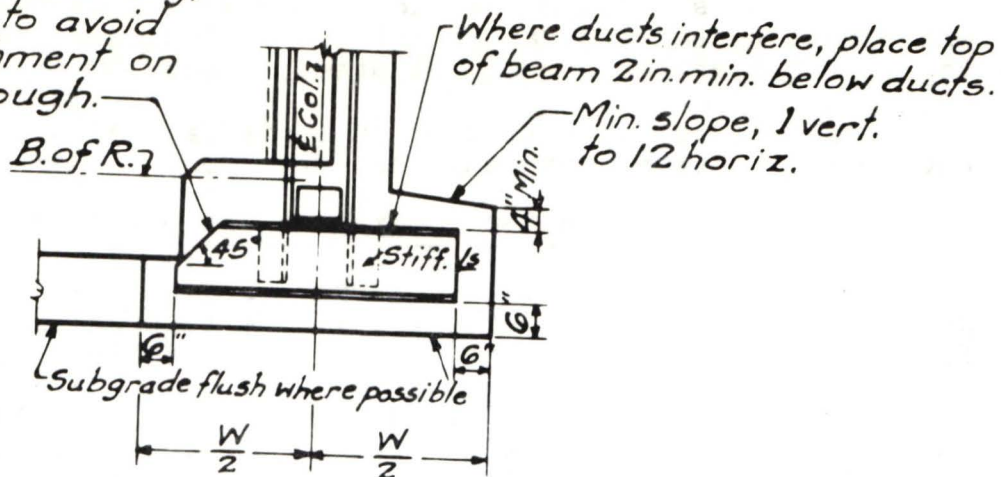


Figure 8

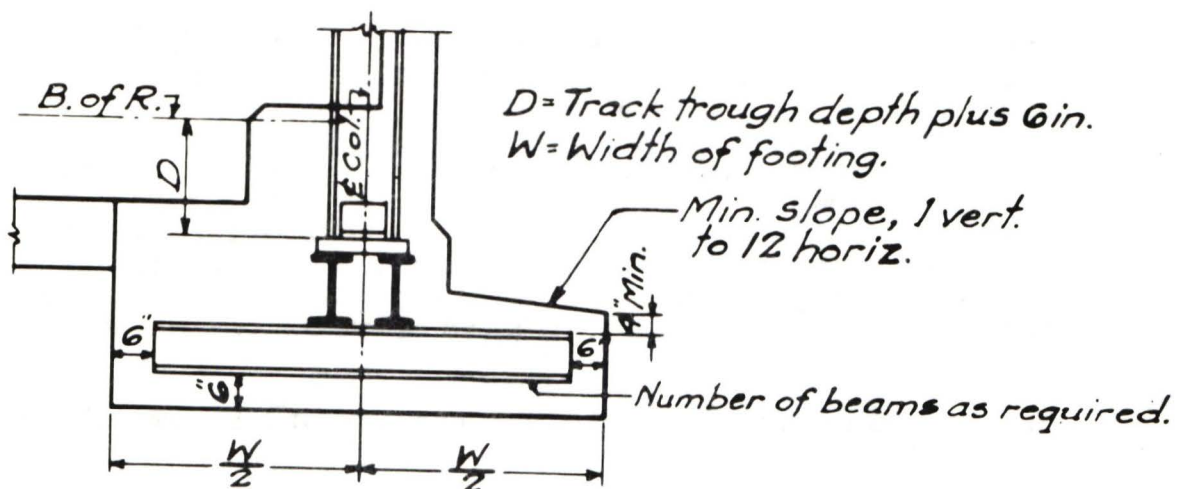


Figure 9

20. In earth below water level, a steel beam invert for distributing the load over the entire subgrade shall generally be provided. Where the need for such an invert is doubtful, the design shall be made for a reinforced concrete invert so as to avoid waste if its omission is warranted by the conditions at subgrade, as revealed in the excavation. See also "Loads and Stresses," Sect. 18

SIDEWALL COLUMN FOOTINGS IN ROCK

21. In rock, when the load carried by column and wall, excluding their own weight, is 200 kip or less, and when the bond stress between column and wall does not exceed 30 lb. per sq. in., the concrete at subgrade shall be considered sufficient as a footing; otherwise, a steel slab or grillage shall be provided under the column to distribute the total column load (see "Loads & Stresses", Sect. 17). The bond stress between column and wall shall be computed by the following formula (load in lb., dimensions in in.):

$$\text{Bond Stress} = \frac{\text{Total Column Load}}{\text{Col. length times (2 times width of flange plus 2 times depth of sect. minus 5")}}$$

Footings shall, wherever possible, be designed so as not to project beyond the payment line.

STEEL CANTILEVER FOOTINGS FOR SIDEWALL COLUMNS 5 FT. ON CENTERS IN EARTH ABOVE WATER LEVEL.

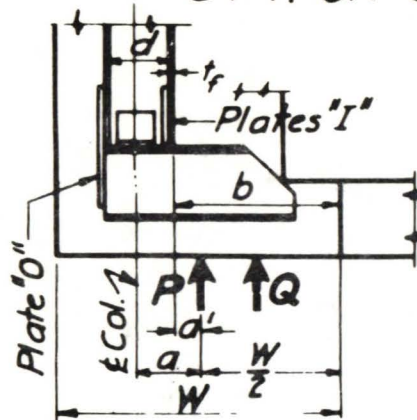


Figure 10

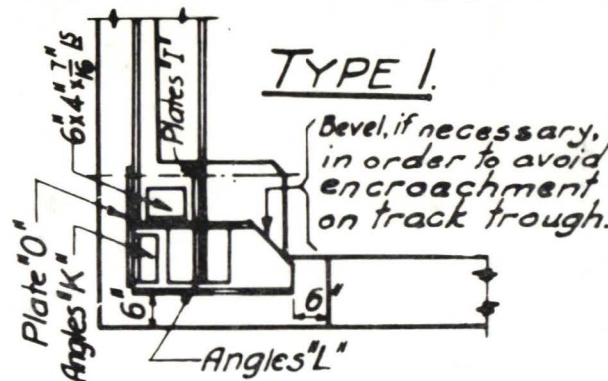


Figure 11

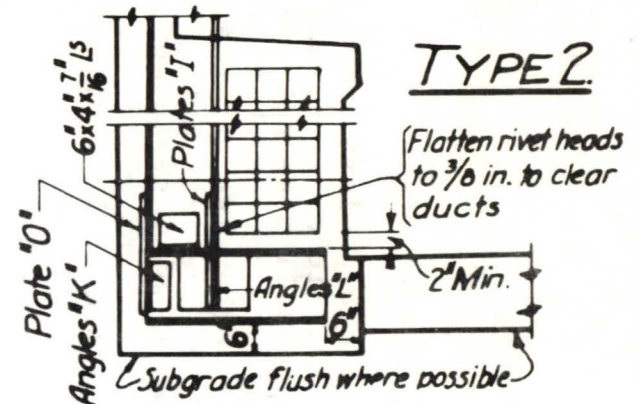


Figure 12

FORMULAS (Lengths in in., Loads in kip):

$$Q = \frac{Pb}{W}; \quad M_b = \frac{Qb^2}{2}; \quad M_c = Pa; \quad T = \frac{Pa'}{d}; \quad C = T + P; \quad f_s = \frac{P}{A} + \frac{M_c}{S}$$

W = Required footing width.

P = End reaction of roof beam, including load to back of column, plus reaction due to intermediate floors, if any, plus weight of wall taken at 0.75 kip per ft. of height.

Q = Upward pressure on portion b of footing (= max. shear on beam).

M_b = Maximum moment in cantilever beam.

M_c = Moment at bottom of column.

T = Tension in plate "O".

Notes: Bearing on soil assumed uniform at 8 kip per sq. ft.

Value f_s for Type 1 shall not exceed 20 kip per sq. in..

Value f_s for Type 2 shall not exceed 25 kip per sq. in. (22 kip for Bldg. Code).

Bearing length of beam web shall be taken as thickness t_f (Fig 10) of column flange plus spread through fillet.

C = Compression in plates "I" and column flange.

a = Distance from center line of column to center of footing.

a' = Distance from face of column to center of footing.

b = Distance from face of column to toe of footing.

d = Depth of column section.

f_s = Maximum unit stress at bottom of column.

A = Area of column section.

S = Section modulus of column section.

Chapter 6

Chapter 6

DESIGN OF

CONCRETE AND REINFORCED CONCRETE STRUCTURES

TABLE OF CONTENTS

1,2,3	MODIFICATIONS TO ACI 318-63 - - - - -	SD-6-1
4	DENSITY OF PLAIN AND REINFORCED CONCRETE - - - - -	SD-6-1
5	PROPORTION OF MIX - - - - -	SD-6-1
6	QUALITY OF CONCRETE - - - - -	SD-6-2
7	REINFORCING BARS - - - - -	SD-6-2
8	ALLOWABLE STRESSES IN NON-REINFORCED CONCRETE ARCHES - - - - -	SD-6-2
9	ALLOWABLE BOND STRESS BETWEEN CONCRETE AND ROLLED SHAPES - - - - -	SD-6-2
10	TRACK SLABS - - - - -	SD-6-2
11	SHEAR REINFORCEMENT - - - - -	SD-6-3
12	COVERING OF BARS - - - - -	SD-6-3
13	SPACING OF BARS IN A LAYER - - - - -	SD-6-3
14	NEGATIVE REINFORCEMENT IN SIMPLE BEAMS AND SLABS - - - - -	SD-6-4
15	BEARING FOR STEEL BEAMS - - - - -	SD-6-4

Chapter 6

DESIGN OF

CONCRETE AND REINFORCED CONCRETE STRUCTURES

The working stress design provisions specified in the "ACI Standard Building Code Requirements for Reinforced Concrete (ACI 318-63)" as modified below shall be used for design.

However, provisions of other acceptable codes, e.g., N.Y.C. Building Code, may be used for a particular design project, if approved by CEAD.

Use loads as specified in "Loads and Stresses" and "Design of Sidewall Columns."

No reduction (based on these design standards) shall be made to the Authority's typical arch construction.

Modifications to ACI 318-63:

1. Use ACI 318-71 Chapter 3 - Materials, in lieu of ACI 318-63 Chapter 4 - Materials.
2. Use ACI 318-71 Chapter 7 - Details of Reinforcement in lieu of ACI 318-63 Chapter 8 - Details of Reinforcement. (See also Sections 12 and 13, below.)
3. Use ACI 318-71 Chapter 12 - Development of Reinforcement, in lieu of ACI 318-63 Chapter 13 - Bond and Anchorage - Working Stress Design, Section 918 - Anchorage requirements - General and Section 919 - Anchorage of web reinforcement.

NOTE: Use the corresponding provisions of Chapters 3, 7 and 12 in ACI 318-71 for cross-references to Chapters 4, 8 and 13 in ACI 318-63.

4. DENSITY OF PLAIN AND REINFORCED CONCRETE

w = 150 lb./cu. ft.

5. PROPORTION OF MIX

Use a 1:2:4 mix.

6. QUALITY OF CONCRETE

Compressive strength of concrete (f'_c) at age of 28 days = 3000 psi.

7. REINFORCING BARS

Deformed bars shall be rolled from first quality new billet steel, and shall conform to the "Specification for Deformed Billet-Steel Bars for Concrete Reinforcement," ASTM serial designation A615 for grade 60.

Allowable tensile stress = 24,000 psi.

8. ALLOWABLE STRESSES IN NON-REINFORCED CONCRETE ARCHES

a. Compression:

$$f_c = 0.25 f'_c = 750 \text{ psi}$$

b. Tension:

$$f_c = \sqrt{f'_c} = 55 \text{ psi}$$

c. Shear:

$$v \text{ (as a measure of diagonal tension)} \\ = \sqrt{f'_c} = 55 \text{ psi}$$

9. ALLOWABLE BOND STRESS BETWEEN CONCRETE AND ROLLED SHAPES

$$u = 30 \text{ psi}$$

10. TRACK SLABS

A. Minimum Thickness

The minimum total thickness of reinforced concrete one-way slabs supporting tracks shall be 1/12 of the span.

B. Allowable Stresses

- a. Concrete: Multiply all allowable stresses specified in these design standards by 0.55.

b. Reinforcing Steel: Multiply allowable stress specified in these design standards by 0.75

c. Shear Reinforcement:

Provide a minimum of shear reinforcement as specified in Section 11, below. Shear reinforcement shall consist of stirrups perpendicular to the longitudinal reinforcement.

11. SHEAR REINFORCEMENT

Provide a minimum of shear reinforcement in all primary reinforced concrete beams and girders. This reinforcement shall consist of at least #3 stirrups perpendicular to the longitudinal reinforcement and spaced not further apart than $d/2$.

12. COVERING OF BARS

The distance from the concrete surface to the outermost surface of the steel shall be as follows:

	<u>Minimum</u>	<u>Standard</u>
a) In wall footings and column footings	3"	3½"
b) At surface exposed to weather	2"	2½"
c) In beams and columns	2"	2½"
d) In slabs and walls	1"	1½"
e) In thin slabs (effective depth less than 4")	¾"	1"

13. SPACING OF BARS IN A LAYER

In beams and slabs, the minimum center to center distance of parallel bars shall be 4" for No. 6 or smaller bars. For larger bars, the minimum clear space between bars shall be 4".

