PROGRESS REPORT

MASS RAPID TRANSIT PROGRAM

LOS ANGELES METROPOLITAN TRANSIT AUTHORITY

VOLUME 2, TECHNICAL DATA

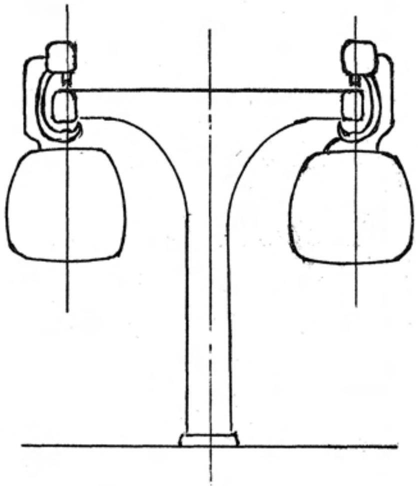
Daniel, Mann, Johnson, & Mendenhall
Planning, Architecture, Engineering

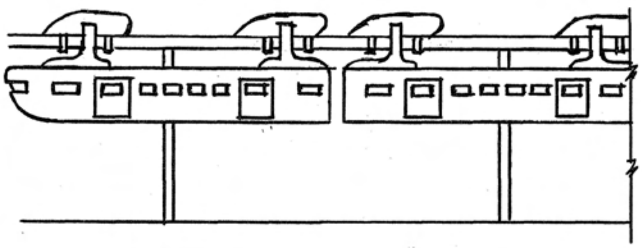
3. SUSPENDED SYSTEMS - ASYMMETRIC

A. Wilbo Industries - MAN

B. Goodell Monorail

C. Greene Monorail





System Type:	ASYMMETRIC SUSPENDED MONORAIL
System:	MAN
Proponent:	Maschinenfabrik Augsburg-Nurnberg A.G.-Germany
Existing Installations:	Wuppertal Line
Type of Use:	For LAMTA Overhead and Underground.
Development Engineering:	Modified existing line and design.
Power System:	Direct current.
Propulsion:	Direct current.
Running Gear:	Double flanged steel wheel.
Guidance:	Inherent guiding, no guide wheels necessary.
Type of Switch:	Special switch, not developed.
Design Speed:	56 miles per hour.
Submitted Sufficient Information:	Substantially complete design and specification.
Reference Material Submitted or on Hand:	Documented description of triple-car suspension railway unit with LAMTA questionnaire fully answered and dated (December 10, 1959).

System Description

The system is the asymmetrical type. The single rail is mounted on a prestressed single concrete beam. Each car has two trucks with two tandem steel double flanged wheels.

The D.C. electric motors are geared to the wheels and the carrier truck is provided with a ball seat to carry its portion of the car weight. The car couplers are attached to vertical weight carriers and swiveled to allow for ease of negotiating curves.

The suspension is pure pendulum type without any restraint and is self-damping in action.

The underside of the concrete beam is provided with a rail. Its function is to limit the car oscillation along the transverse plane on positive stops.

System Evaluation

The asymmetric monorail concept is not suited to application in a complex rapid transit system such as is projected for the Los Angeles area.

The asymmetric feature precludes reasonable accomplishment of necessary operational functions such as cross-overs, turnbacks and other switching functions, without the provision of extensive, costly, duplicate structure.

The train consists of three cars with capacity of 300 standees and 186 seated passengers. Estimated three-car train weight, with equipment, is 55 tons (121,000 lbs.)

The car bodies are suspended from "C" frames on spring mounted spherical bearings in the trucks. The springs are rubber mounted to dampen running noise.

The trucks are equipped with disc brakes and electric track brakes. Dynamic braking is the prime brake. The disc brake actuated by spring is the secondary brake used for parking. Hand braking is possible through the use of the disc brake system.

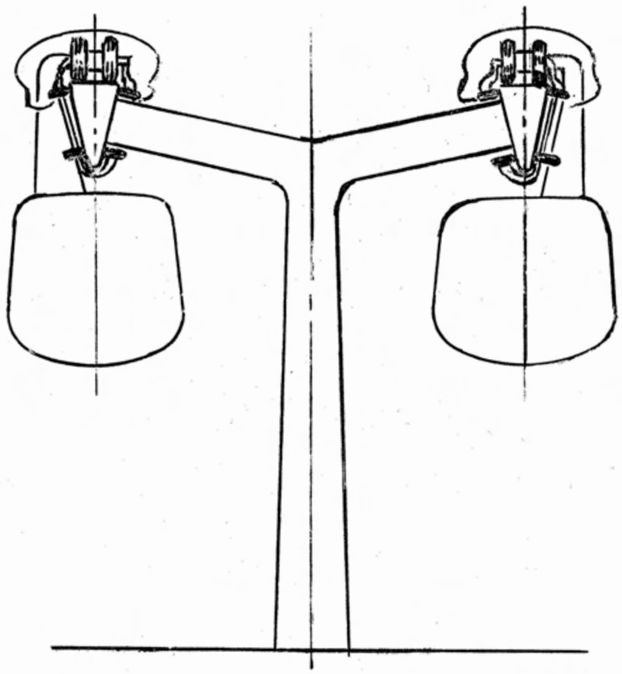
In addition, a magnet rail brake will be provided to ensure fast deceleration. This brake will be energized by battery current. All braking will be arranged to operate by automatic electronic control.

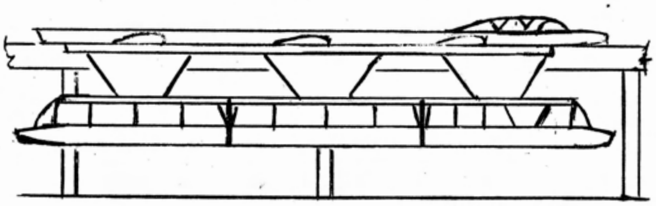
Trucks are suspended on a pair of tandem steel wheels. The wheels are rubber mounted at the hubs to reduce traction noise. Wheels are 31-1/2 inches diameter on tread. There are eight electric motors, each 100 HP per train of three cars.

The transmission gears are fully enclosed spiral bevel gears. The wheels run on rubber mounted standard rail, further reducing the traction noise.

Recommendation

No further consideration should be given to this proposal for application in the LAMTA service area.





Type of System:	ASYMMETRIC SUSPENDED MONORAIL
System:	GOODELL MONORAIL TRANSPORTATION SYSTEM
Proponent:	Goodell Monorail - Western Division
Existing Installations:	Dallas, Texas - fair attraction.
Type of Use:	Foruse LAMTA overhead system.
Development Engineering:	In progress.
Power System:	Electric or combustion engine.
Propulsion:	Not specified.
Running Gear:	Pneumatic rubber tires by Michelin.
Guidance:	Pneumatic rubber guide wheels.
Type of Switch:	Special switch under development.
Design Speed:	80 miles per hour.
Submitted Sufficient Information:	Insufficient information.
Reference Material Submitted or on Hand:	Goodell Monorail four-page brochure; photos of artists' drawings.

System Description

A triangular beam of pre-stressed concrete supports dual traction wheels. Car is suspended from the trucks and is mounted on ball joint pad. Two sets of lateral stabilizing wheels engage the sides of the rail. The propulsion motors are mounted on a yoke which is attached to the top of car.

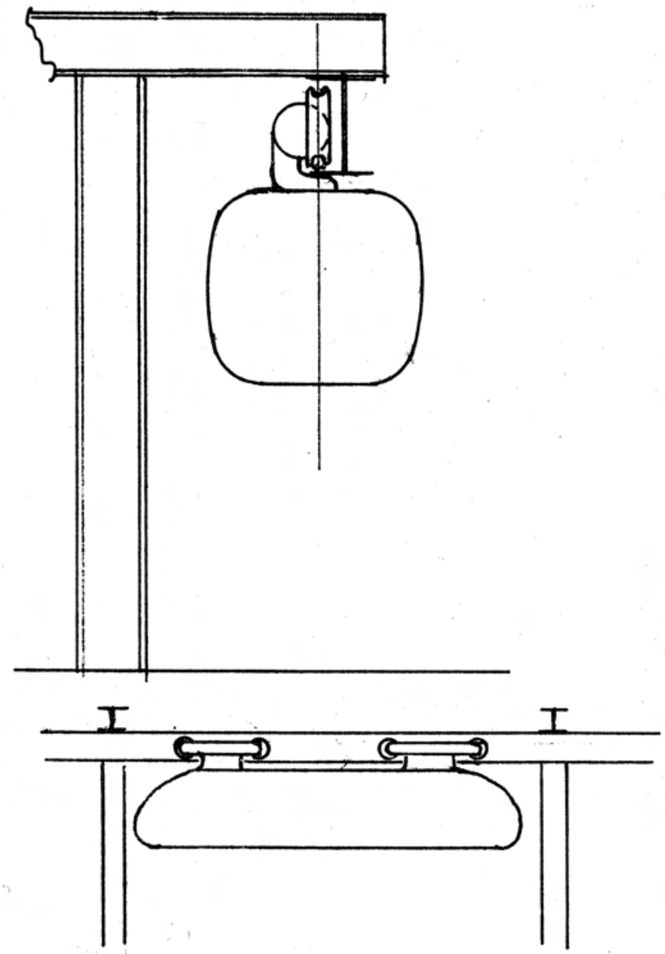
The system is of the asymmetric or classical monorail type, in which the car body is connected to the trucks or bogies by hanger arms located to one side of the supporting beam.

System Evaluation

The asymmetric monorail concept is not suited to application in a complex rapid transit system, such as is projected for the Los Angeles area. The asymmetric feature precludes reasonable accomplishment or necessary operational functions such as cross-over, turnbacks and other switching functions, without the provision of extensive, costly, duplicate structures. Provision in this proposal for reducing sway limits the supporting beam to only one section dimension, thereb effectively limiting span dimensions.

Recommendation

No further consideration should be given to this proposal for application in the LAMTA service area.