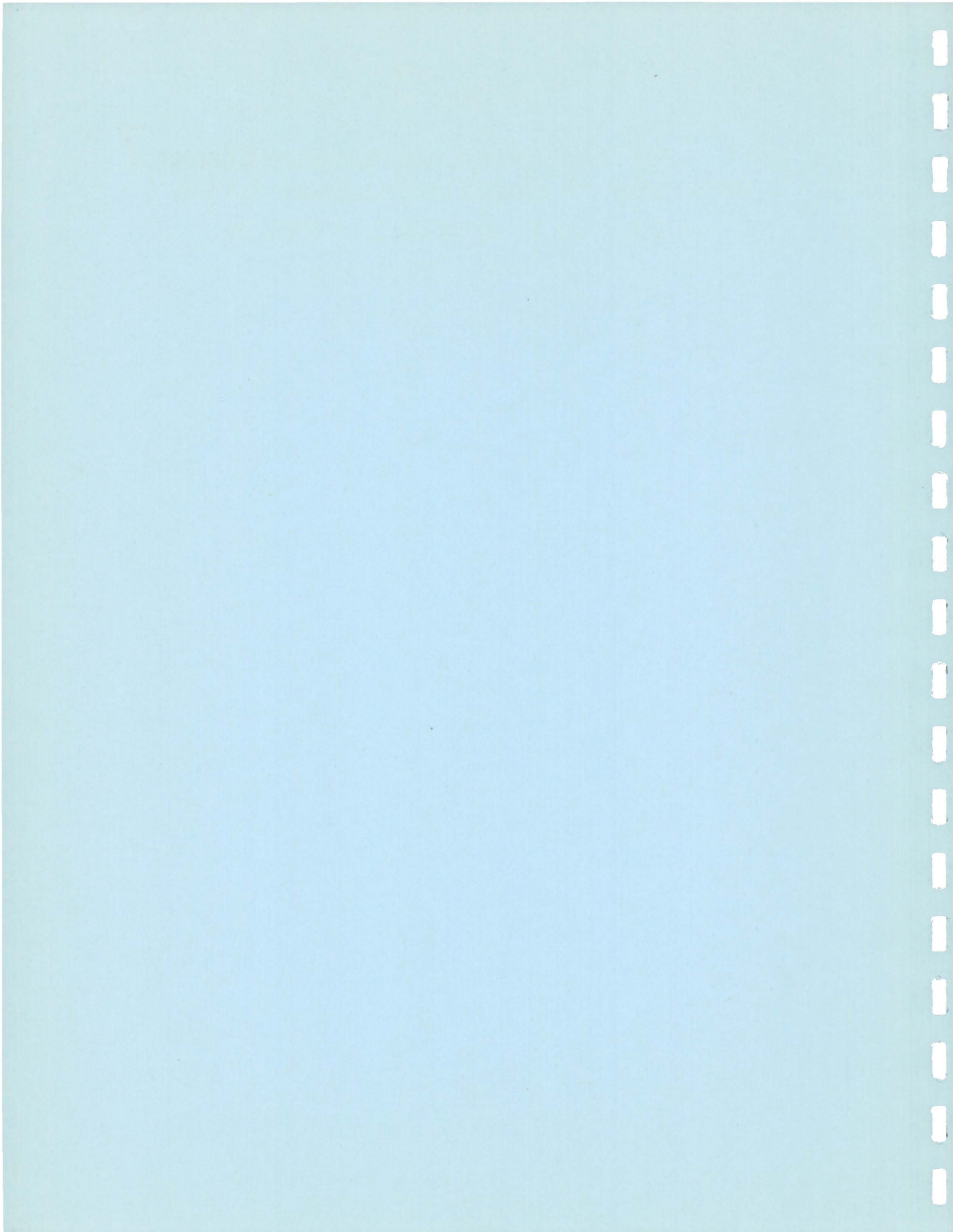
14. NEGATIVE REINFORCEMENT IN SIMPLE BEAMS AND SLABS

In simple beams and slabs supported on interior or side walls, negative reinforcement of at least $1/2$ times the maximum area of the positive reinforcement shall be placed above the supports to prevent cracking. These bars shall have a length of at least 50 times their thickness and shall extend to the quarter points of adjoining spans.

15. BEARING FOR STEEL BEAMS

Where steel beams rest on concrete walls, provide bed plates set back from face of wall a distance of $1/4$ times the wall thickness, not to exceed 3". The bed plates shall be considered as transmitting uniformly the full end reaction.

Chapter **7**



Chapter 7

WATERPROOFING OF SUBWAYS WITH CONSTRUCTION FOR SUBWAY FLOOR AND DETAILS OUTSIDE OF STEEL IN ROOF AND SIDEWALKS

TABLE OF CONTENTS

1. ROOF - - - - -	SD-7-1
2. SIDE WALL - - - - -	SD-7-1
3. INVERT - - - - -	SD-7-1
4. FLOORS AT SIDE PLATFORMS, PASSAGEWAYS AND ENTRANCES - - - - -	SD-7-2
5. WATERPROOFING AT VENTILATOR AND DRIP PAN - AT STATIONS - - - - -	SD-7-3
6. WATERPROOFING AT VENTILATORS BETWEEN STATIONS - - - - -	SD-7-4
7. SECTIONS IN EARTH BETWEEN STATIONS - - - - -	SD-7-5
8. SECTIONS IN ROCK BETWEEN STATIONS - - - - -	SD-7-6

Chapter 7

WATERPROOFING OF SUBWAYS WITH CONSTRUCTION FOR SUBWAY FLOOR AND DETAILS OUTSIDE OF STEEL IN ROOF AND SIDEWALKS

ROOF

Above El.100.0 or Ground Water Level	At Stations	2" Min.Conc.-1 Ply W.P.- 1 Layer of Brick in Asph.Mastic-4" Conc.
	Bet.Stations	2" Min.Conc.-3 Ply W.P.-4" Conc.
Below El.100.0 or Ground Water Level	At and Bet. Stations	2" Min.Conc.-1 Ply W.P.-1 Layer of Brick in Asph.Mastic-4" Conc.

SIDE WALL

Above El.100.0 or Gnd. water level	At Stations	Earth	4"± Conc.-3 Ply Waterproofing-4" Conc.
		Rock	4"± Conc.-3 Ply Waterproofing-3" Conc.
	Between Stations	Earth	6"± Conc. No. 6 Rods, Horizontal, 1'6" Ctrs.
		Rock	3"± Concrete
Below El.100.0 or Gnd. water level.	At & Between Stations	Earth	4"± Conc.-4 Ply Waterproofing-4" Concrete
		Earth	2"± Conc.-4" Brick in Asph.Mastic-1 Ply W.P.-4" Conc.
		Rock	4"± Conc.-4 Ply Waterproofing-3" Concrete

*To be used for severe water conditions approximately
12 ft. or more below El.100.0 or Ground Water Level.

INVERT

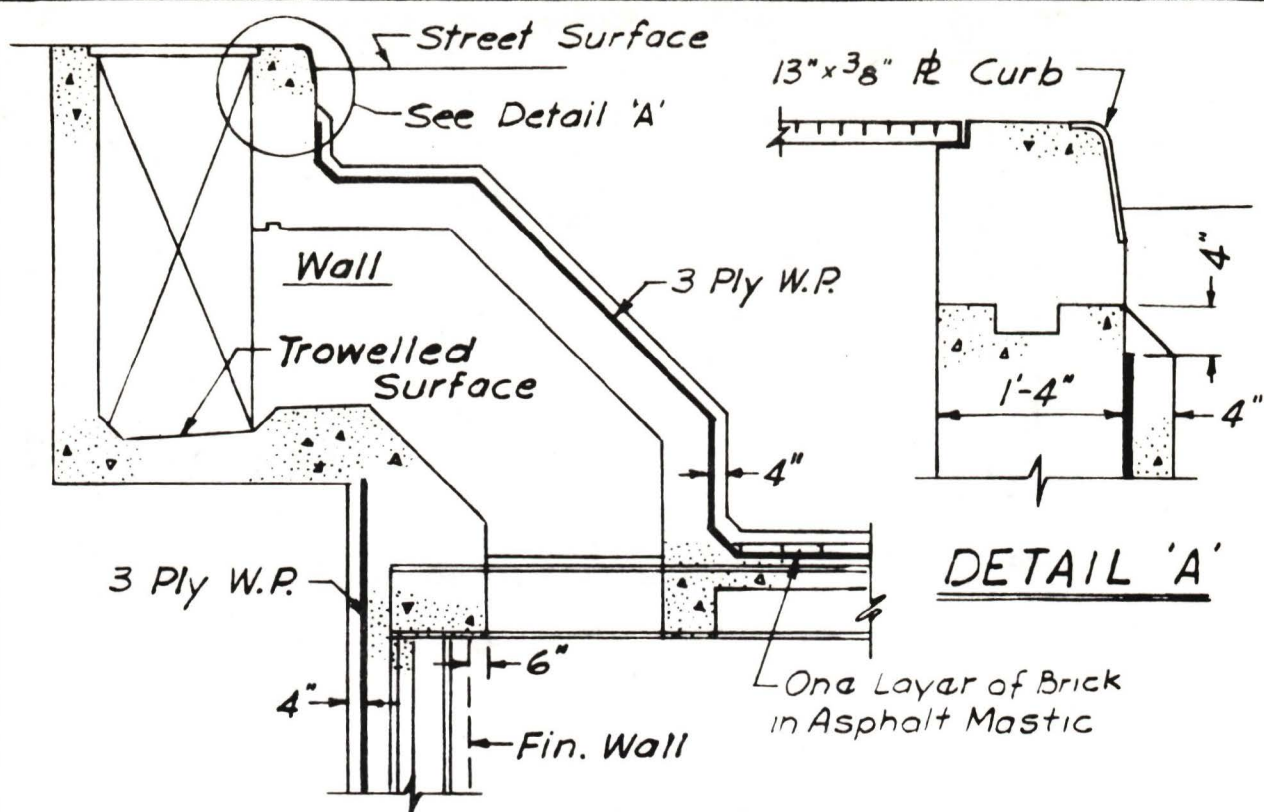
At and Between Stations	B.of R. Above El.100.0 or Ground Water Level	Earth	12" Concrete, if approved by the Civil Engineering and Architectural Division
		Rock	6" Concrete
	B.of R. Below El.100.0 or Ground Water Level	Earth	Steel Invert-4" Conc.-1 Layer of Brick in Asph.Mastic-1 Ply W.P.6" Conc.
			Reinf. Conc.Invert-1 Layer of Brick in Asph.Mastic-1 Ply W.P.6" Conc.
		Rock	6" Concrete

FLOORS OF SIDE PLATFORMS, PASSAGEWAYS & ENTRANCES

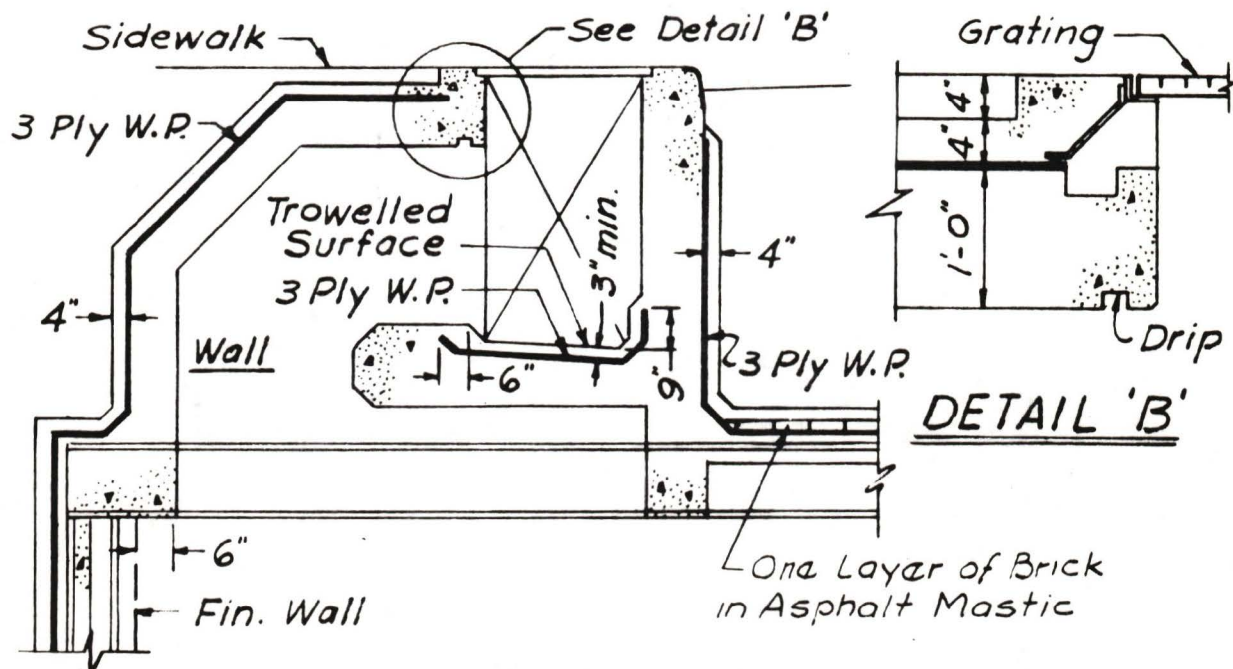
Top of Finished Floor Higher than 5' Above El.100.0 or Ground Water Level	Earth	No W.P.-8" Conc. No. 5 Transverse Rods - 12" Centers
	Rock	No Waterproofing - 4" Concrete
Top of Fin. Floor Bet.El.100.0 or Ground Water Level & 5' Above	Earth	8" Concrete-3 Ply Waterproofing-4" Concrete
	Rock	4" Concrete-3 Ply Waterproofing-4" Concrete
Floor Below El.100.0 or Ground Water Level	Earth	Steel Invert-4" Conc.-1 Layer of Brick in Asph.Mastic-1 Ply W.P. 6" Conc. Reinf. Conc. Invert-1 Layer of Brick in Asph.Mastic-1 Ply W.P.-6" Conc.
	Rock	Platform Conc.-4 Ply Waterproofing-4" Concrete

NOTES FOR WATERPROOFING OF SUBWAYS:

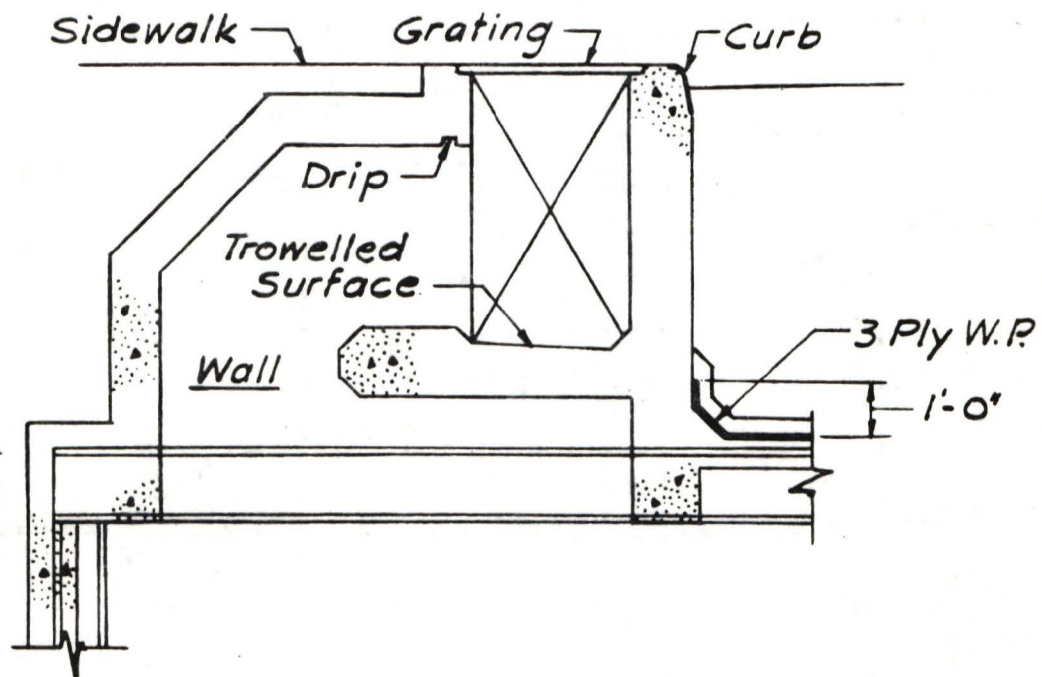
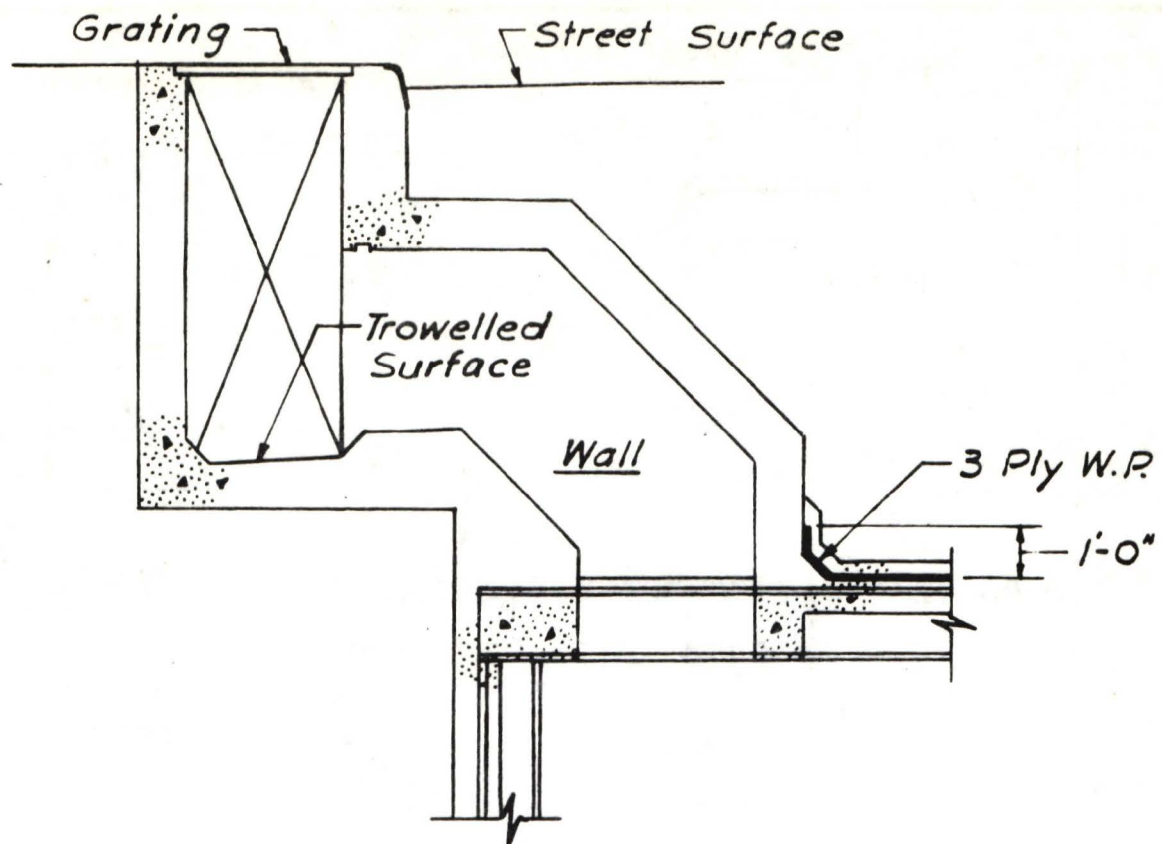
1. Chiller Rooms, Climate Changer Rooms, Under Platforms, Fan Rooms, Fan Chambers and Control Rooms, Elevator and Escalator Machinery Rooms and Pits, Ejector Rooms, Sump and Pump Chambers, Circuit Breaker Houses, Electrical Distribution Rooms, Electrical Panel Rooms, Substations, Relay Rooms, Signal Tower Control Rooms, Central Instrument Rooms, Communications Rooms, Compressor Rooms, Telephone Compartment Rooms & Cable Shafts to be completely protected by waterproofing.
2. At the start of each contract, a recommendation for the use of either (a) ASPHALTIC membrane waterproofing or (b) ELASTOMERIC membrane waterproofing shall be submitted to the Civil Engineering and Architectural Division for APPROVAL.



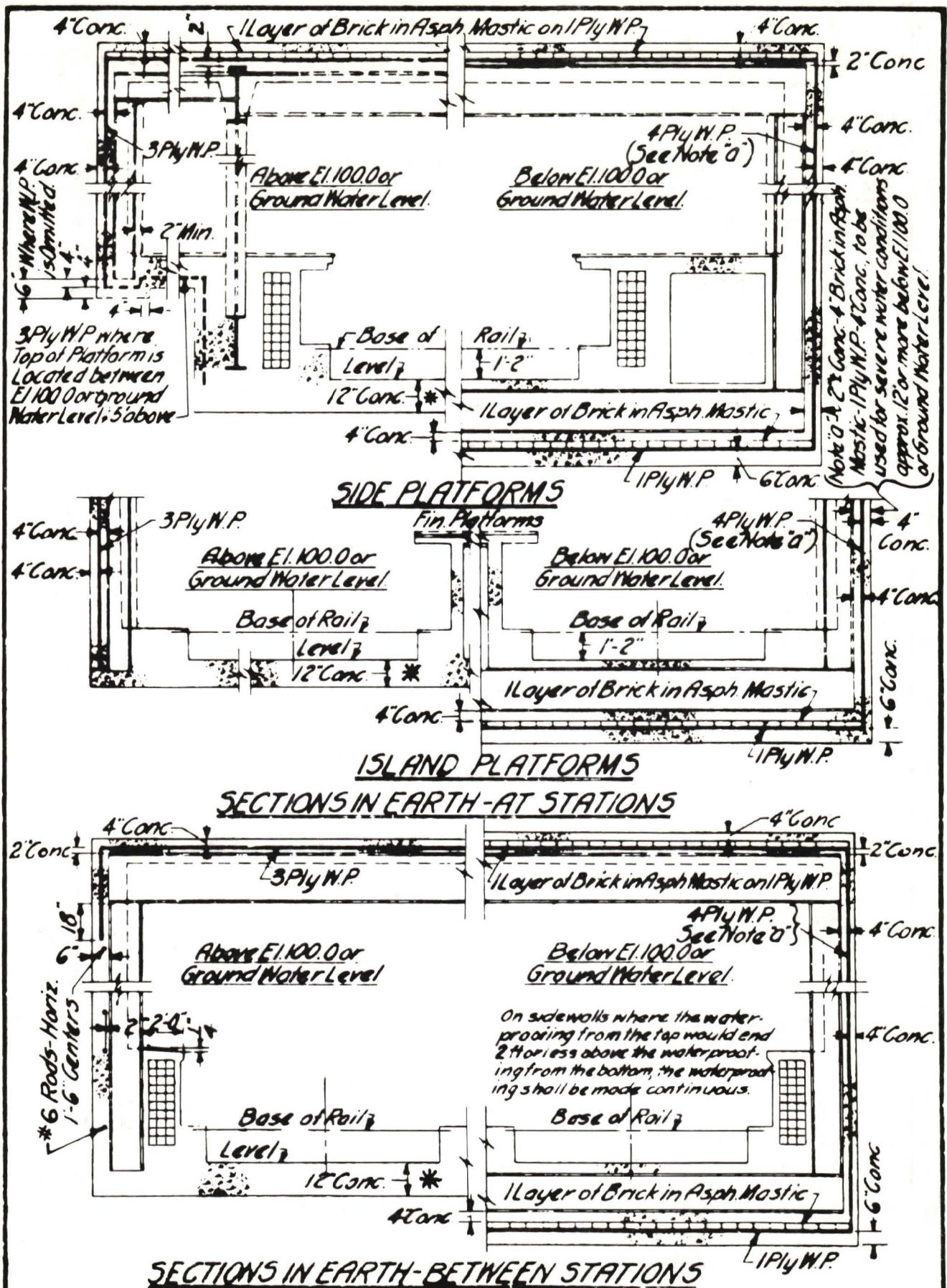
WATERPROOFING AT VENTILATOR AT STATIONS (ABOVE EL. 100.0 OR GROUND WATER)



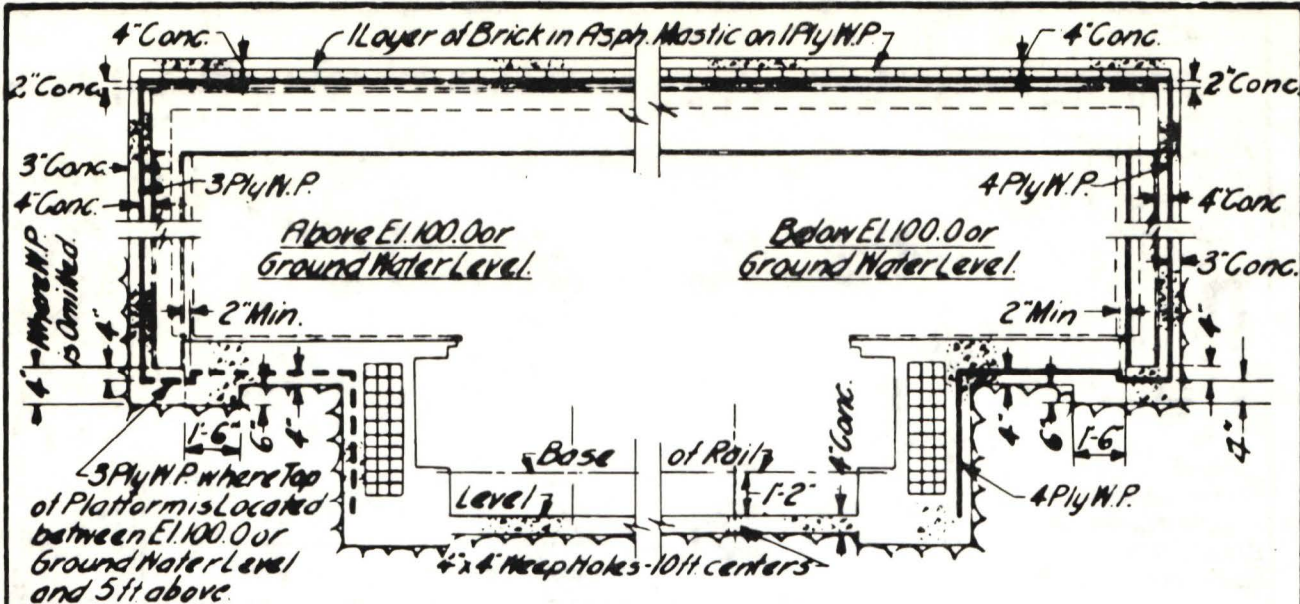
WATERPROOFING AT VENTILATOR AND DRIP PAN — AT STATIONS (ABOVE EL. 100.0 OR GROUND WATER)



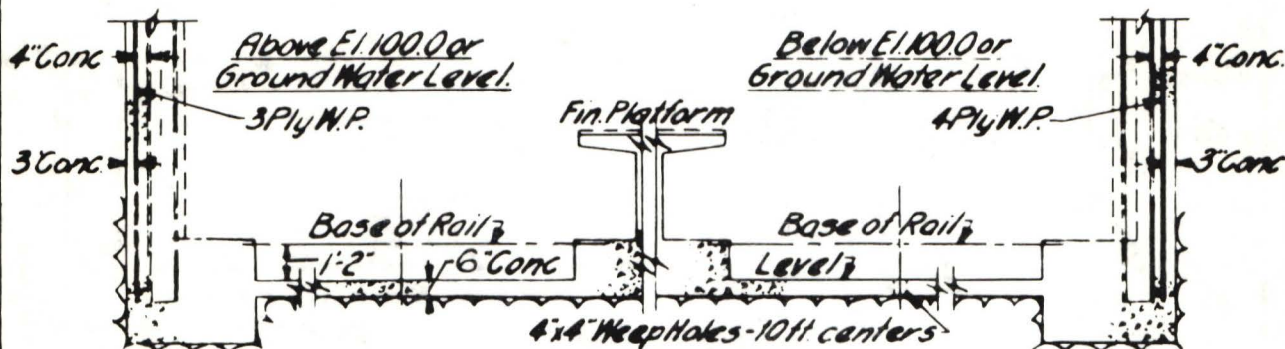
WATERPROOFING AT VENTILATORS
BETWEEN STATIONS
(ABOVE EL. 100.0 OR GROUND WATER)