Type of System:	ASYMMETRIC SUSPENDED
System:	NON-STOP MONORAIL SYSTEM
Proponent:	GREENE MONORAIL SYSTEMS, LOS ANGELES
Existing Installations:	None
Type of Use:	For LAMTA overhead system.
Development Engineering:	Concept with preliminary cost estimates (based on concept only).
Power System:	Alternating current.
Propulsion:	Electric motors.
Running Gear:	Two truck per car, rubber wheels.
Guidance:	Inherent guiding.
Type of Switch:	Hinged switch blade, not designed. In concept stage only, air operated.
Design Speed:	65 miles per hour.
Submitted Sufficient Information:	Engineering information is not sufficient.
Reference Material Submitted or on Hand:	Brochure (a proposal to LAMTA) dated January 25, 1960. Four-page decitation on rubber tire application to railway wheels; two-page "The Range of 'Michelin' Rail Car Units"

System Description

This proposal indicates use of a modified asymmetrical suspension system. However, all of the limiting factors inherent in the asymmetric concept are present. Other features basic in this system include fully automatic operation of small high-speed cars capable of seating 34 passengers. Car could be stopped at stations only if a passenger wished to leave, or if a person at a station wished to board. This would be accomplished on a push button basis, such as one would use an automatic elevator.

System Evaluation

The asymmetric monorail concept is not suited to application in a complex rapid transit system such as is projected for the Los Angeles area. The asymmetric feature precludes reasonable accomplishment of necessary operational functions, such as crossovers, turnbacks and other switching functions, without the provision of extensive, costly, duplicate structures.

We deem it necessary to have one supervisor per operation unit or train when considering automatic operation, and the number of such supervisors required for the small units proposed for this system would present a tremendous burden in operating costs.

Recommendation

No further consideration should be given to this proposal for application in the LAMTA service area.

4. SUSPENDED SYSTEMS - SYMMETRIC

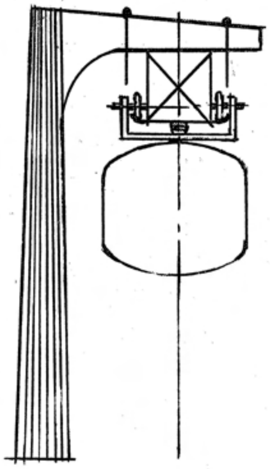
A. Davino Monorail

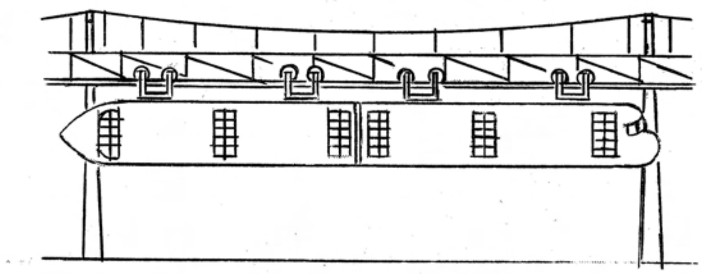
B. S.R.V. Monorail

C. Fussell Monorail System

D. T. R. Webb Combined Carrier

E. A. F. Vinje





Type of System:	SUSPENDED-SYMMETRICAL
System:	DAVINO - DUO-RAIL CATENARY TYPE
Proponent:	Al Davino.
Existing Installations:	None
Type of Use:	For use LAMTA Overhead System.
Development Engineering:	None.
Power System:	Electric - not determined.
Propulsion:	Electric current.
Running Gear:	Rubber tire wheels not developed.
Guidance:	Channel Rails.
Type of Switch:	Not Designed.
Design Speed:	Not specified.
Submitted Sufficient Information:	No engineering data submitted.
Reference Material Submitted or on hand:	Brochure - "Davino Suspended Rapid Transit System"; cost estimate sheets; five concept drawings.

System Description

The Duo-Rail System is a suspended type transit system. Trains are pendant from rubber tired wheels vertically contacting two parallel out-facing channels separated by approximately 5'0" by lattice type supporting structure. Power is applied to the wheels from electric motors mounted atop the cars through large spur gearing.

Alternate structural configurations were proposed. The first is a rigid steel support system with piers at 100' spacing. The second envisions support of the runner channels from steel cable catenaries spanning 320 feet.

System Evaluation

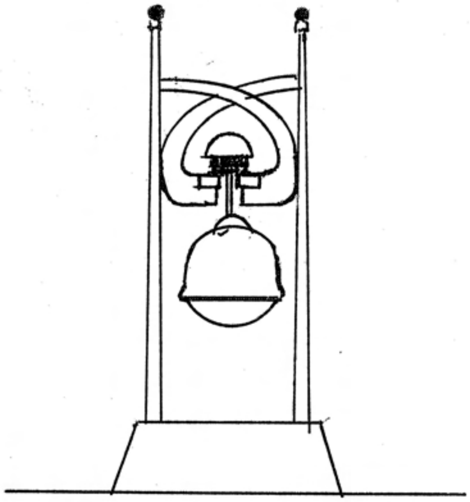
The proposed car suspension and drive systems of this form of split-rail "monorail" do not appear feasible. The driving gear linkages are bulky and inefficient. No horizontal guides are provided for the wheels other than contact between the axle-end and the channel face.

No sway control is incorporated in the car suspension. Switching devices have not yet been developed.

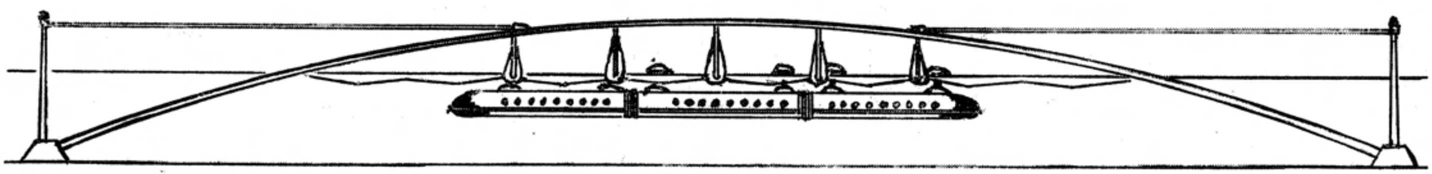
The rigid structure is preferable to the "suspension bridge" concept. The cable supported structure is certainly subject to side sway, and likely to present a vertically undulating ride under the variable loading applied by a moving train.

Recommendation

No further consideration should be given to this proposal for application in the LAMTA service area.



Type of System:	SUSPENDED-SYMMETRIC
System:	SPEED RAIL SYSTEM
Proponent:	S.R.V. CORPORATION
Existing Installations:	None.
Type of Use:	For use by LAMTA Overhead System.
Development Engineering:	Very incomplete - mostly advanced concept stage.
Power System:	Direct Current.
Propulsion:	Electric motor.



Running Gear:	Steel flanged wheels.
Guidance:	No guidance necessary - self-guiding.
Type of Switch:	No switch developed.
Design Speed:	225 miles per hour.
Submitted Sufficient Information:	Insufficient information for evaluation obtainable.
Reference Material Submitted or on hand:	Four photographs of artist's concept. Small-scale model demonstration.

System Description

The Speed Rail System is a suspended type transit system originally conceived for high speed (200+ miles per hour) transcontinental service.

The three car articulated trains are suspended below electrically driven trucks which ride on standard rails. Train operating characteristics include acceleration to 150 miles per hour in 30 seconds, so special safety seats are utilized, with no standees permitted.

System Description (Cont'd)

Each rail is carried on a continuous logitudinal beam which is mounted through heavy cradles to 1000' span arch structures. The 55' high arches are welded fabrications of tubing tapered from 4'6" diameter at abutments to 2'0" at mid-span.

System Evaluation

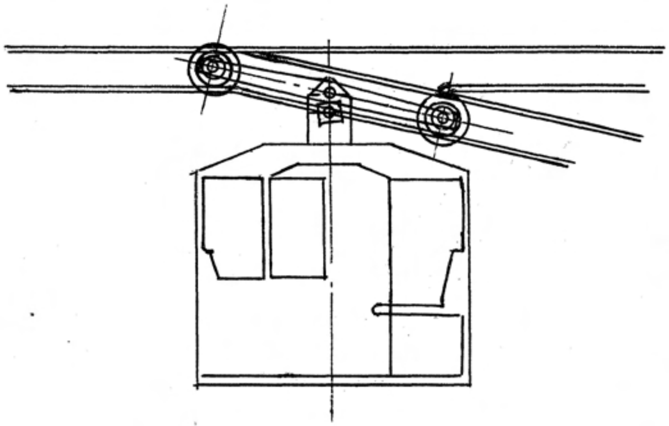
This system, devised for long distance operations, will apparently have great difficult negotiating curves of any proportion. The basic structure itself is certainly adapted only to long straight routes. As cross-ties between rails must be omitted to allow for the underslung pendant train configuration, it is believed that great difficult in maintaining proper track gage would be encountered at curve locations subject to horizontal wheel flange loading.

Switching is an unexplored problem.

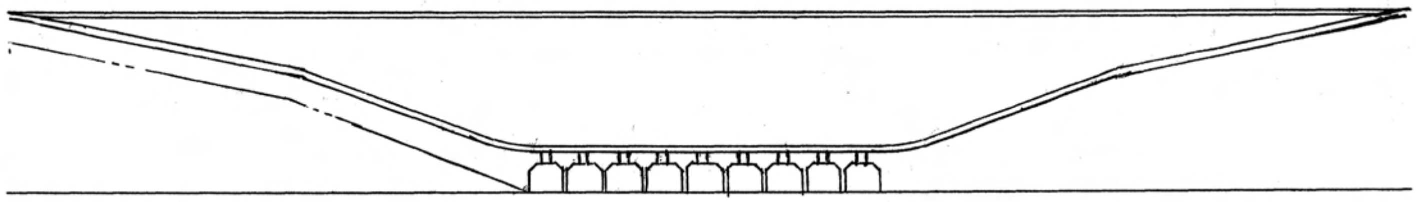
Discussion and Recommendations

The relatively short routes and frequent stations involved in a metropolitan rapid transit system are deemed incompatible with the design embodied in this system.

No further consideration of this proposal is recommended.



Type of System:	SUSPENDED-SYMMETRICAL
System:	FUSSELL TRANSIT SYSTEM
Proponent:	Henry M. Fussell
Existing Installations:	None
Type of Use:	For LAMTA Overhead System.
Development Engineering:	Concept stage.
Power System:	Direct current.
Propulsion:	Electric motor.



Running Gear:	Double Channel.
Guidance:	Self-guiding.
Type of Switch:	Special switch (in vertical plane)
Design Speed:	30-40 miles per hour.
Submitted Sufficient Information:	Insufficient for evaluation.
Reference Material Submitted or on hand:	Brochure "Criteria for LAMTA"

System Description

The Fussell Transit System consists of a closely spaced grid of routes for "100% coverage". Two passenger suspended monorail cars are boarded at side-walk level, rise and accelerate to the overhead mainline track 30 feet above the street, and proceed non-stop to the passenger's destination as determined by push button control.