* See page SD-7-1

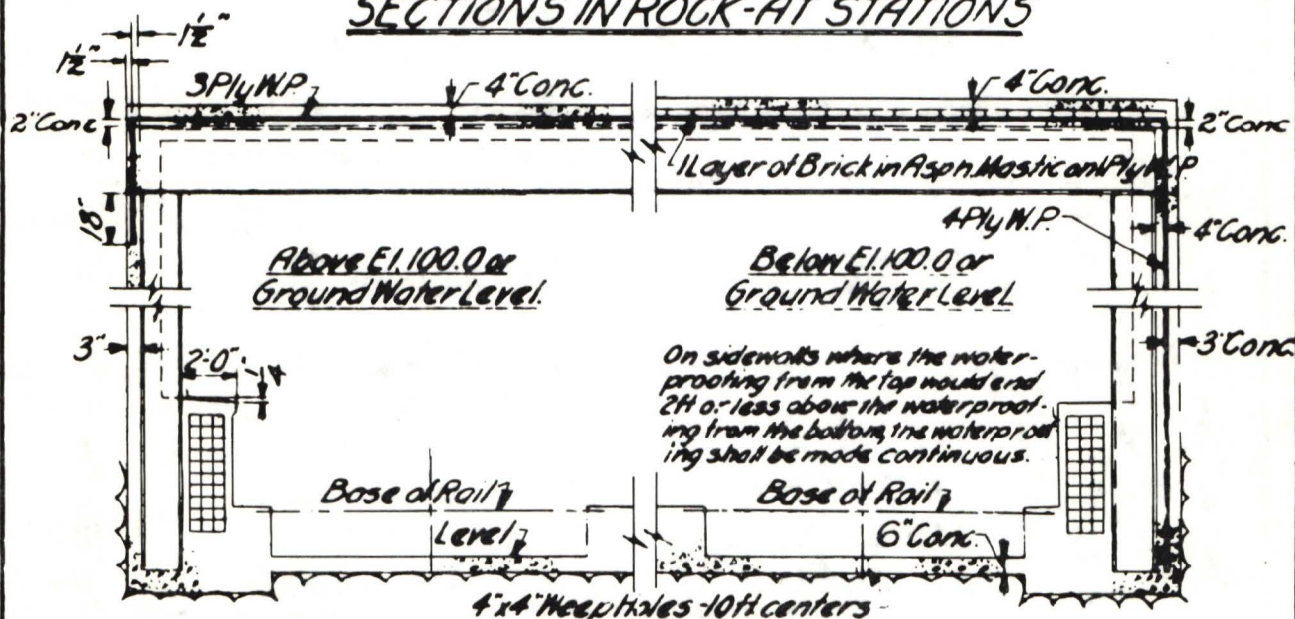


SIDE PLATFORMS



ISLAND PLATFORMS

SECTIONS IN ROCK-AT STATIONS



SECTIONS IN ROCK - BETWEEN STATIONS

Chapter 8

8. 1944

Chapter 8

NATURAL VENTILATION DESIGN CRITERIA BETWEEN STATIONS

TABLE OF CONTENTS

1	NATURAL VENTILATION DESIGN	
	CRITERIA BETWEEN STATIONS - - - - -	SD-8-1
2	VENT SHAFT THRU ROOF - - - - -	SD-8-2
3	VENT SHAFT THRU SIDEWALL	
	(FLUE UNDER SIDEWALK) - - - - -	SD-8-3
4	VENT SHAFT THRU SIDEWALL	
	(FLUE UNDER ROADWAY) - - - - -	SD-8-3
5	LAYOUT OF STANDARD BANK	
	OF 8 VENT SHAFTS - - - - -	SD-8-4
6	LOCATION OF BLAST SHAFT GRATINGS - - - - -	SD-8-4
7	PLAN A-A (FLUE UNDER SIDEWALK) - - - - -	SD-8-5
8	PLAN A-A (FLUE UNDER ROADWAY) - - - - -	SD-8-5
9	SECTIONS AND DETAILS - - - - -	SD-8-6
10	SECTIONS AND DETAILS - - - - -	SD-8-7
11	MODIFIED VENT SHAFT THRU ROOF - - - - -	SD-8-8
12	MODIFIED VENT SHAFT THRU SIDEWALL	
	(FLUE UNDER ROADWAY) - - - - -	SD-8-9
13	MODIFIED VENT SHAFT THRU SIDEWALL	
	(FLUE UNDER SIDEWALK) - - - - -	SD-8-10

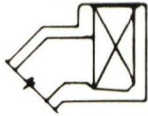
- 14. PLAN A-A (FLUE UNDER STREET) - - - - - SD-8-11
- 15. PLAN A-A (FLUE UNDER SIDEWALK) - - - - - SD-8-11
- 16. SECTIONS AND DETAILS - - - - - SD-8-12
- 17. SECTIONS AND DETAILS - - - - - SD-8-13

Chapter 8

NATURAL VENTILATION DESIGN CRITERIA BETWEEN STATIONS

1. A blast shaft with 200 $\pm$ square feet net grating area shall be provided at the entrance portal of each station. (See layout on page SD-8-5).
2. In addition to the blast shaft, vent shafts with a net grating area of 1.0 square foot for every 850 cubic feet of tunnel volume shall be spaced uniformly between the stations in banks of 6 to 8 bays per bank. The first bank of gratings shall be placed as close to the end of the previous station as practical and will function as relief vents for that station. Tunnel volume shall be measured from end of platform of previous station to beginning of platform of next station, not including volume of enclosures.
3. Vent shafts for emergency fan chambers between stations shall be utilized for natural ventilation net area requirements by providing an inlet opening to bypass fans where feasible.
4. Large single shafts shall be substituted for banks of vents when the subway is constructed under deep cover. The net area of the large single shaft shall be equal to the net grating area of the substituted banks of vent.
5. The net cross-sectional area of the vent shaft safety grill or other obstructions shall not be less than the net area of the grating. The net grating area is the cross-sectional area of the opening minus the area occupied by bearing and cross bars.
6. The standard vent shafts shown on pages SD-8-3 and SD-8-4 shall be used except where a sidewalk width is less than 13 feet or where utility restoration precludes a standard 4'-0" x 4'-2" vent shaft, in which case the modified vent shaft shown on pages SD-8-9, SD-8-10 and SD-8-11 shall be used.

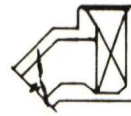
STANDARD VENT SHAFT



See Pages
SD-8-2 and
SD-8-3

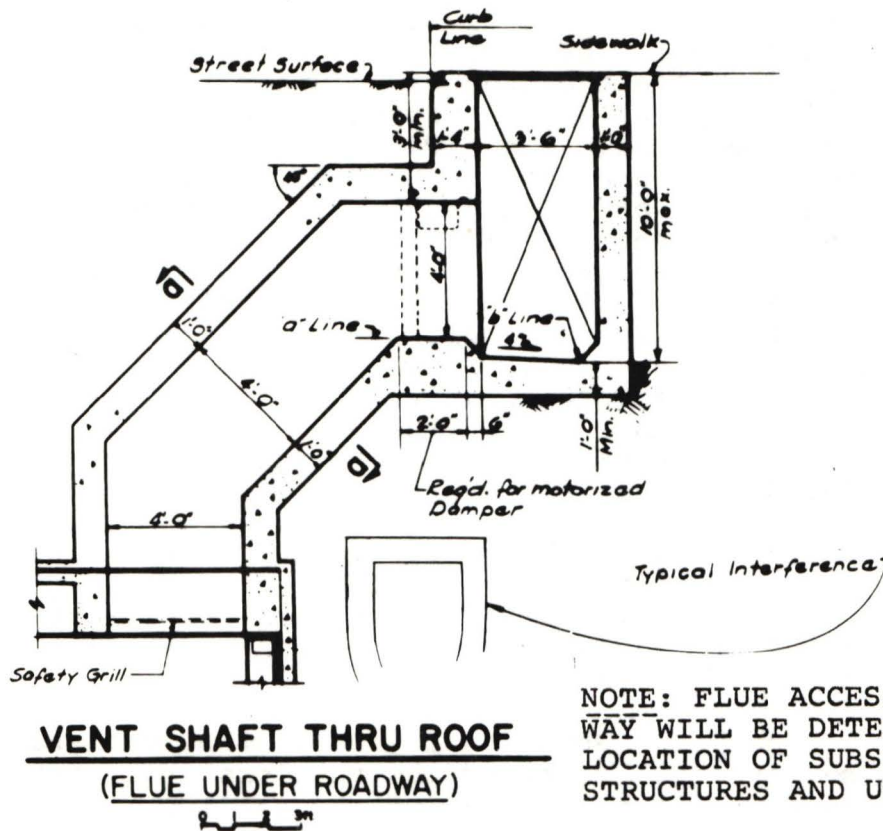
Assume Net Grating Area
= 13.75 Ft² per 5 Ft. Bay for
Net Area Computation

MODIFIED VENT SHAFT



See Pages
SD-8-8, SD-8-9
and SD-8-10

Assume Net Grating Area
= 11.75 Ft² per 5 Ft. Bay for
Net Area Computation



CROSS REFERENCES

For Section a-a ----- See Page SD-8-3

Alternate Location

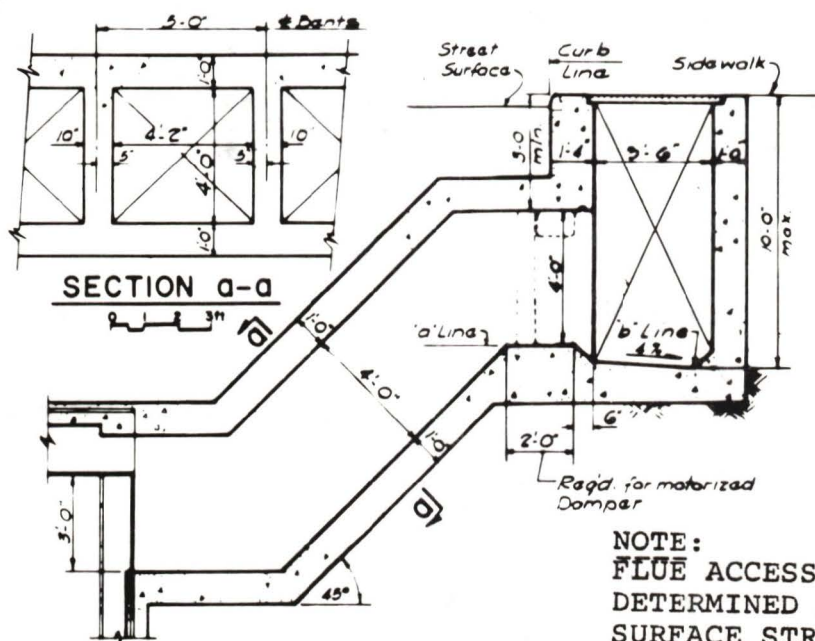
Street Surface
Curb Line
Sidewalk

10'-0" max.
1'-6"
3'-6"
1'-0"
1'-8"
4'-0"
1'-0"
4'-0"
2'-6"
4'-6"
3'-0"

b'Line
On 1%

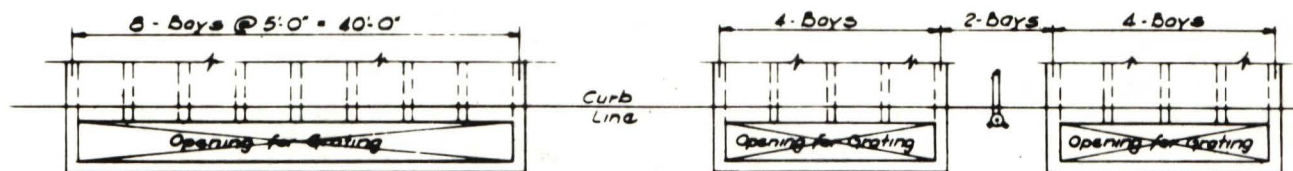
Alternate Lo

VENT SHAFT THRU SIDEWALL
(FLUE UNDER SIDEWALK)



NOTE:
FLUE ACCESS TO TRACKWAY WILL BE
DETERMINED BY LOCATION OF SUB-
SURFACE STRUCTURES AND UTILITIES

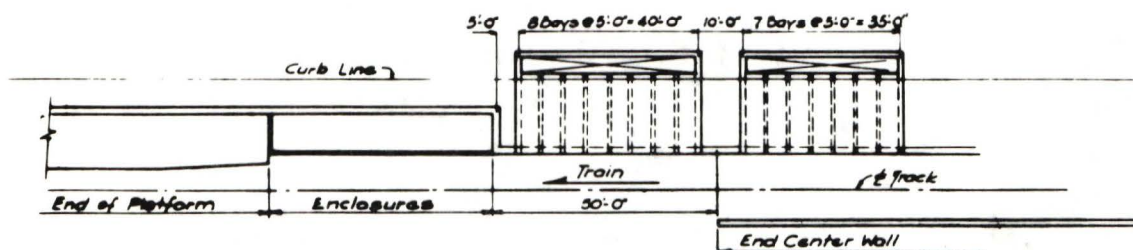
VENT SHAFT THRU SIDEWALL
(FLUE UNDER ROADWAY)