System Description (Cont'd)

Cars hang below electrically powered, rubber tired, bogies riding on two parallel channels.

Operation is completely automatic. Vertical switches at each station allow cars to enter and leave the main line. Car speed and spacing is controlled.

System Evaluation

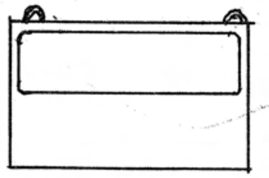
Several advantages are claimed by this system. Convenience of single occupancy, non-stop travel from "curb-to-curb" in low noise level, automatically operated cars is emphasized. No waiting for cars is anticipated, as empties are stored at stations. Purported economics are based on the light structure required, and use of public streets and sidewalks.

The system is only in the concept stage. The tremendous amount of development work on the automatic traffic programming of a large number of self-contained, automatically controlled units has not been done. Routing from one grid track to another with independent traffic characteristics would appear to be a definite problem; although the actual switching device is well engineered.

The individual cars themselves deserve more attention. Large power units are required to accelerate to mainline speed while rising from a station. Sway control of the pendant cars is not yet engineered. The effort involved in maintaining the great number of individual cars, coupled with the total route effect of single car failure, places unprecedented emphasis on unit reliability.

Discussion and Recommendations

The convenience and total coverage advanced by this concept are commendable. However, the lack of development design information hinders evaluation and prohibits further consideration of the Fussell Transit System.



System Type: SUSPENDED DUAL RAIL

System: COMBINED CARRIER SERVICE

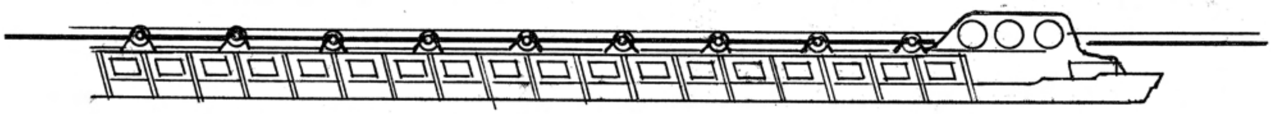
Proponent: Mr. T. R. Webb

Existing Installations: None

Type of Use: For innerurban and interurban service

Development Engineering: Early concept form, no engineering done.

Power System: Not disclosed.



Propulsion: Not disclosed.

Running Gear: Dual wheels on trucks and power nacelles with third wheel driving under the rail.

Guidance: A "T" rail guides dual wheels on face of tires.

Type of Switch: Not designed.

Design Speed: 100 Miles per hour.

Submitted Sufficient Information: Insufficient information submitted.

Reference Material Submitted or on Hand: Combined Carrier Service Manual and four sketches.

System Description

The cars are suspended on a hanger and run on dual wheels with the third wheel engaging the bottom of the track held in place by two hydraulic actuators. The manner in which the "T" rail is suspended is not explained and is not shown. One must conclude that the entire system of suspension is supported by extension rods in a manner used in the industrial overhead service.

The cars have a capacity of three persons each. Car body appears to be demountable and transferable to auto-chassis for surface use. Top of this car shell is equipped with four hangers by which it is suspended to a three wheeled truck with one wheel driving under the "T" rail, and the dual carrying wheels assuming the total weight of the vehicle.

How the car shells are transferred to the main line truck or removed from it is not disclosed.

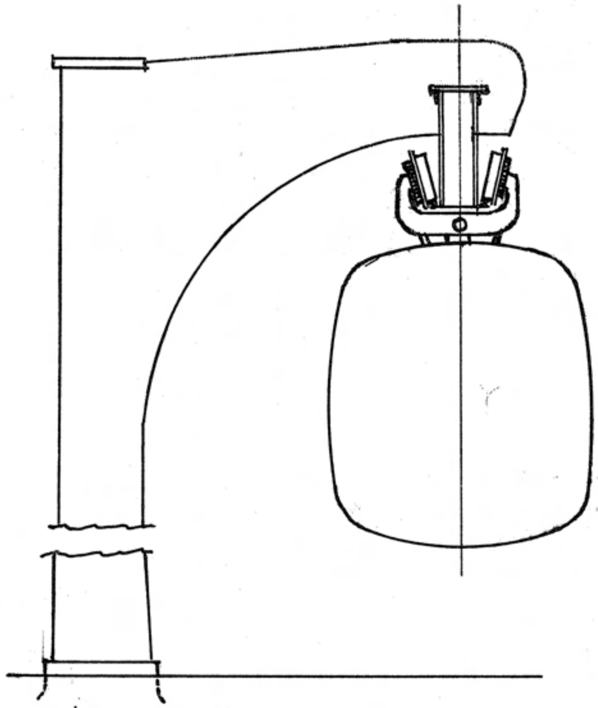
The interurban train consists of any number of detachable car shells as described in the preceeding paragraph and are coupled to a power unit, which has not been explained. The sketch shows four wheel truck mounted on top of rail and drivers pod suspended below.

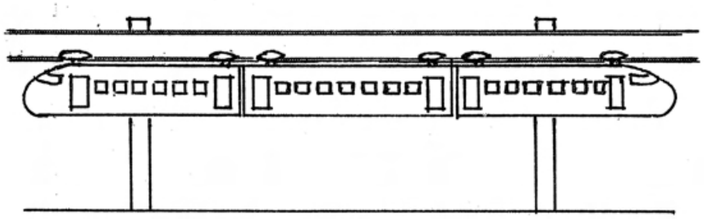
System Evaluation

The system does not meet the criteria established because of the small size of the cars and the necessity for train type operation. The equipment cost would be high because of the small cars and train make-up and break-up would appear to be a serious problem. The system is only a concept with no engineering or development work completed.

Recommendation

No further consideration should be given to this proposal for application in the LAMTA service area.





System Type:	SUSPENDED MONORAIL ON-DUAL WHEELS
System:	VINJE MONORAIL RAPID TRANSIT SYSTEM
Proponent:	A. F. VINJE
Existing Installations:	None
Type of Use:	For LAMTA overhead system.
Development Engineering:	Advanced concept with only preliminary engineering done.
Power System:	Direct Current.
Propulsion:	Electric Motors.
Running Gear:	Steel flnged wheel truck.
Guidance:	Inherent guiding.
Type of Switch:	Pivoting cartilever beamway proposed.
Design Speed:	60 miles per hour.
Submitted Sufficient Information:	Insufficient information.
Reference Material Submitted or on Hand:	The "Vinje Monorail Rapid Transit System" brochure.

System Description

This concept embraces suspended monorail trains riding on parallel tracks resting on the bottom flanges of steel box beam runway. Propulsion units are electric motors mounted in the wheel nacelles.

Wheels and rails are tilted 20°degrees from the vertical. This configuration plus a damping system integral with the suspending yoke is purported to provide increased comfort and safety, particularly on curves.

System Evaluation

The system embodies safety from derailment and slender structural design common to most monorail concepts.

Evident desire for minimum bulk of wheel nacelles has led the designer to connect motor to wheel through right angle gearing, an inefficient power transmission system for high speeds.

Evaluation of other facts of this approach to mass transit is impossible due to lack of design information.

Discussion and Recommendations

The concept was devised as an improvement over the Wuppertal Monorail (1901); the attempt could possibly be successful.

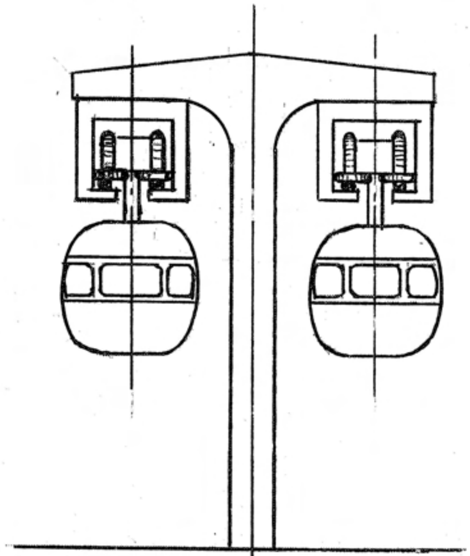
However, no independent development has been done, nor is any projected.

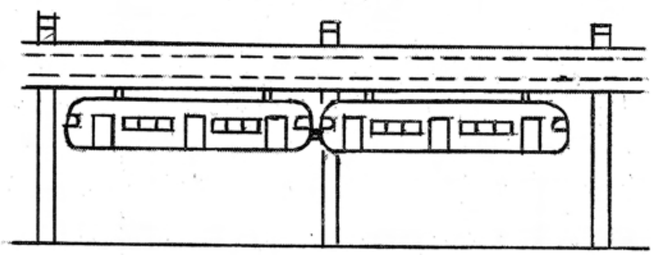
We recommend no further consideration of the Vinje Monorail System.

5. SUSPENDED SYSTEMS - SYMMETRIC SPLIT RAIL

A. S.A.F.A.G.E.

B. Northrup





System Type:	OVERHEAD SUSPENDED SPLIT RAIL TYPE
System:	SAFAGE RAPID TRANSIT SYSTEM
Proponent:	SOCIETE ANONYME FRANCAISE D'ETUDES DE GESTION ET D'ENTER-PRISES
Existing Installations:	Yes - experimental test track is now ready for use in France.
Type of Use:	For use LAMTA Overhead system.
Development Engineering:	Yes, with changes for incorporation.
Power System:	Direct current.
Propulsion:	Direct electric current.
Running Gear:	Pneumatic rubber tires, by Michelin.
Guidance:	Pneumatic rubber tires guiding laterally.
Type of Switch:	Special switch, now under development.
Design Speed:	60 miles per hour.
Submitted Sufficient Information:	Sufficient information for evaluation on hand.
Reference Material Submitted or on Hand:	1. "Overhead Suspended Rapid Transit" (Brochure-108 pgs.) 2. "Overhead Suspended Rapid Transit" Drawings of Technical Features dated Sept. 1959) 3. "LES TRAINS SUR PNEUMATIQUES DU CHEMIN DE FER METROPOLITAIN DE PARIS," dated April, 1954 and November 8, 1956 4. Photographs of split rail, open track, split rail manufacturing techniques, 1/10th scale model boggie, switch supports and switch.

System Description

This system is of the overhead suspended split rail type. The split rail is a steel structure prefabricated in an inverted "U" form with the car truck wheels running on steel plates. It is supported on appropriate "T" vertical members spaced approximately 100 feet apart. Switch has been developed and is automatic in action.

System Evaluation

A primary and secondary suspension system has been developed which appears to control sway. The decentering feature obtained automatically by the use of the special suspension system, reduces torsional stresses through the trucks and the split rail structure, allowing for much reduction in steel (weight and cost), and, in turn, greater and lighter unsupported lengths of the split rail box section and fewer "T " type supports per mile of track.

Trucks (Bogie): Two trucks per car equipped with tires designed by Michelin.

Split Rail Truck: The suspended all steel and welded double box section is prefabricated in approximately 100 feet long sections.

Switching: Switching time is estimated as 10 seconds. The sliding members are supported by a set of "A" frames.

Propulsion: 600 V-DC current is supplied by an overhead conductor mounted within the split rail structure.

Braking: Dynamic braking is used down to three miles per hour. The internal expanding shoe brake is used for final stopping and as parking brakes.

Axle: Each axle is driven by an 100 horsepower electric motor, or 400 horsepower per car at maximum of 66 miles per hour.

Car (Existing prototype): Capacity - 123 passengers, full load. Car length - 50 feet; car weight - 18,700 pounds and can be driven from either end; weight of bogies-18,700 pounds. Total weight 36, 700 pounds.

Advantages

The primary and the secondary sway control design is perhaps the most outstanding feature of the system. It does away with the presently objectionable feature of having to slow down before entering the station platform and provides controlled banking of the car, producing comfortable ride.

The use of a differential in the truck is a very desirable feature.

Disadvantages

Tires: Michelin tires are steel reinforced, and it is believed that further development is required to produce tires with higher safety factor.

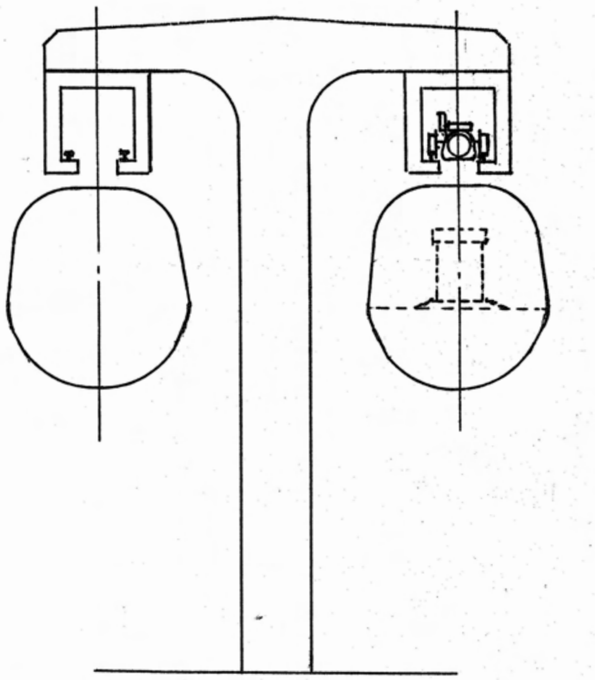
Differential Drive vs. Braking: As the case may happen, one wheel sliding with the brakes set and opposite wheel rolling assuming total braking load on one wheel only. This condition will cause excessive tire wear and produce the equivalent to a flat steel wheel. The flattened tire will produce shock loads in excess of the normally slim safety margin, resulting in injury to wheel bearings and eventual tire blowout.

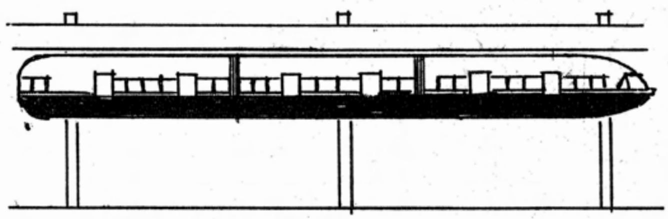
Siwtching: Switching mechanism is quite complicated and additional development seems required. The switch as such, is actually a large transfer table. For lack of more detail on the switch, it is felt that emphasis should be placed on the actual experience which will be forthcoming in the near future in France on the test track.

Electrical Grounding: The negative collector shoe contacts the steel split rail structure, creating grounding problems.

Recommendation

This sytem merits further detailed study.





System Type:	OVERHEAD SPLIT RAIL TYPE (As presented for Seattle Exposition)
System:	GYRO GLIDE TRANSIT SYSTEM
Proponent:	Norair (Division of Northrop Corp.)
Existing Installations:	None
Type of Use:	For LAMTA overhead system.
Development Engineering:	Advanced concept with some engineering done.
Power System:	Direct current.
Propulsion:	Electric motors.
Running Gear:	Steel flanged wheel truck.
Guidance:	Inherent guiding.
Type of Switch:	Not specified.
Design Speed:	50 miles per hour.
Submitted Sufficient Information:	Insufficient information.
Reference Material Submitted or on Hand:	The "Northrop Gyro-Glide Transit System" brochure.

System Description

The suspended cars are driven by truck running in a "split rail" beam on steel rails and wheels. Distinctive feature of the system is inertial drive gyro-power unit, which eliminates the need of third rail between stations, or "hot wire" usually found in electrical systems.

The gyro-power unit resists the sway motion found in suspended cars. The power pod is removable for maintenance. Each car provides an integral passenger loading ramp, which is built into the door mechanism. System does not require turn-around loop at the end of the line. Train consists of four cars with a total of 256 seats. The two-car train has 128 seats.

There are two power pods per each train, one at each end. The total inertial unit weight is directly supported by the truck and none of the pod structure will carry the unit weight.

The gyro-unit is regenerated at each station and for approximately 600 feet down the line from the station, after which time the train draws energy from the gyro-unit.

System Evaluation

The split rail concept application is similar to several other presentations. The gyro-power is unique but not new. (A system of this type is in use in Europe - The Orlicon Company of Switzerland.)

The concept has been engineered to a small degree and some experimental work performed by Norair.

Advantages

The simplest type of stabilization.

Reduction in cost of power distribution system.

Disadvantages

System adaptable for short station spacing only (½ mile).

Should the train be held up for a considerable time, at any part of the track between stations, it is reasonable to assume that train would be unable to proceed on its own power to the nearest recharge station.

An automatically operated train must have continuous supply of energy for efficient operation. A stalled train will disrupt the efficient and continuous system operation.

Recommendation

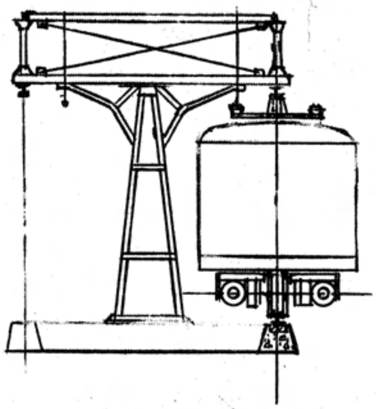
The possibility of motive power loss between stations makes it impossible for the system to be recommended for adoption, and should not be considered further for adoption to the Los Angeles Transit picture. However, the split rail concept should be given additional study.

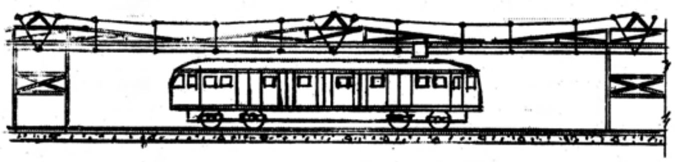
6. SUPPORTED SYSTEMS - OVERHEAD OR SIDE STABILIZED

A. E. W. Chalmers Kearney High Speed Railway

B. Mono-Tri-Rail, Ltd., R. P. Harshberger

C. Airway Rail Transport, Mrs. R. C. Lafferty





System Type:	SUPPORTED, OVERHEAD STABILIZED
System:	KEARNEY HIGH SPEED RAILWAY SYSTEM
Proponent:	E. W. Chalmers Kearney (England)
Existing Installations:	None
Type of Use:	For LAMTA Overhead and Ground Level.
Development Engineering:	Development dates to 1908.
Power System:	Direct current.
Propulsion:	Electric Motors
Running Gear:	Double flanged tandem wheels.
Guidance:	Inherent guiding at the traction wheel and yoke and wheel guiding at the top rail.
Type of Switch:	Not specified.
Design Speed:	Not specified.
Submitted Sufficient Information:	Insufficient information.
Reference Material Submitted or on hand:	Reprint from "Modern Transit" dated May 31, 1958.

System Description

The Kearney High Speed Railway consits of an electrically powered vehicle or train supported by a single traction rail below. A guide rail directly above the car body provides both lateral stability and derailment protection. The system is tendered for either elevated, on grade, or tunnel installation.

Mr. E. W. Chalmers Kearney first introduced this system in 1908 after six years of experimentation. In the last fifty years, individual details of the system - tye type of wheels, guide roller pressure compensation, motive power, etc. - have varied, but the general principle has persisted.

KEARNEY HIGH SPEED RAILWAY SYSTEM

System Evaluation

The rolling resistance of a Kearney train is slightly less than that of a conventional rail train. A maintained pressure on the guide rail above the train makes possible the negotiation of sharp vertical curves.

The value of these two advantages is maximized in an underground installation with stations just below grade connected to deep tunnels by steeply inclined ramps. Total power requirements are reduced during acceleration by the incline, and at full speed by the lowered train resistance. The single wheel arrangement would allow smaller tunnel bore than required for other systems, and the overhead guide rail would have ready support from the tunnel roof.

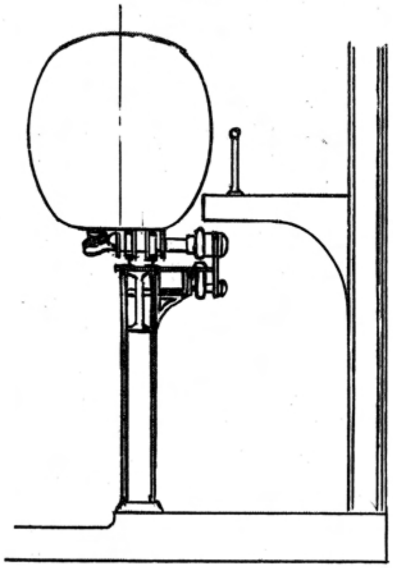
Above grade, however, these advantages evaporate. Stations would be at or below the level of the main line; power would then be governing at initial acceleration of the train mass; a bulky structure would be necessary to provide rigid attachment for both rails.