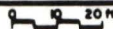
PREFERRED

CONDITION AT FIRE HYDRANT OR LIGHT POLE

LAYOUT OF STANDARD BANK OF 8 VENT SHAFTS

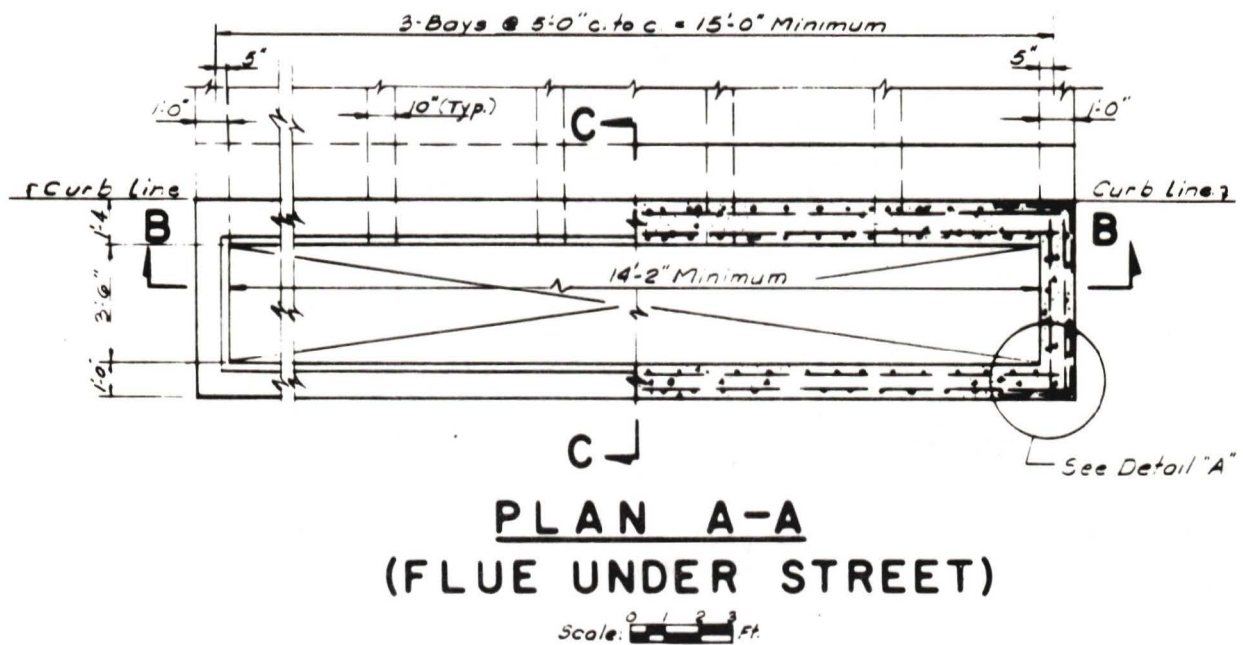
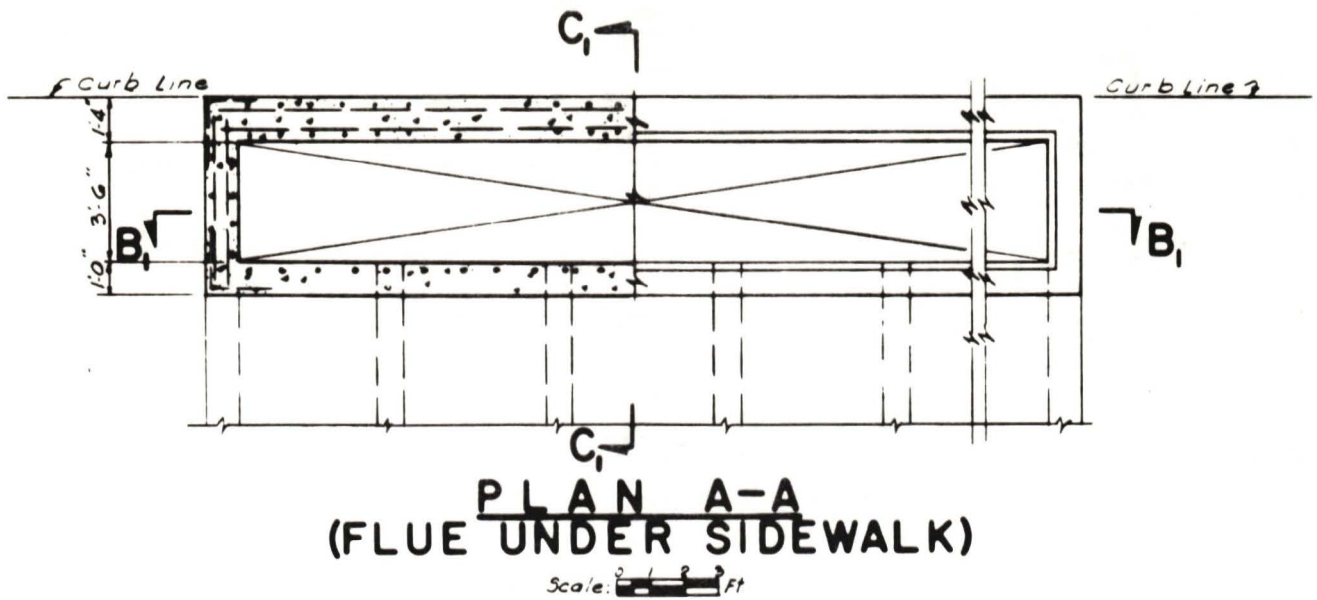


LOCATION OF BLAST SHAFT GRATINGS



CROSS REFERENCES

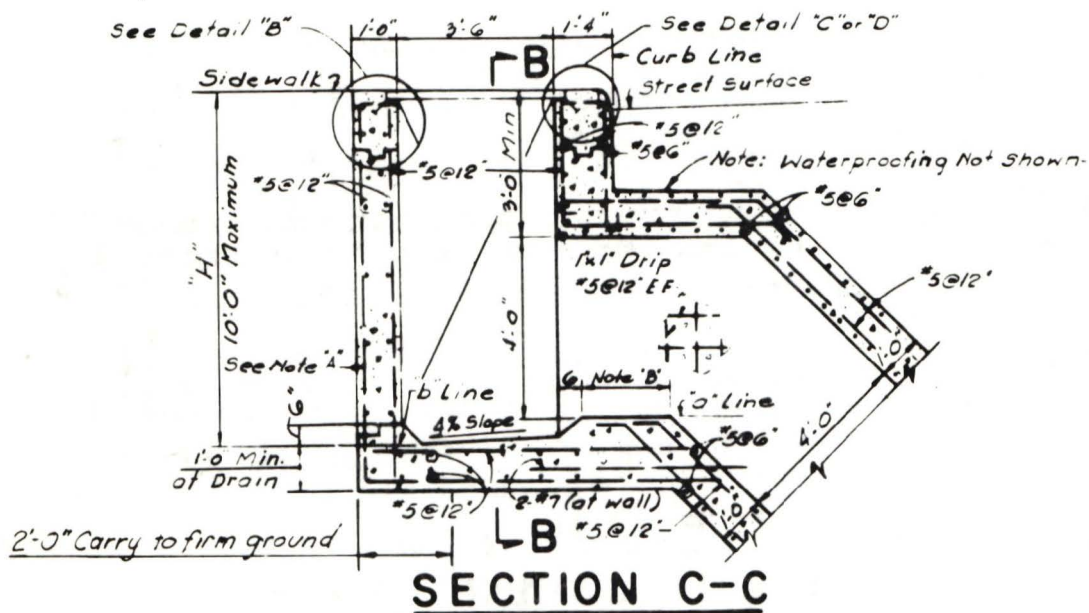
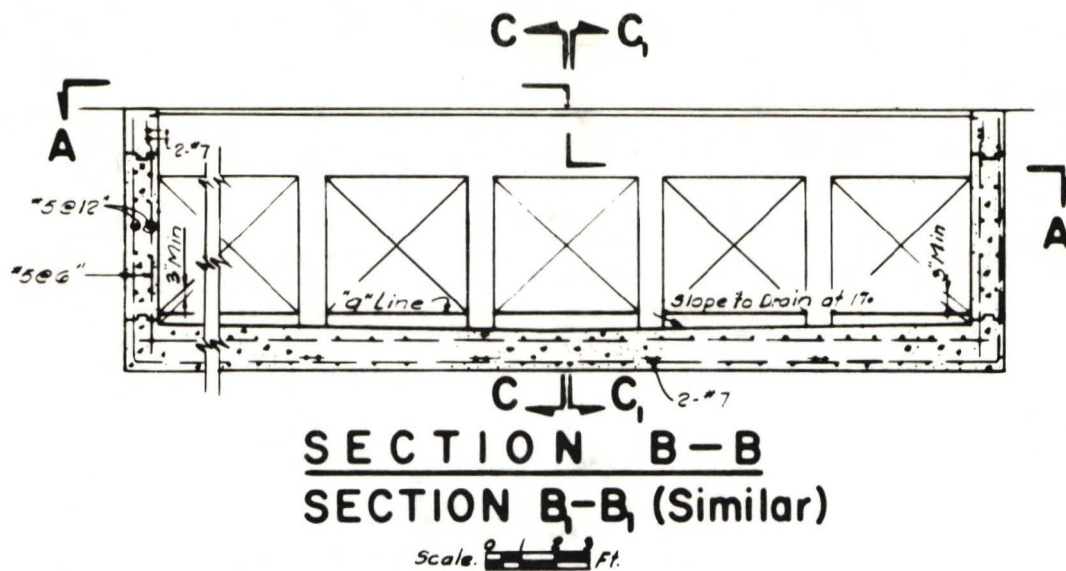
- For Standard Vent Shaft
Construction Details - - - - See Pages SD-8-5, SD-8-6, SD-8-7
- For Modified Vent Shaft
Standards - - - - - See Pages SD-8-8, SD-8-9, SD-8-10
- For Modified Vent Shaft
Construction Details - - - - See Pages SD-8-11, SD-8-12, SD-8-13



CROSS REFERENCES

For Sections B-B, B₁-B₁ & C-C----- See Page SD-8-6
 For Section C₁-C₁ ----- See Page SD-8-7
 For Detail "A" ----- See Page SD-8-7

STANDARD VENT SHAFT CONSTRUCTION DETAILS
 SD-8-5

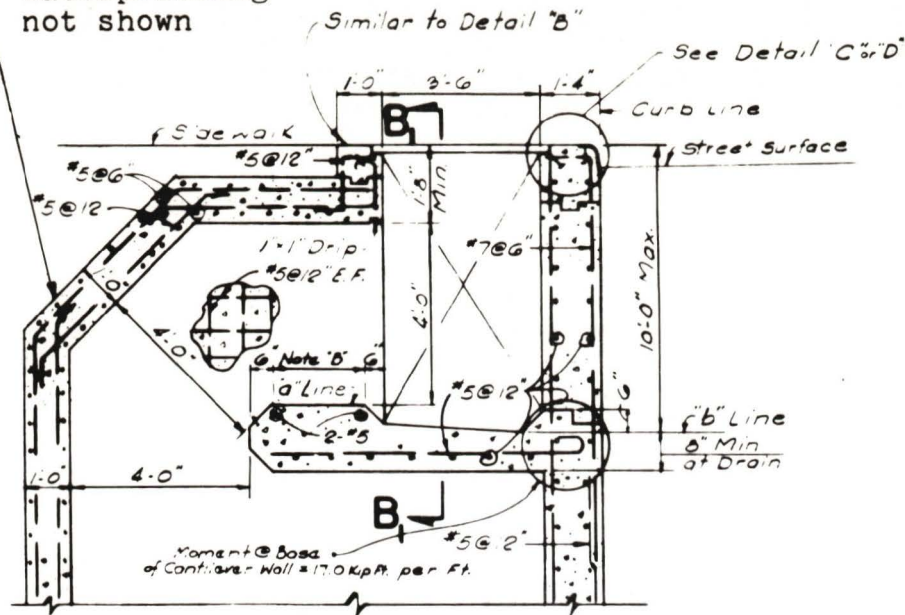


CROSS REFERENCES

For Plan A-A----- See Page SD-8-5
 For Details "B", "C" & "D" See Page SD-8-7
 For Drip Pan Drainage - - - - - See Design Criteria
 for Hydraulics
 For Waterproofing - - - - - See Pages SD-7-2, SD-7-3

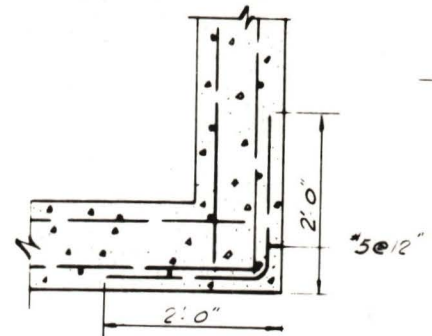
STANDARD VENT SHAFT CONSTRUCTION DETAILS

Note:
Waterproofing
not shown



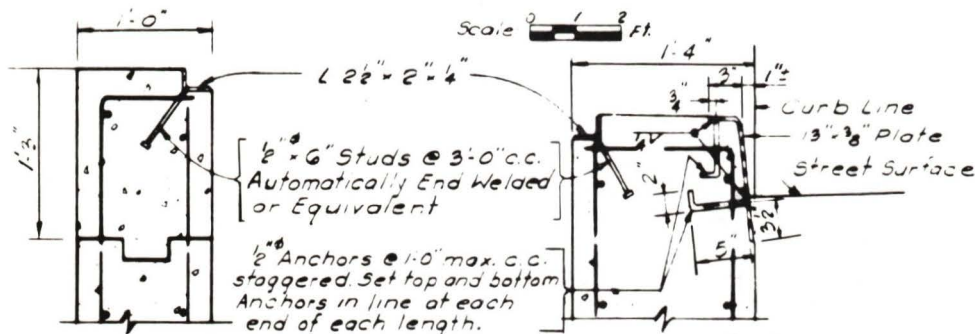
SECTION C-C

Scale: 0 1 2 Ft.



DETAIL "A"

Scale: 0 1 2 In.



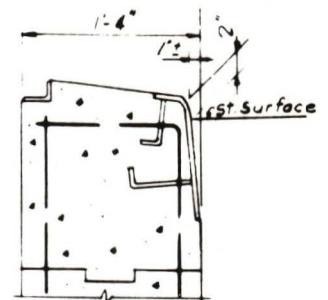
DETAIL "B"

Scale: 0 1 2 In.

DETAIL "C"

TYPE "D" STEEL FACED CURB

Scale: 0 1 2 In.



DETAIL "D"

TYPE "D" STEEL FACED CURB
AT DRIVEWAYS

Scale: 0 1 2 In.

CROSS REFERENCES

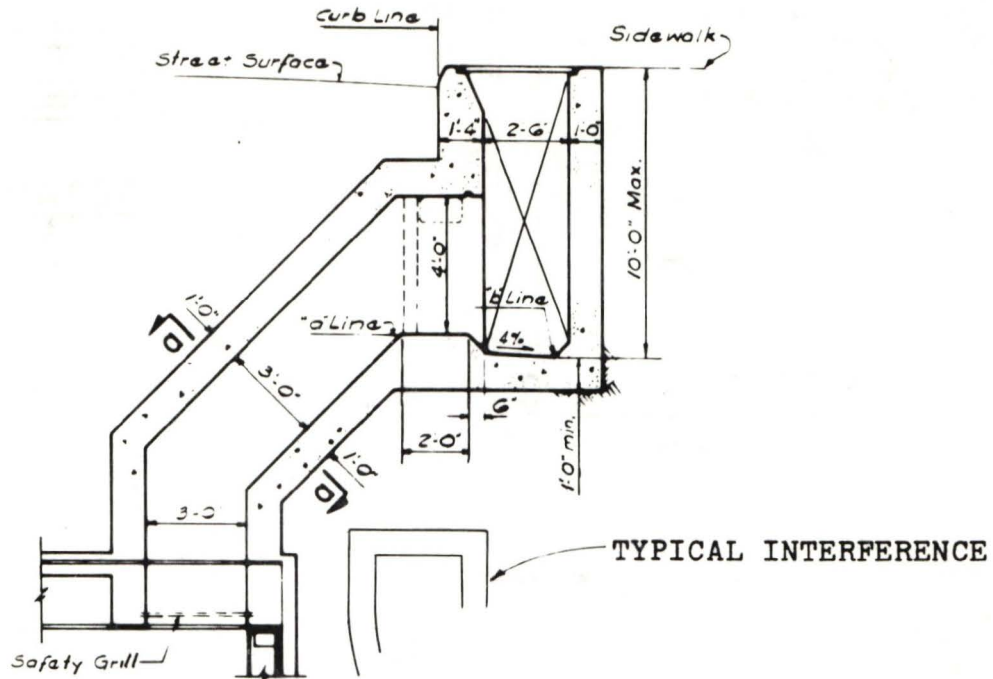
For Section B, -B, ---- See Page SD-8-6
For Note "B" ----- See Page SD-8-6
For Drip Pan Drainage - - - - - See Design Criteria
for Hydraulics
For Waterproofing - - - - - See Pages SD-7-2, SD-7-3

STANDARD VENT SHAFT CONSTRUCTION DETAILS

SD-8-7

NOTE:

THE MODIFIED VENT SHAFT SHOWN ON PAGES SD-8-8, SD-8-9 & SD-8-10 SHALL BE USED ONLY WHERE THE SIDEWALK WIDTH IS LESS THAN 13 FEET, OR WHERE UTILITY RESTORATION PRECLUDES THE USE OF THE STANDARD VENT SHAFT CONFIGURATION SHOWN ON PAGES SD-8-2 & SD-8-3



MODIFIED VENT SHAFT
THRU ROOF

(FLUE UNDER ROADWAY)



NOTE:

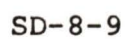
THE MODIFIED VENT SHAFT SHOWN ON THIS SHEET SHALL BE USED ONLY WHERE THE SIDEWALK WIDTH IS LESS THAN 13 FEET, OR WHERE UTILITY RESTORATION PRECLUDES THE USE OF THE STANDARD VENT SHAFT CONFIGURATION SHOWN ON PAGES SD-8-3, SD-8-4, SD-8-5

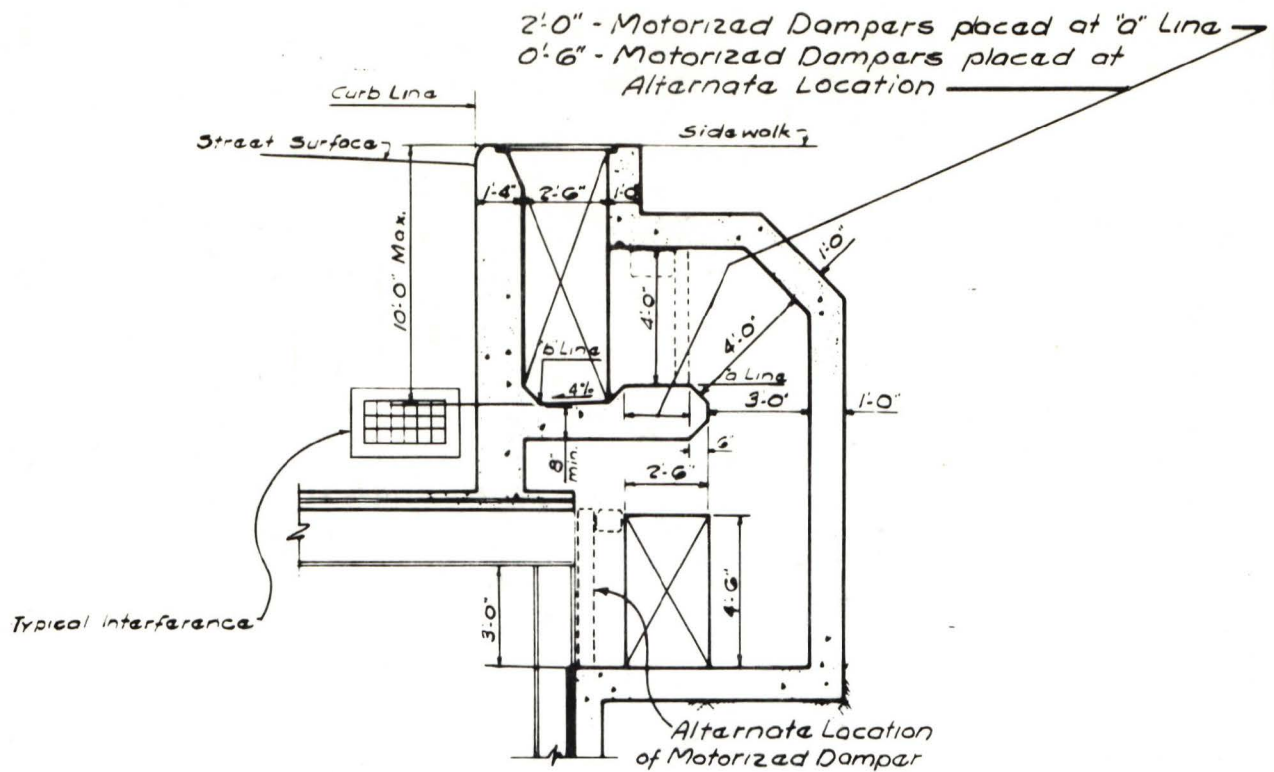
CROSS REFERENCES

FOR SECTION a-a - - - - - SEE PAGE SD-8-9

**FOR MODIFIED VENT SHAFT
CONSTRUCTION DETAILS - - - - SEE PAGES SD-8-11, SD-8-12, &
SD-8-13**

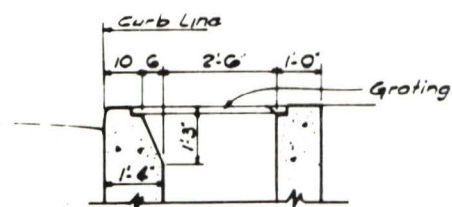
MODIFIED VENT SHAFT CONSTRUCTION STANDARDS





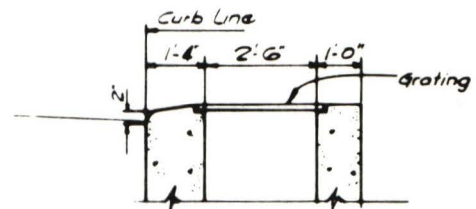
**MODIFIED VENT SHAFT
 THRU SIDEWALL
 (FLUE UNDER SIDEWALK)**

0 1 2 3'



Modified Vent Top Detail

0 1 2 3'

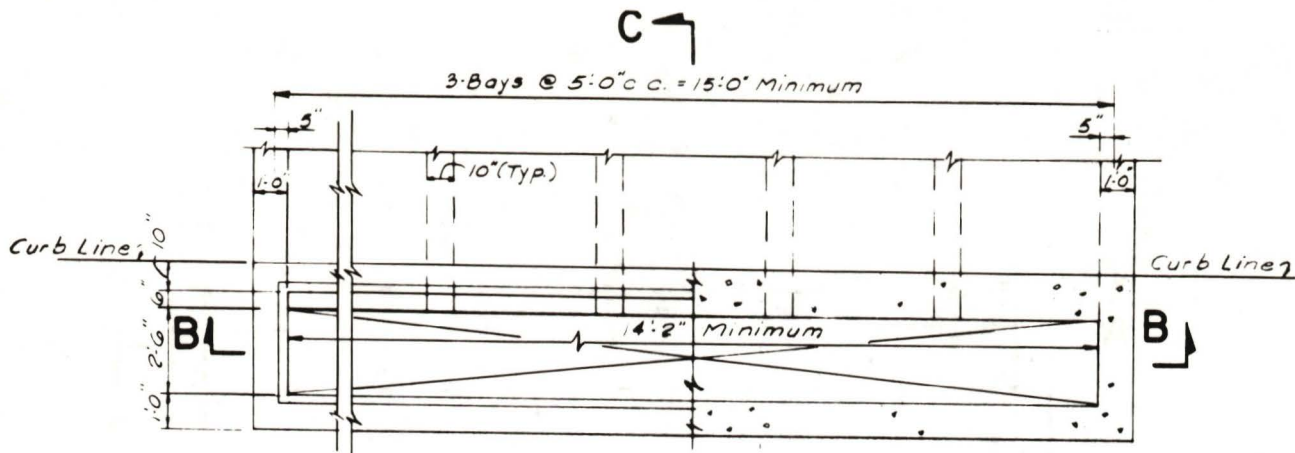


Modified Vent Top Detail
 at Driveway

0 1 2 3'

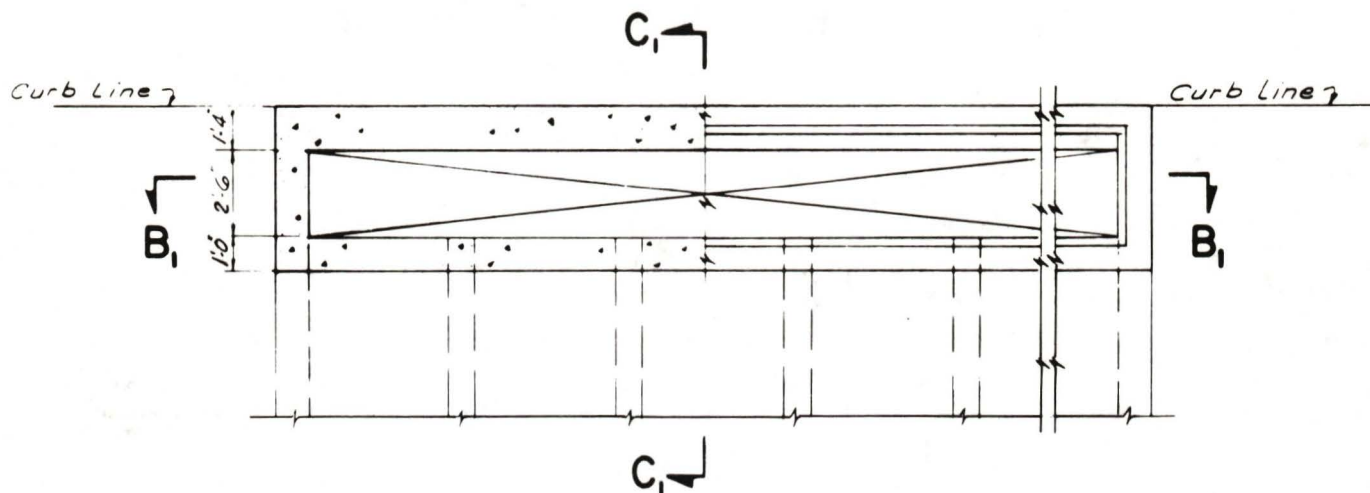
MODIFIED VENT SHAFT STANDARDS

SD-8-10



PLAN A-A
(FLUE UNDER STREET)

Scale: 0 1 2 3 Ft.



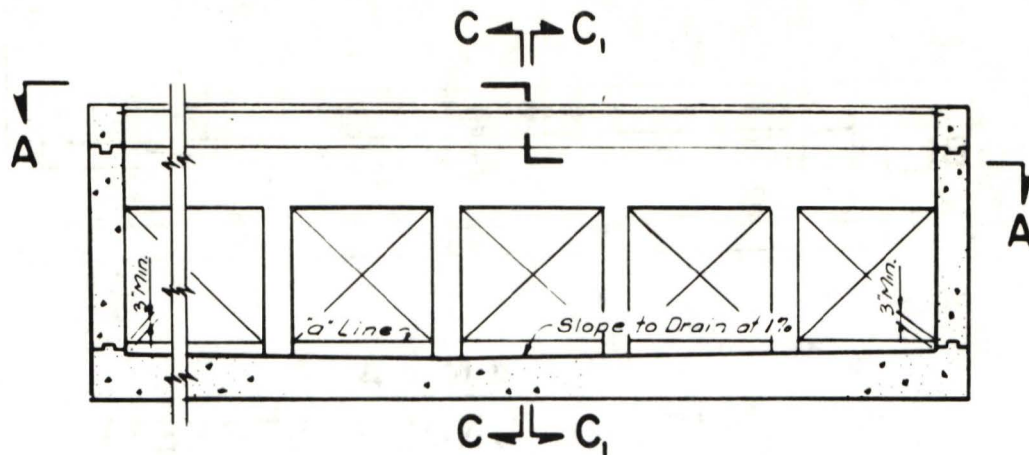
PLAN A-A
(FLUE UNDER SIDEWALK)

Scale: 0 1 2 3 Ft.

CROSS REFERENCES

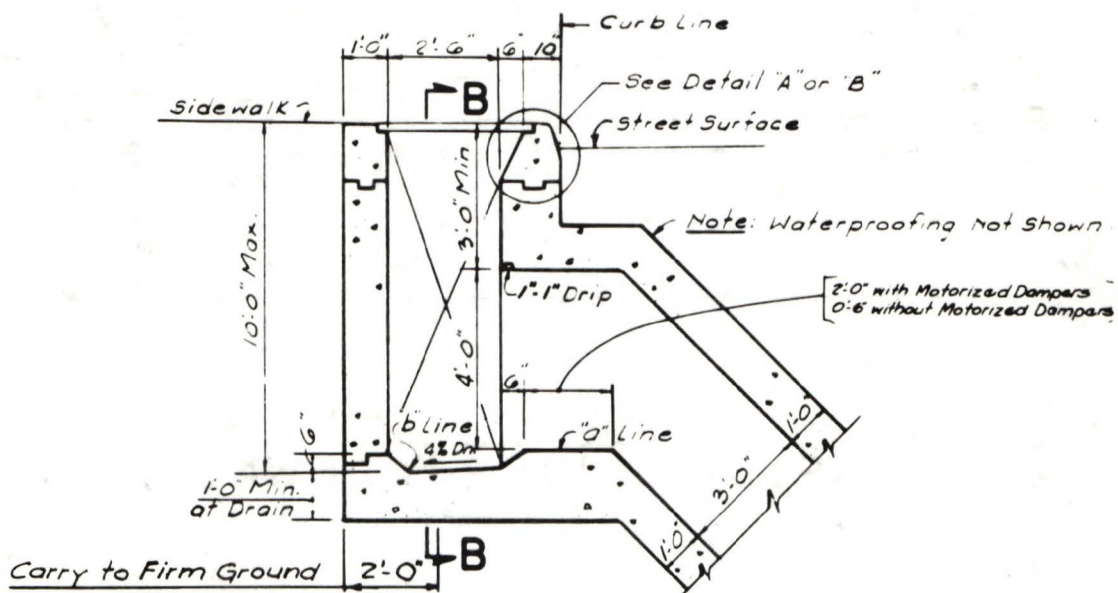
For Sections B-B, B ₁ -B ₁ , & C-C	See Page SD-8-12
For Section C ₁ -C ₁ -----	See Page SD-8-13
For Reinforcing-----	See Note on Page SD-8-13

MODIFIED VENT SHAFT CONSTRUCTION DETAILS



SECTION B-B
SECTION B-B, (Similar)

Scale: 0 1 2 Ft.