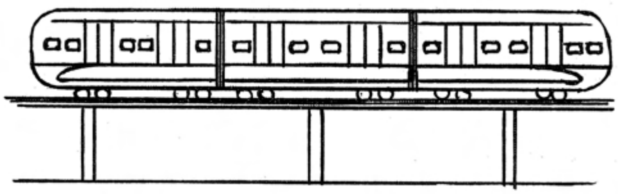
Switching would, in any case, be more cumbersome than conventional rail design.

Discussion and Recommendations

Unless a complete subway installation were planned, no advantage would be gained by adoption of this system.

We do not recommend further consideration of the Kearney High Speed Railway System.





System Type:	SUPPORTED, SIDE STABILIZED
System:	MONO-TRI-RAIL, LTD.
Proponent:	R. P. Harshberger, Licensor
Type of Use:	For use LAMTA Overhead System
Existing Installations:	None
Development Engineering:	
Power System:	Electric - not determined.
Propulsion:	Electric current.
Running Gear:	Steel flange wheels.
Guidance:	Depends on Wheel flanges.
Type of Switch:	Not designed.
Design Speed:	Not specified.
Submitted Sufficient Information:	No. Announcement Card
Reference Material Submitted or on hand:	One Off-set true line picture rendering (#48)

System Description

The Mono-Tri-Rail System is a railway system designed specifically for implementation of elevated right-of-way. Steel wheels are set to a narrow gage to reduce the width of the carrying structure and thus decrease the undesirable effects of such an installation over public streets.

Stability of the narrow gage vehicle is provided by an outrigger attached to its trucks. The outrigger consists of rubber idler wheels located both above and below a continous track mounted to the side of the structure. The car body is offset away from the outriggers slightly over-balancing the unit; thus, contact of the bottom idler wheel against the continuous track is maintained.

The outriggers also provide a degree of derailment protection. The system is now only a concept.

System Evaluation

The system is now only a concept. Neither design development nor test facility construction has been initiated.

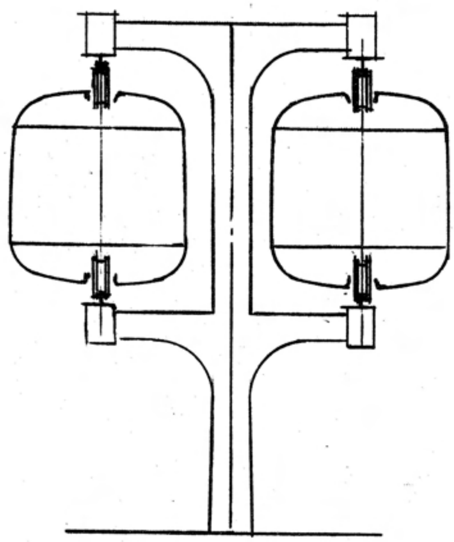
The system essays to minimize the overhead structure inherent to an elevated transit system. Several design and operating problems are introduced in this attempt. The torsion loads applied to the supporting beam by the outrigger wheels will, especially at curves, increase beam dimensions beyond those required for a direct vertical load.

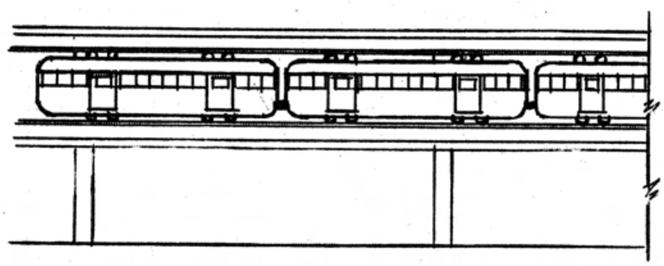
Operation of small rubber tires at high speeds is questionable. Switching methods have not been proposed, nor can any workable approach be projected. Positive derailment protection is not provided, although the outrigger arrangement does afford some degree of safety. The outrigger arrangement would be awkward for installations at, or below, grade.

Comments and Recommendations

There is no apparent advantage in application of this transit configuration. No substantial improvements are provided and some problems are introduced.

We do not recommend further consideration of the Mono-Tri-Rail System.





System Type:	SUPPORTED, OVERHEAD STABILIZED
System:	THE LAFFERTY PLAN - AIRWAY RAIL TRANSPORT
Proponent:	Mrs. Robert C. Lafferty
Type of Use:	For use LAMTA Overhead System.
Existing Installations:	None
Development Engineering:	None
Power System:	Not Specified.
Propulsion:	Electric Motors.
Running Gear:	Single wheel in tandem form.
Guidance:	Flange Wheel and Channel Guide Optional.
Type of Switch:	Not developed.
Design Speed:	Not specified.
Submitted Sufficient Information:	Insufficient information - a very sketchy concept form.
Reference Material Submitted or on Hand:	Three reprints of six pages from unknown publication; two blueprints #112 and #54.

System Description

The Airway Rail Transport system is very similar to the Kearney System previously discussed. A single rail below the car is supplemented by an overhead stabilizing rail.

System Evaluation

The advantages and disadvantages of the Kearney System are believed to be equally applicable to this scheme. However, Airway Rail Transport is but a concept, with very few details worked out, and no development accomplished.

Discussion and Recommendations

We recommend no further consideration of the Airway Rail Transport Plan.

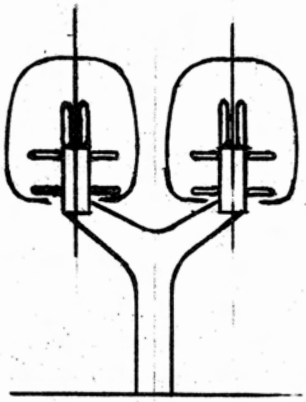
7. SUPPORTED SYSTEMS - OVERRIDING

A. ALWEG

B. Lockheed

C. Alan Hawes

D. de Kanter



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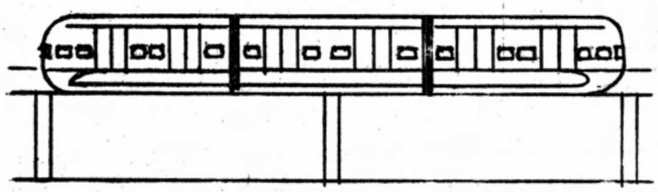


ELEVATION

System Type:	SADDLE BAG SUPPORTED TYPE
System:	ALWEG SYSTEM
Proponent:	Rapid Transit Systems of California
Existing Installations:	Test track
Type of Use:	For use LAMTA overhead system
Development Engineering:	Yes - completed engineering for test installation
Power System:	Direct current
Propulsion:	Electric direct current
Running Gear:	Pneumatic tires, developed
Guidance:	Pneumatic guiding wheels
Type of Switch:	Special switch - is developed
Design Speed:	60 to 75 miles per hour
Submitted Sufficient Information:	Very complete
Reference Material Submitted or on Hand:	1. "Description of the Alweg System" 2. "Presentation of the Alweg System for the City of Los Angeles - Drawings" 3. "Mass Rapid Transportation System for the Los Angeles Metropolitan Area" 4. "Budd Railway Disc Brake"

System Description

Basically the Alweg System operates in the same manner as the conventional mass rapid transit system in that a car or train runs on a track , and here the similarity ends.

The supporting structure is constructed of pre-stressed,pre-cast concrete in the form of I beam, and is supported on "A" frame columns and pylons approximately every 100 feet apart on reinforced concrete bases.

The running beam expansion joints are provided with steel rocker arrangement, resting on the cross girders.

Cars straddle this six-foot deep running beam. Dual pneumatic drive wheels run on the top of the beam, and horizontal guide wheels bear against its side.

Passenger space is located above the level of the beam. Drive wheel housings intrude on this floor space. Installations of this system are in operation at Disneyland and in Cologne, Germany. The various design features (braking, signalling, switching, and facility construction) have been well developed.

System Evaluation

This proposed system is fully developed. Engineering design problem areas have been approached with the benefit of actual performance data.

Switches have been constructed.

The configuration of the drive and guide wheels presents some maintenance problems, as does the use of pneumatic tires. The off-senter drive motor location heavily loads the tires on one side; their life span and design safety factor are questioned. At the same time, however, a smooth, quiet ride is afforded with positive derailment protection.

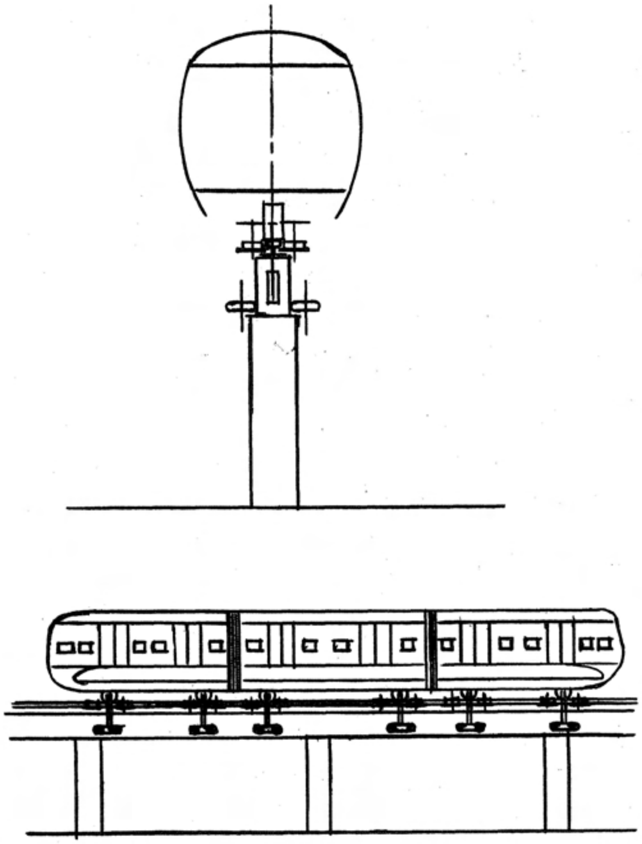
Excessive car sway which must be considered in suspended systems is not present. Thus, clearance requirements and curve limitations at station approaches are less stringent for overriding systems.