SECTION C-C

Scale: 0 1 2 Ft.

CROSS REFERENCES

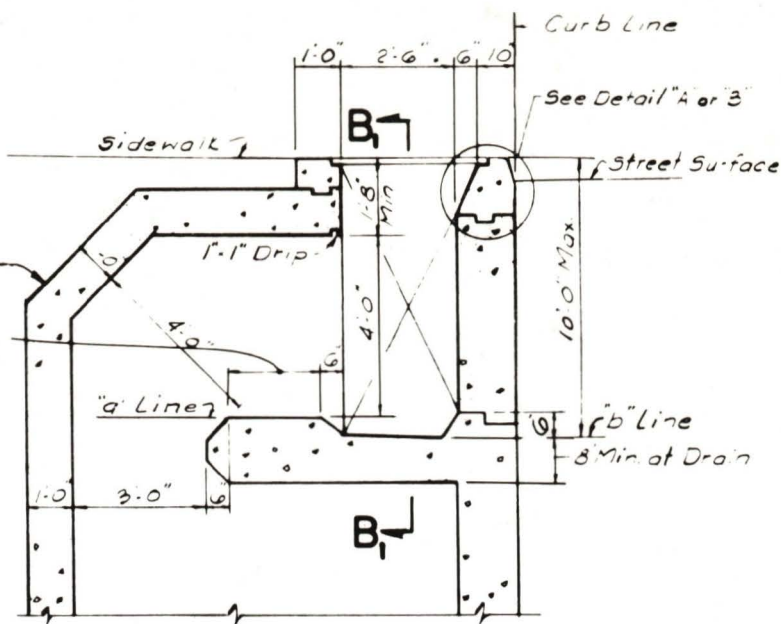
For Plan A-A	See Page SD-8-11
For Section C,-C,	See Page SD-8-13
For Details "A" & "A"	See Page SD-8-13
For Reinforcing	See Note on Page SD-8-13

MODIFIED VENT SHAFT CONSTRUCTION DETAILS

SD-8-12

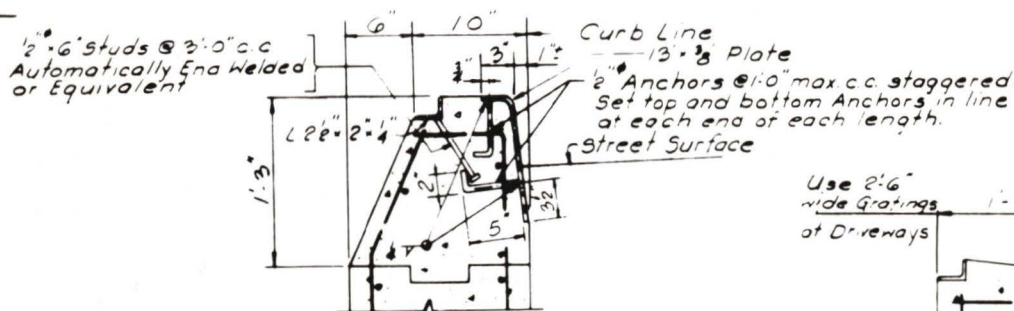
Note:
Waterproofing
not shown

2'-0" with Motorized
Dampers
0'-6" without Motor-
ized Dampers



SECTION C-C

Scale 0 1 2 Ft

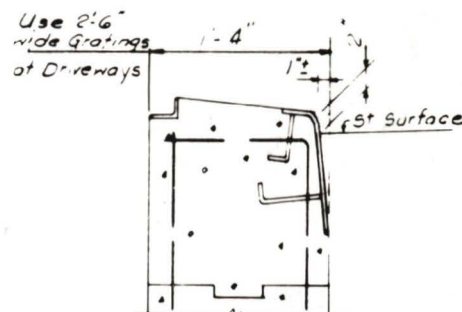


DETAIL "A"

TYPE "D" STEEL FACED CURB

Scale 0 4 8 In.

NOTE:
FOR LOCATION AND SIZE OF
REINFORCING RODS SEE
SIMILAR PLANS AND SECTIONS
ON PAGES SD-8-5, SD-8-6 & SD-8-7.



DETAIL "B"

TYPE "D" STEEL FACED CURB AT DRIVEWAYS

Scale 0 4 8 In.

FOR SECTION B₁-B₁----- See Page SD-8-12

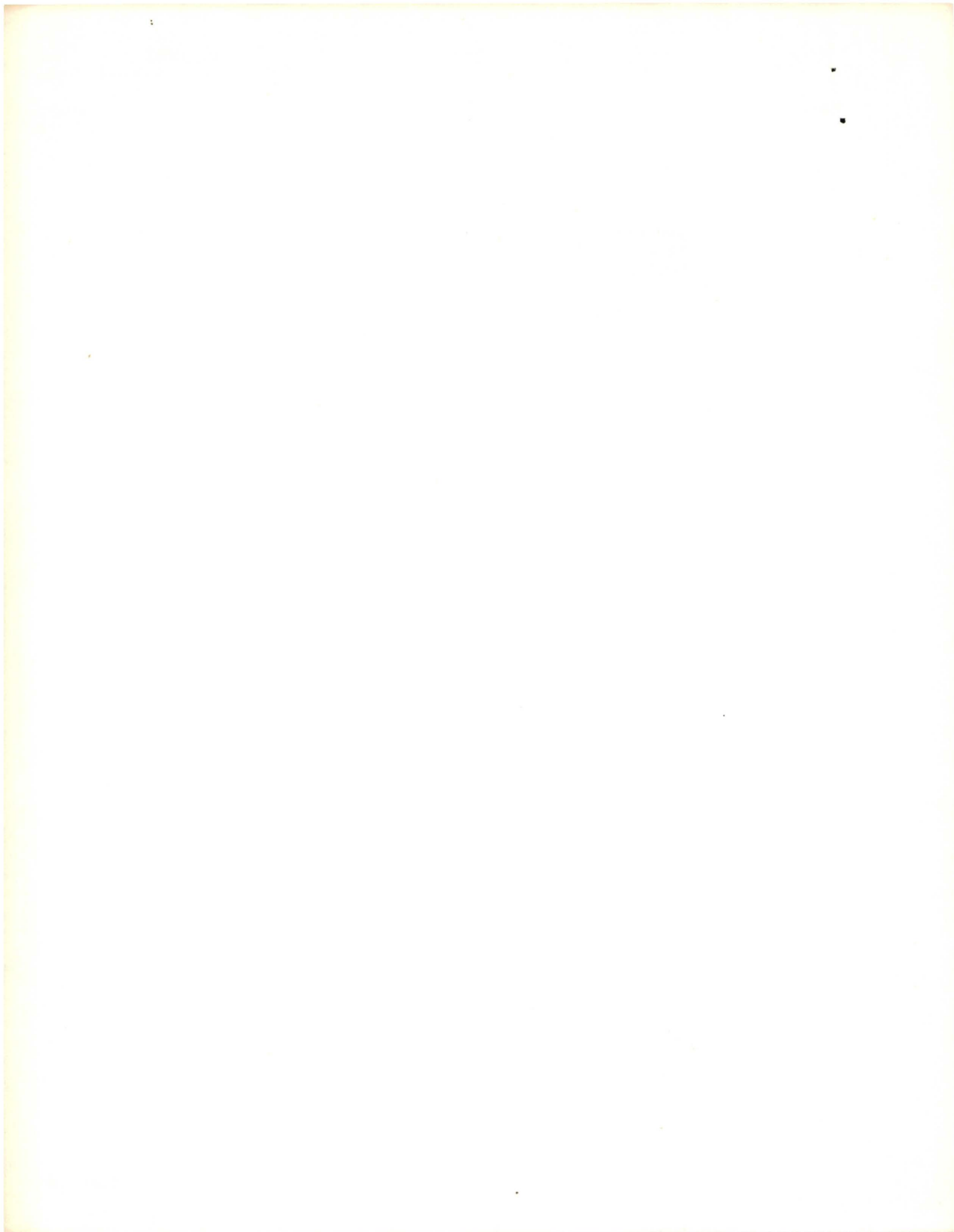
MODIFIED VENT SHAFT CONSTRUCTION DETAILS

S.C.R.T.D. LIBRARY

STATION PLANNING GUIDELINES



Addendum No 1
May 1975



INTRODUCTION

These Standards for Station Planning are designed to provide guidance to the Project Architect during the process of initial planning and design. It furnishes the basic criteria applicable to stations with which the Project Architect should be familiar.

Stations consist primarily of space, equipment and people. It is the task of the Project Architect to integrate the people with the space they pass through and the equipment they use and view. The station design should therefore be one which satisfies the operational needs of the transit system and the aesthetic needs of the passenger.

These Standards do not constrain the imagination of the Project Architect, instead they permit and encourage him to evolve the best design possible within budgetary constraints by coordinating all the elements in a pleasing and meaningful way.

If it should become necessary or desirable for the Project Architect to deviate from these Standards he must substantiate the need for the deviation and submit the proposal to the Transit Authority Executive Officer for approval.

CHIEF ARCHITECT

PAUL KATZ

AUTHOR

ISAAC
LAWRENCE ~~ISAAC~~

- When platform columns are required the minimum distance between a column and the platform edge shall be 5'-0".
- All accessories required for the operation of the transit system and exposed within the station (ie. conductor's board, signal equipment, antennas, etc.) are to be incorporated into the total design.
- Provide platform edge and warning strip as per standard TA design.
- All above ground stations are to be provided with full length canopies and full length windbreakers.
- All platform and mezzanine columns must be fire-proofed when located within property lines.
- Platform and mezzanine steel columns may be enclosed.
- All approaches to vertical circulation on above ground platforms are to be provided with electric snow melters.
- All station sidewalls adjacent to a track are to be provided with "grab bars".
- Grab bars are to be of ^{1 1/2"}~~1 1/2~~ inch round ^{non-metallic}~~stainless~~ ~~steel~~ ^{24"} ~~15~~ inches long, spaced ^{vertically?} ~~10'-0"~~ ^{15'-0"} on center. (standard TA design)
- Grab bars are to be mounted 5 foot from floor (base of rail or toe bench) to bottom of bar.

G. EMERGENCY FACILITIES

Fire Lines

- Wet fire lines are to be installed in each station with siamese inlet standpipe connections at street level ^{closest to the station meter room, 2'-0" from the building line recessed into the sidewalk.} ~~near station entrance~~ conforming to Fire Department standards.
- The wet fire lines are to be situated in a manner which will provide three (3) hose valves per platform. They are to be recessed in a fire hose cabinet (Standard TA Design) in the station sidewall at side platforms and

I. SEATING

TYPES

- Individual seats grouped.
- Benches with separators for individual seating.
- Benches and seats are to have replacable units.

LOCATION

- Within control areas.
- Along platform as required.
- Arranged not to interfere with passenger circulation.

J. PIPE IDENTIFICATION

- To be coded as per TA standards.

K. TOILETS

TYPES

- Public toilets for men and women at transfer and major stations only.
- ~~One~~ Employee toilets, ~~per station~~, as required.
- Crew room toilets with provisions to suit each specific situation.

GENERAL REQUIREMENTS

- Public toilets shall have an attendant station, supervising both the mens and womens toilets.
- With provisions for closing the facility at night.
- All public toilets to be located in the paid area of the station, preferrably within view of the token agent.
- All stalls are to have coin locks.

HANDICAPPED REQUIREMENTS

- Each public toilet (men & ladies) shall have one stall with the following requirements:
 - Width: ~~3'-0"~~ 6'-0"
 - Depth: ~~4'-8" minimum~~ 5'-0" ~~preferred~~
 - Door width: ~~2'-8"~~ 2'-8" swing out, not to interfere with access to other stalls.
 - Handrails on ~~each~~ interior side of the stall, 33" high and parallel to the floor, 1-1/2" clearance

between rail and wall, fastened securely at ends and center of rail.

- Water closet with seat 20" from the floor.
- Stall to be identified with appropriate graphics.

L. PUBLIC TELEPHONES (STANDARD TA DESIGN)

- Public telephones within view of the token agent are to be provided in and outside of the paid areas of the station.
- The Telephones shall have a '911' emergency provision.
- One phone to be provided for the hard of hearing and shall be identified with appropriate graphics.
- Provisions for public telephones are to be provided at the station platforms.

M. ADVERTISING (STANDARD TA DESIGN)

LOCATION

- Not to conflict with graphics.
- To be treated as elements within the total station design concept.
- To be grouped in selected areas.

N. CONCESSIONS (STANDARD TA DESIGN)

LOCATIONS

- Not to obstruct passenger flow or interfere with the operation of transit facilities.
- Accessible to normal passenger flow.
- Concessions not permitted on platforms.
- Not to interfere with other concessions or advertising.
- All concessions to be observable by the token agent.

GENERAL REQUIREMENTS

- Automatic vending must be within view of the token agent and is to be grouped in units of an approved modular design.
- All manned concessions and storage areas to be provided with ~~sprinkler systems~~ fire protection as per TA standard.
- Concessionaires are to use rubber-tired dollies and hand trucks only rather than steel wheeled which tend to damage stair and floor finishes.
- Areas chosen for concessions are to be designed as part of the total station concept and not as an after-thought.
- Wet vending is not permitted, however areas designated for vending are to be provided with concealed utility connections including required drainage facilities.

O. MAINTENANCE, SERVICE & EQUIPMENT ROOMS

The following rooms shall be provided as required. For heating, ventilation and air cooling requirements, see ventilation and air cooling standards.

EQUIPMENT ROOMS

- Electrical Distribution Room (normal and reserve)
- Ejector Pit
- Electrical Duct Manhole
- Central Instrument Room
- Pump Room (with ~~pump~~ below) ↑ sump
- Relay Room
- Circuit Breaker House
- Fan Room
- Climate Changer Room (with adjacent ~~Stationary~~ Maintenance Personnel
~~Engineers~~ Room)
- Moving Stair Machinery & Pit Areas
- Panel Board Room
- Telephone Compartment Room
- Radio Base Station Room
- Other Areas as required

SERVICE ROOMS

- First Aid Storage Closet (for medium station)
- First Aid Treatment Room (for major station)
- Storage Rooms
- Dispatcher's Office
- Police Quarters
- Toilets, Public & Employee
- Other Areas as required

MAINTENANCE ROOMS

- Porter's Closet (mezzanine & platform)
- Refuse Disposal Area
- Track Lubrication Room
- Maintainer's Quarters (for Signals, Tracks, Power, Structure & Line Equipment Groups)
- Dressing & Locker Room
- Utility Room (for automatic floor scrubber)
- Other Areas as required

P. DOOR SIZE AND TYPES

- All doors 3'-0"x7'-0" with louvers except-

- Ejector Pit - louvered double doors
4'-0" x 7'-0"
- Fan Room - dust tight sliding door
3'-6" x 7'-0"
- Pump Room - non-louvered sliding door
4'-0" x 7'-0"

ELECTRICAL DISTRIBUTION ROOM

General

Personnel doors

- 3'-0" x 7'-0" H.M. Class 'A' Fire Door
- panic hardware
- swing out
- dustproof (as permitted by U.L.)