Support structures for both elevated and depressed routes are lower, smaller and less costly than those for suspended systems.

An advantage of this system over conventional rail is its ability to negotiate up to 7% grades, thus allowing more flexibility in route profile and layout. The added safety of positive derailment protection, especially on elevated routes, is also in its favor.

Recommendation

We recommend further detailed study to establish the desirability of system application to the LAMTA requirements.



Type of System:	OVERHEAD SUPPORTED SINGLE RAIL TYPE
System:	LOCKHEED RAPID TRANSIT SYSTEM
Proponent:	Lockheed Aircraft Corp.
Existing Installations:	None
Type of Use:	For use by LAMTA overhead system.
Development Engineering:	Engineered to a high degree.
Power System:	Direct current.
Propulsion:	Electric motors.
Running Gear:	None - flanged steel tandem wheels.
Guidance:	Guided by horizontal steel wheels.
Type of Switch:	Beam switch under development.
Design Speed:	60-75 miles per hour.
Submitted Sufficient Information:	Sufficient information received for evaluation.
Reference Material Submitted or on Hand:	Lockheed Rapid Transit System data for LAMTA evaluation, Report #14232

System Description

The Lockheed Rapid Transit system also consists of supported monorail trains electrically operating over a beamway. The design is arranged for complete automation (with manual overriding controls), operated from a central control area.

The four-foot deep beamway and supporting pylons (85' on center) are structural steel fabrications.

Each car is mounted on two tracks. A truck consists of vertical tandem steel drive wheels and six horizontal steel guide wheels supported on a common yoke. The driver wheels and four upper guide wheels run on steel track atop the running beam. The lower guides ride along the sides of the beam. The passenger compartment is above the beam and drive wheels, providing a flat floor area.

No installations of this type have been fully planned and constructed but considerable engineering effort has been expended in establishing the system design.

System Evaluation

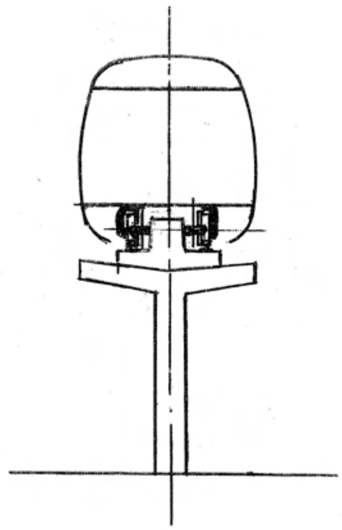
The system inherently provides the basic advantages of a supported monorail system. Derailment is a virtual impossibility. Maximum possible grades are much steeper than those practical for conventional rail. The car sway problems of suspended systems are averted.

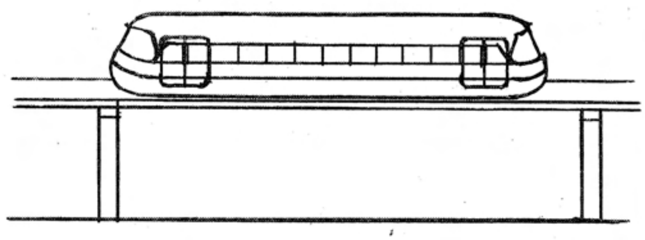
The steel wheel and track incorporated in this system design afford it the proven background of railroading practice. Rubber mounting of the wheels should minimize noise of operation.

Switching devices have been designed.

Recommendation

We recommend that further consideration be given to this concept.





System Type:	SADDLE BAG SUPPORTED TYPE
System:	ALAN HAWES SYSTEM
Proponent:	Alan Hawes & Associates
Existing Installations:	Amusement park in Massachusetts-park rides.
Type of Use:	For use by LAMTA Overhead Transportation.
Development Engineering:	Complete for approximately one-half scale.
Power System:	Direct current.
Propulsion:	Electric motor.
Running Gear:	Pneumatic rubber traction tires.
Guidance:	Side pneumatic rubber tire guiding.
Type of Switch:	Special switch.
Design Speed:	60 miles per hour.
Submitted Sufficient Information:	Insufficient information.
Reference Material Submitted or on Hand:	One brochure dealing with the Seattle Metropolitan Transit Authority presentation.

System Description

The Hawes system of supported monorail primarily differs from the previously discussed designs in running beam and truck configuration.

The running beam is a foreshortened, inverted "tee" of prestressed concrete, 4'-6" wide and 1'-8" from top of beam to top of tee arms. Traction wheels ride on replaceable runway surfaces on these arms. Guide wheels roll against the vertical sides of the stem. Wheels are pneumatic throughout, but flanged steel wheels parallel drive wheel to assume load in case of tire failure.

These steel wheels are important in that they are utilized in a switching arrangement, allowing standard railroad short-radius switch installation at yard and maintenance areas.

The car body fits snugly to the beam while affording unrestricted passenger floor space

LOS ANGELES METROPOLITAN TRANSIT AUTHORITY

PROGRESS REPORT

RELATING TO

INITIAL CONSIDERATION OF SYSTEMS AND ROUTES

FOR A

MASS RAPID TRANSIT PROGRAM

VOLUME II - TECHNICAL DATA

February 2, 1960

DANIEL, MANN, JOHNSON, & MENDENHALL

Architects & Engineers

VOLUME II - TECHNICAL DATA

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AND

REVIEW OF TRANSIT SYSTEM EQUIPMENT & ACCESSORIES

FEBRUARY 2, 1960

BY

DANIEL, MANN, JOHNSON, & MENDENHALL

ARCHITECTS & ENGINEERS

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APPENDIX A

EVALUATION OF INDIVIDUAL TRANSIT SYSTEMS

1. General

The systems proposed or considered for the Los Angeles Metropolitan Transit Authority Rapid Transit Program have been divided into categories for convenience of evaluation. Each of the systems for which material was submitted or for which material was available has been reviewed.

For a general analysis and evaluation of the systems, reference is made to SECTION III of the Summary Report.

The sketches for the individual systems shown herein are not to scale and are included only for the purpose of indicating the general basis of the system.

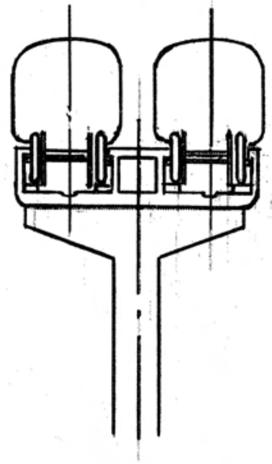
The evaluations have generally considered only those aspects considered unique or special to that system.

2. CONVENTIONAL RAIL SYSTEMS

A. Aerial Transit - H. K. Norton

B. Hastings Plane-O-Rail - Senator Hastings

C. Los Angeles Midget Subway - E. J. Smith



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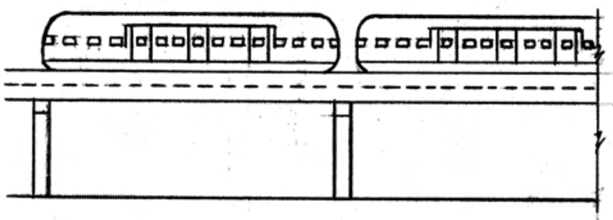


ELEVATION

System Type:	CONVENTIONAL OVERHEAD SUPPORT
System:	AERIAL TRANSIT
Proponent:	Mr. Henry K. Norton
Existing Installations:	No - Presented on ideas developed by H.K. Norton for aerial transit for New York Metropolitan Area.
Type of Use:	For use LAMTA overhead system.
Development Engineering:	No
Power System:	Direct current
Propulsion:	Direct current
Running Gear:	Rubber tires - not developed.
Guidance:	Steel flange, guiding on rail.
Type of Switch:	Special switch - not developed.
Design Speed:	80 miles per hour.
Submitted Sufficient Information:	Insufficient, in concept stage.
Reference Material Submitted or on Hand:	1. "Is Monorail The Answer?" 2. "Statement of H. K. Norton to the Metropolitan Rapid Transit Commission, New York, N.Y." 3. "Press Release by Mr. H. K. Norton 4. Five Photographs

System Description

The presentation is based on the use of existing lightweight railway rolling stock, modified as follows:

The truck axles would be extended through and beyond the normally fully enclosed bearings. This diversion from standard equipment design is intended to provide for safety and in case of derailment. The function of the axle extension has deterring action in case of derailment.

The way structure has a wrap-around ledge forming a barrier for the axle ends, less than the depth of the flanges of the guide wheels for uplift.

System Evaluation

1. The wrap-around ledge axle to structure interference is supposed to hold the car from leaving superstructure in case of derailment. The dynamics of moving

cars and trains at 75-80 miles per hour are great. Assuming derailment, we must visualize trucks being thrown askew, wedging in the retaining sides of the concrete "U" structure. The car with its load would shear off the trucks. Resulting damage to the superstructure concrete could prevent the resumption of the traffic. Thus, the channel structure does not necessarily guarantee freedom from accidents or derailment.

2. Tires

The development of tires for specific high-speed railway has not been accomplished to date. The Parisian Subway Michelin Steel Cord tires are known to be the only tires capable of sustained loads of approximately 5,000 lbs. per wheel, but they seldom exceed 30 miles per hour.

Granting that the 5,000 lbs. per tire load rating can be eventually increased, it also appears that the increase in load carrying would be accomplished by increase in the tire diameter.

3. Trucks

Trucks become non-standard on account of special axles and special guide wheel arrangements.

4. Advantages

No interference with surface traffic system, is adaptable to overhead, open cut, private right-of-way at ground level and subway. This system is adaptable to both horizontal and vertical segregation. The rubber tires would produce a smooth quiet ride.

5. Disadvantages

The axle clearance to the wrap-around safety ledge poses the following problem:

Beginning with the laying of the pre-stressed precast way structure alignment, it will be necessary the the wooden plant bed be shimmed for surface continuity.

There is no presently operating or test installation.

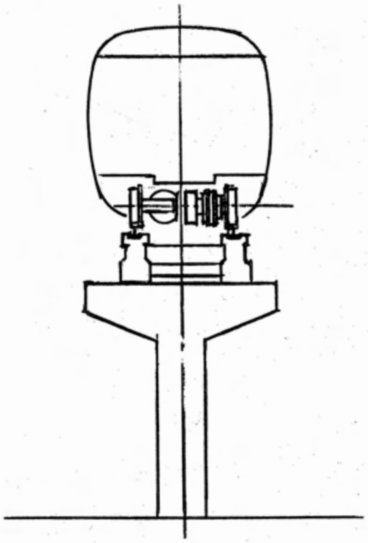
Development not completed.

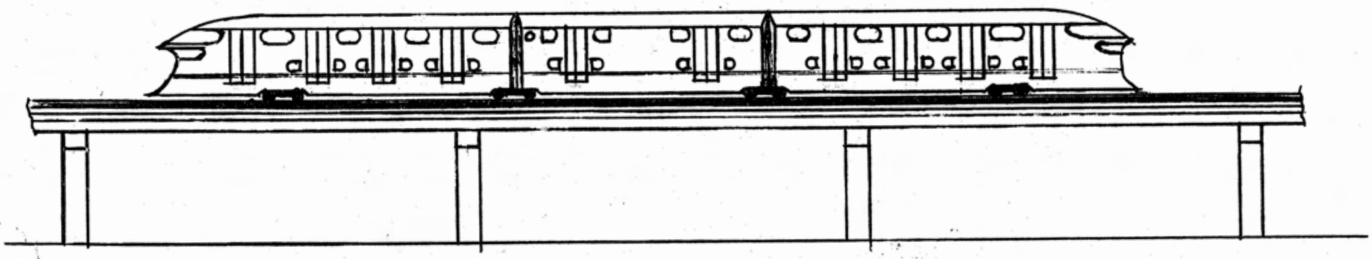
6. Discussion

The lightweight cars for this system are standard existing railway rolling stock of 44,000 lbs. to 46,000 lbs. per empty car. Using the trucks as proposed, we find each pneumatic wheel tire greatly overstressed with no safety margin factor.

7. Recommendations

Since the system is included in the general category of the conventional rail system which is recommended for further study, some additional investigation should be made to see if the work done on the pneumatic tires and the safety features has application.





System Type:	SUPPORTED CONVENTIONAL RAIL TYPE
System:	PLANE-O-RAIL SYSTEM
Proponent:	Senator Hastings
Type of Use:	For use LAMTA overhead system.
Existing Installations:	None
Development Engineering:	In engineering development stage.
Power System:	Diesel electric generators.
Propulsion:	Electric motors.
Running Gear:	Steel flanged wheels.
Guidance:	Depends on wheel flanges.

Type of Switch:	Standard railroad switch.
Design Speed:	150 miles per hour.
Submitted Sufficient Information:	Insufficient engineering information.
Reference Material Submitted or on Hand:	Transportation Development Corporation brochure; Atomic Economics for the American Railroads; Three artist's renderings.

System Description

This "conventional rail" system consists of lightweight diesel powered rolling stock operating on standard steel rails set in rubber. The rails are carried on continuous pre-stressed concrete beams supported by pylons or other appropriate concrete structure.

The car design features a low center of gravity combined with light total weight. Car trucks are unique. Many vibration, noise, and displacement damping features are incorporated.

System Evaluation

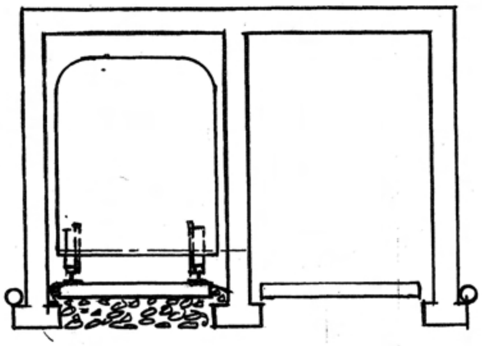
The proposed structural system of continuous rail support on pre-cast beamways offers possibility of smooth, comfortable riding at high speeds. It does, however, emphasize exact placement of heavy members.

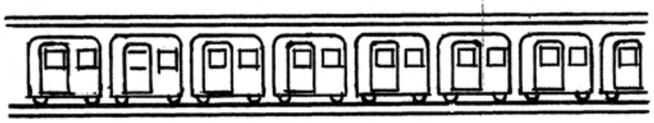
Rubber embedment of rails should provide a comfortable, quiet operation. The rubber, however, is subject to natural aging and cold flow under tremendous instantaneous overloads and might require excessive maintenance. The effectiveness of rail clamps must be determined.

Rolling stock designs appear well engineered. Low car profile and coordination with vibration reducing features of the trucks present excellent riding characteristics.

Discussion and Recommendation

As the system fits the conventional rail category considered for further study, additional study of the rolling stock features and structural design is recommended.





System Type:	MIDGET SUBWAY
System:	LOS ANGELES MIDGET SUBWAY
Proponent:	Edward J. Smith
Existing Installations:	None
Type of Use:	For LAMTA Underground System.
Development Engineering:	None.
Power System:	Electric power.
Propulsion:	Electric motor.
Running Gear:	Two rail flanged wheels.
Guidance:	Inherent guiding on rail.
Type of Switch:	Not specified.
Design Speed:	30 miles per hour.
Submitted Sufficient Information:	Submitted in concept form.
Reference Material Submitted or on Hand:	"Los Angeles Midget Subway" brochure.

System Description

This system is based on completely automatic non-stop operation of two-passenger subway vehicles. Cars embody station-to-station push-button operation by the passenger to control destination. Speed and timing are pre-set.

The miniscule car dimensions enable construction of small, low cost (compared to standard subway structure) subways measuring only 6'-6" high by 12'-0" wide for double track operation.

The proponent envisions eventual construction of a full coverage one-mile grid system.

System Evaluation

This system has been presented as a concept only. No engineering effort has been displayed, so technical evaluation is impossible.

Recommendation

A trunk line corridor system of this type is apparently unable to handle peak hour loads. A visionary grid system with its myriad of small vehicles and complex inter-route switching problems is deemed infeasible.

Continued consideration of the Midget Subway for mass transit application is not recommended.

System Evaluation

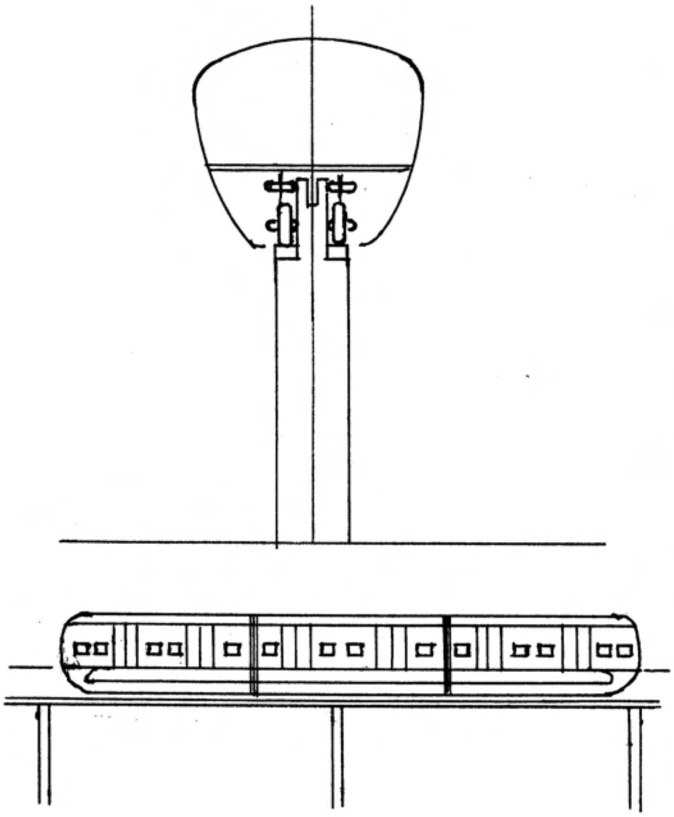
Again, general advantages of the supported monorail are inherent. The wide gage of supporting wheels and low center of gravity of the car are due to shallow beam intrusion provide added stability.

The switching design is particularly attractive for reduced yard and maintenance area size and costs; although a switch similar to that developed for other supported systems would be required for main line locations.

The engineering information received from the system proponent is very sketchy. Even though a miniature system is now operating, it is probable that considerable development work would be pre-requisite to mass rapid transit application.

Recommendation

We recommend additional study of the basic principles of this system, since it falls in the category of supported monorails.



System Type:	OVERHEAD SUPPORTED
System:	DE KANTER SYSTEM
Proponent:	HENDRIK DE KANTER
Existing Installations:	None
Type of Use:	For the LAMTA Overhead system.
Development Engineering:	Concept stage only.
Power System:	Electric
Propulsion:	Direct electric current.
Running Gear:	Rubber tires
Guidance:	Rubber tire guidance horizontal.
Type of Switch:	Not developed
Design Speed:	Not specified
Submitted Sufficient Information:	Sufficient to explain concept only
Reference Material Submitted or on Hand:	A Thesis to the University of Southern California.

System Description

Mr. de Kanter's transit concept is based on construction of two central station structures, one located near the existing freeway four-level interchange, the other, south of the Central Business District. Here north-south and east-west oriented monorail routes intersect. Automatic motor buses connect these stations to the Central Business District. No private surface traffic would be allowed in the Central Business District. Facilities are provided for interchange from private cars, street oriented bus and helicopters.

The primary feature of the stations is the system of escalators integrated with a revolving bus loading dock. A supported monorail design is proposed for this system. The automatically controlled cars ride on an "inverted tee" shaped steel box girder. Vertical drive wheels rest on the top surface of the tee arms and guiding wheels stabilize against the vertical sides of the trunk.

System Evaluation

The stations are interesting in their many integrated mechanical features, but do not correlate adequately with the over-all transit problem of the area. All traffic of every nature would be funnelled through common facilities. The proposed monorail is a generalized concept comparable to the types of supported monorails herein discussed.

The proposal by Mr. de Kanter is very broad and daring in scope, incorporating automatic devices in many phases of area transit. However, engineering design features of the concept are undeveloped.

The gap between concept and equipment/facility design is too broad to bridge at this time.

Recommendation

No further consideration should be given to this proposal for application in the LAMTA service area.