Equipment doors

- pair of 4'-3" x 8'-0" H.M. Class 'A' Fire doors, swing out
- or - 8'-6" wide x 8'-0" high Class 'A' rolling fire door
- dustproof (as permitted by U.L.)

Requirements for rooms located above tracks

- Personnel - Two doors located at opposite ends of room
- Equipment - Removable floor hatch (8'-0" x 10'-0")

Requirements for rooms located adjacent to track duct bench

- Personnel - Two doors located at opposite ends of room
- Doors are to be ~~recessed~~ **recessed** when opening on to duct bench
- Equipment - Rolling Door
- Drum located on interior side of room

All other locations

- Personnel - Two doors located at opposite ends of room
- Equipment - Pair of H.M. doors

U. TOKEN BOOTHS

At each station, one token booth shall be designated as the Master Token Booth and shall be equipped with public address and TV facilities as described above in Paragraphs ~~7~~ ^(G, R) and T.

In addition, each token booth shall have the following communications equipment:

Each booth shall be provided with a telephone.

Each booth shall be provided with a public intercommunication system. This system shall permit the booth agent to talk to people at the selling window. A separate amplifier shall be provided for each selling window. All required equipment for this system shall be installed in the booth.

Each booth shall be provided with a Station Department intercommunication system. This system shall enable the booth agent to communicate with designated field supervisors and with Jay Street Station Department headquarters. The auxiliary equipment required for this system shall be installed in the Telephone Compartment Room. T.A. cable shall be used to connect the booth agent to field supervisors and Jay Street.

In addition, the following communications equipment may be required in token booths:

At outdoor stations, where required, emergency alarm equipment shall be installed in a designated token booth.

Where elevators are installed in stations, an elevator intercommunication unit shall be installed in a designated token booth.

V. TELEPHONES AND MISCELLANEOUS EQUIPMENT

Telephones shall be provided in rooms as required (e.g., Relay Rooms, Signal Rooms, Crew Rooms, Dispatcher's Offices, Electrical Distribution Rooms, Equipment Rooms of various types, etc.) and on station platforms.

- Minimum clearance: 2-1/2" between edge of hand-rail and wall.
- Handrails and Center Stair Railings are to be 3'-0" high above landings and continuous through all intermediate landings.
- Extend handrails 18" beyond top and bottom risers wherever possible, however, no less than 12" is permitted.
- Handrails for both sides of a stair.
- Maximum stair width without Center Railing: 7'-4".
- Handrail end shall return to wall.
- Minimum height of railing around stair well opening: 3'-8".
- Stair trough- TA Standard.

GENERAL STAIR CRITERIA

- Stairways shall not merge into stairways of lesser capacity unless provisions for future widening are included.
- In high density and/or traffic areas provide a minimum of four entrances per control area.
- Where stairs occur alongside a moving stair, the nosing line should be set to match the slope of the moving stair and the stair situated in a manner that the handrail remains below the moving stair deck plate.
- ~~Bottom~~ Bottom and top riser of each stair run^{to be} yellow as per TA standards.

2- MOVING STAIRS

- GENERAL REQUIREMENTS
- Escalation is to be provided by including at least one up and one down moving stair from street to mezzanines, galleries and platforms in addition to normal stair requirements.

Moving stairs to and from street level are to be located at the point of greatest passenger traffic wherever possible.

- Speed: 90 & 120 feet/minute.
- Reversible moving stairs.
- Automatic starting treadle, top and/or bottom, where and when specified.
- Access to machinery rooms and moving stair pits outside of passenger flow wherever possible.
- Emergency shut-off switches at head and base of moving stair and in nearest full time token booth.
- All escalators shall have sprinkler systems.
- Handrails are to be black and are to have white circular inserts spaced approximately 2'-0" on center.

3- ELEVATORS FOR THE HANDICAPPED

- Each station is to be provided with an elevator from the street to the mezzanine and from the mezzanine to each platform. Design criteria as per TA standards.

4- RAMPS

REQUIREMENTS FOR USE BY THE HANDICAPPED

- Slope of ramp: 5% maximum
- Maximum ramp length: 30'-0"
- Minimum intermediate landing length: 3'-0"

GENERAL REQUIREMENTS

- Slope of ramp: 8% maximum.
- Width determined by projected patronage.
- Continuous handrails along both sides.
- Provide electric snow melters for exterior ramps.
- Provide drainage.

SP-3-4

Rev. May 75



Chapter 4

LIGHTING

1-GENERAL ~~CRITERIA~~ REQUIREMENTS

Lighting should be of a nature and type applicable to a rapid transit station. Passenger safety and ease of maintenance should be given prime consideration. The following criteria should be considered minimum and varied to allow the lighting to complement the station design concept.

CONCEPT

- Illumination levels within any major area should be varied to create interest and to point out specific local area functions. Similar functions should have the same illumination levels throughout the station. Typical areas to be emphasized.

would be platform edges, tops and bottoms of stairways and moving stairs, token booths, information signs, etc. Glare from lighting sources should be kept to a minimum.

FIXTURE CRITERIA

- Enclosed type fluorescent fixtures may be used only in mezzanine and entrance areas.
- Fixtures shall be readily maintainable and fabricated of industrial grade materials to minimize vandalism.
- Mounting positions for fixture shall be permanently fixed after final installation.

LAMP CRITERIA

- Fluorescent and mercury lamps are to be used for all station areas. Incandescent lamps may be used only in pipe chambers, escalator enclosures, equipment and maintenance areas, etc.
- Mercury lamps may be utilized for special application and effects and not for broad general application. The mercury lamp is to be a non-reflector type, phosphorous coated of 100,175 and 250 watt sizes.
- Fluorescent lamps shall be ^{cool white} ~~warm white~~ only of 4 foot and 6 foot lengths.

ILLUMINATION LEVELS

- The listed illumination levels are average, maintained, in service values with a floor working plane and Maintenance Factor of 0.65.

AREA	ILLUMINATION LEVEL (fc)
- Platform, below ground	20
- Platform, above ground with canopy	15
- Platform, above ground without canopy	5

4- REFERENCES

- Guidelines and Principles For Design of Rapid Transit Facilities - May 1973
Institute For Rapid Transit
~~Draft Copy - December 1971~~
- IES Lighting Handbook
Illuminating Engineering Society

Chapter 7

REFUSE DISPOSAL

RECEPTACLES

1. REFUSE ~~RECEPTACLES~~ FOR PASSENGER USE (STANDARD TA DESIGN)

- To be located in all station areas accessible to the passenger.

2. DISPOSAL SITES FOR COLLECTED REFUSE

TYPES

- Island Platform
- Side Platform
- Terminal Station

3. LOCATION

The disposal site is to be located in an extended area beyond one end of the passenger portion of the station platform.

ISLAND & TERMINAL PLATFORMS

- one per platform
- location to be designated

SIDE PLATFORMS

- one per platform
- located at outbound end

4- SIZE OF DISPOSAL SITE

- Clear Height: same as platform
- Length: 15'-0" minimum
- Width: platform width less clearance for tunnel walkway

5- EQUIPMENT & ACCESSORIES

BALING MACHINE

- one machine
- used only at sites generating a high volume of refuse

REFUSE CANS OR ROLL-ONS

- as required

VENTILATION

- positive system

SPRINKLER SYSTEM

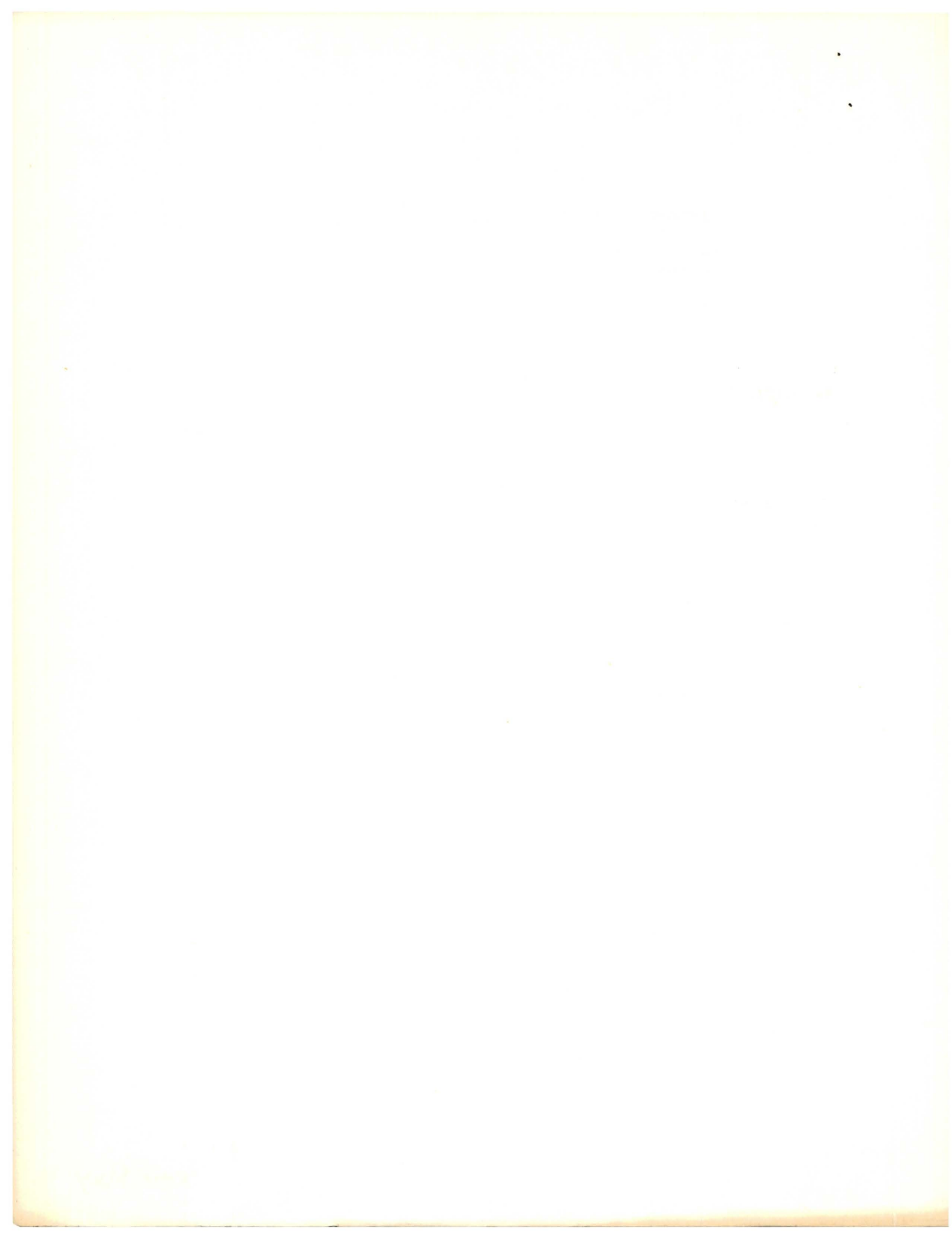
- connect to domestic supply

FLOOR DRAINS

- provide sedimentation bucket
- connect to track drainage

HOSE BIB~~X~~

- one at each site



ELECTRIC CIRCUITRY

- include provision for baling machine at each site

SAND BOX

- one at each site

LIGHTING

6- ENCLOSURE TREATMENT

Platform End Wall:

- Horizontal closing door with side coiling box against or recessed into wall or suitable alternative.

Track Side:

- Overhead rolling shutter door operated manually from the duct bench.
- Alternate: 5'-0" high masonry wall with 5'-0" opening for access to disposal site.

Interior Finish:

- Concrete wall surfaces to receive epoxy paint to provide easy maintenance.
- Ceiling and floor surfaces to be dust proof.

7- GENERAL REQUIREMENTS

TOOL ROOM

at terminal

- include a 12'x12' room ~~at terminal~~ stations for car cleaner tools.
- whenever battery charging is included, provide a mechanical exhaust system.

DISPOSAL OF REFUSE

- Collected refuse will be transferred onto work trains. These trains in turn will transfer the refuse at disposal yards to private collectors.



- Environmental Control
- Graphics Standards Manual

3- TYPICAL STANDARDS FOR STATION AMENITIES

- | | |
|--------------------------------------|---|
| - Exit Gates | - Part Time Entrance Barrier |
| - Turnstiles | - Temporary Entrance Enclosure |
| - Advertising | - Track Wall Grab Bar |
| - Concessions | - Parapet Safety Barrier |
| - Railings & Handrails | - Hydraulic Elevator |
| - Telephones | - Elevator Cab |
| - Utility Cabinets | - Elevator Rail |
| - Conductor's Starting Light | - Escalator and Stair Landing |
| - T.V. Surveillance | - Escalator Treadle |
| - Passenger Address System | - Escalator Module, Rail & Emergency Stop |
| - Refuse Receptacles | - Station Names and Locations |
| - Illuminated Entrance Post | - Graphics for Temporary Entra. Enclosure |
| - Token Booth | - Hardware |
| - Stair Trough | - Standard Stair Tread |
| - Track Wall fin. & drainage details | - Antenna |
| - Platform Edge | - Free Standing Illum. Advert. Panel |
| - Utility Access Cover | - Plug-in Illum. Advert. Panel |
| - Manifold Cabinet | - Platform drain. |
| - Toilet for the Handicapped | |

4- CODES & REGULATIONS

- The New York City Building Code is not applicable in transit station design, but can be used as a guide in areas not specifically covered by the Transit Authority Structural Design Standards or these Station Planning Standards.
- All plumbing work approvals and permits shall be obtained from the Department of Water Resources and Bureau of Water Pollution Control, subsidiaries of the Environmental Protection Administration.

05164

S.C.R.T.D. LIBRARY