8. MISCELLANEOUS SYSTEMS

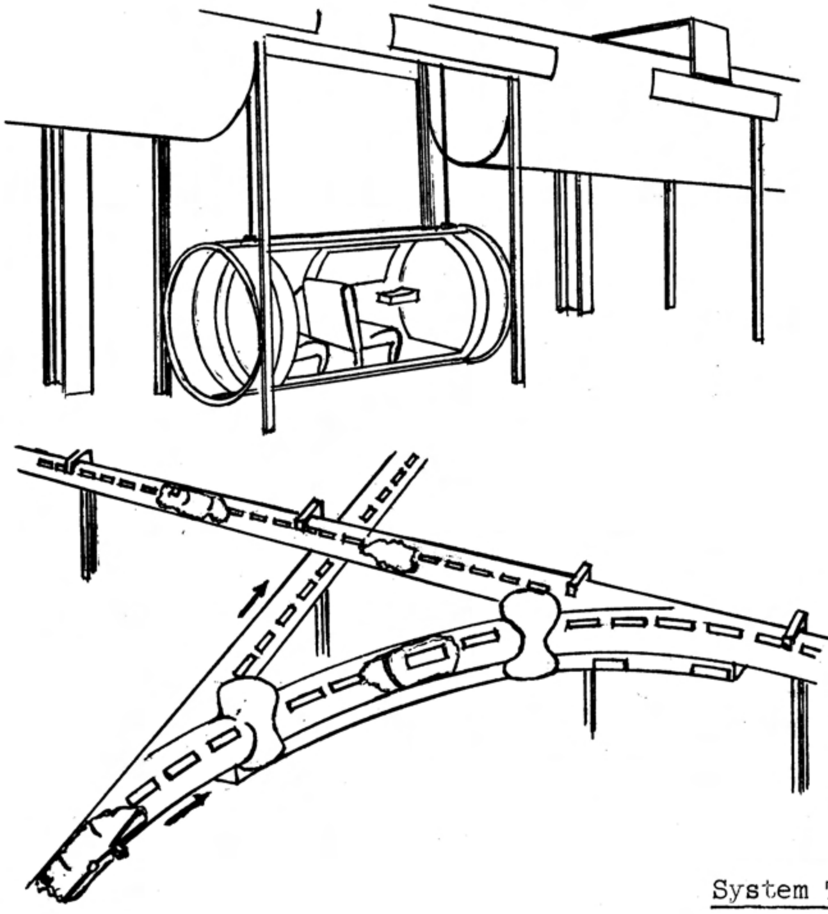
A. Airmobile Transit

B. Los Angeles Airways

C. Bus Systems

D. Stephens-Adamson Carveyor

E. Ideonics Corporation



System Type:	OVERHEAD DUCT TYPE
System:	AIRMOBILE TRANSIT SYSTEM
Proponent:	Logan E. Setzer
Existing Installations:	None
Type of Use:	For LAMTA overhead system.
Development Engineering:	In concept stage except the automatic addressing and routing appendix "C".
Power System:	Not specified.
Propulsion:	Air pressure.
Running Gear:	Recirculating ball race and return tube.
Guidance:	Channel track within the tube.

Type of Switch:	Special "air lock" switch.
Design Speed:	Approximately 30 miles per hour.
Submitted Sufficient Information:	Substantially complete criteria presentation.
Reference Material Submitted or on Hand:	Documented criteria- "The Sleigh Duct, A Mass Transportation System".

System Description

This system consists of a network of ducts in which small (two passenger) cars are propelled by air pressure. The cars would be lowered from the proposed elevated duct to street level for passenger boarding at station stops.

The switch consists of an air lock wherein the capsule comes to stop and "gate valve" allows a section of "tube" ahead of capsule to decompress. Capsule is then released and pushed into this turnout and enters second air lock, where the aforementioned procedure is repeated before the capsule is allowed to re-enter the main line tube.

Motive power for the capsules is furnished by series of 600 HP air compressors spaced at two mile intervals.

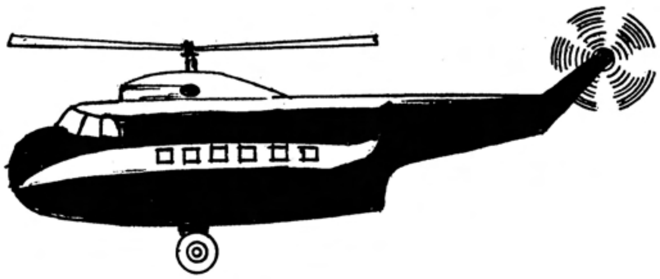
Car inside dimensions are 28 inches wide by 49 inches high by 108 inches long.

System Evaluation

Minor variations of this system have been periodically proposed for over 50 years, and no new concepts are involved. Passenger carrying capacity in peak periods is insufficient for application in the Los Angeles area, and speed is far below minimum requirements.

Recommendation

No further consideration should be given to this proposal for application in the LAMTA service area.



Type of System:	HELICOPTER SERVICE
System:	SCHEDULED HELICOPTER SYSTEM
Proponent:	Los Angeles Airways
Existing Installations:	Yes - network in Southern California.
Type of Use:	Cooperative feeder line for LAMTA overhead system.
Development Engineering:	Fully developed.
Power System:	Aircraft type engine and turbine.
Propulsion:	Jet turbine.
Running Gear:	Not applicable.
Guidance:	Pre-scheduled Omni System (all weather guidance).
Type of Switch:	Not applicable.
Design Speed:	Not determined (approx. 150 miles per hour).
Submitted Sufficient Information:	Sufficient information.
Reference Material Submitted or on Hand:	Attachments: A. "A New Dimension in Transportation" B. Map C. "Los Angeles Airways" D. Photos of helicopters.

System Description

Helicopters are currently operating in Los Angeles with approximately one hundred flights per day in and out of the Los Angeles International Airport, carrying 1,000,000 lbs. of mail and express per day. There are plans for expansion in the future.

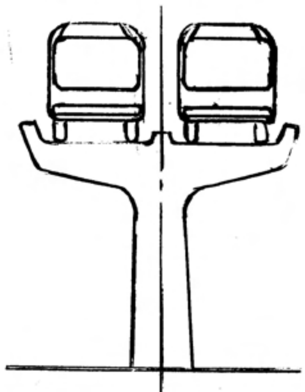
The vehicle cost is $600,000 for a 26-passenger helicopter and a landing strip size of 200 feet by 400 feet is required.

System Evaluation

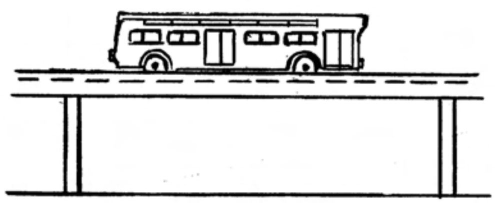
Application of this service to mass transportation in the foreseeable future is unlikely, due to the high cost of equipment, operating expense and resultant high fares.

Recommendation

Consider providing helicopter landing facilities at key rapid transit stations as part of integrated transportation system.



SECTION



ELEVATION

System Type:	BUS ON ELEVATED RUNWAY
System:	BUS LINE
Proponent:	General Motors Corp.
Existing Installations:	Generally standardized surface conveyance in Los Angeles
Type of Use:	For LAMTA overhead lines
Development Engineering:	Accepted standard current design
Power System:	Standard engine
Propulsion;	V-6 diesel engine
Running Gear:	Standard pneumatic rubber tires
Guidance:	Manually steered
Type of Switch:	No switch used
Design Speed:	56.5 miles per hour maximum
Submitted Sufficient Information:	Complete in every respect
Reference Material Submitted or on Hand:	Documented by G.M. brochure, model TDH 5301

System Description

This bus system is standard, individually operated on elevated structures.

System Evaluation

The buses will operate on an elevated structure, with no ground traffic interference. It is also possible to operate the buses on the surface streets by running ramps to the elevated.

Bus

Bus will seat 43 passengers and 10 standees for a total of 53 passengers. The coach weight is, empty with 95 gallons of fuel oil, 17,560 lbs. Body width is 95-3/4 inches; body height is 118 inches. Bus wheel base is 235 inches. Turning radius wheel, right and left, is 32 feet 2 inches; turning radius at body corner, right and left, is 37 feet 1 inch. Tire size is 10.00/20 inches.

Heating and ventilating is combined and will furnish 1500 CFM of air. Air suspension springs are self-leveling.

Power

Maximum BHP @ 2000 RPM with 560 injector 204 HP. Starting motor, 12 volt, the overrunning clutch drive type.

Transmission

Fully automatic BM hydraulic VH drive. Generator and batteries - 12 volt.

Discussion

This type of bus has just arrived in Los Angeles and is now operational. The useful life cycle of the bus has been estimated to be 19 years.

Advantages

It is suitable for flexible type application. It is currently new and the latest reliable piece of equipment of limited size.

Disadvantages

1. The bus passenger capacity os too small for rapid transit operations.

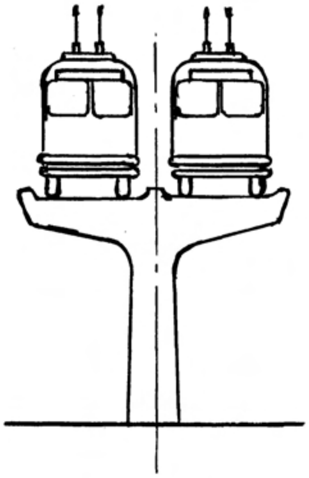
2. A system based on this bus requires too many operating personnel.

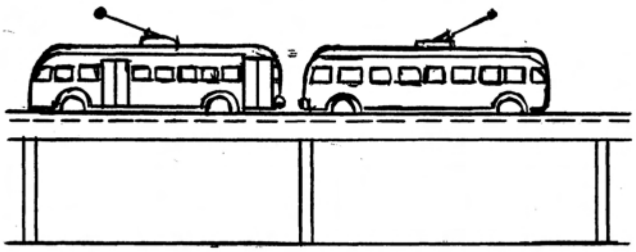
3. The diesel fuel exhaust is very objectionable.

4. Unless the vehicle was guided on the superstructure, it may be very precarious driving.

Recommendation

The system being very flexible has a potential. We recommend that some further consideration be given.





System Type:	BUS
System:	ELECTRIC TROLLEY BUS (For ground level, subway, overhead application).
Proponent:	Flexble Coach Company
Existing Installations:	In most all large cities in the United States.
Type of Use:	Feeder line to rapid transit system and main line use.
Development Engineering:	Trolley developed.
Power System:	Direct current.
Propulsion:	Electric motors.
Running Gear:	Standard bus design.
Guidance:	Manual.
Type of Switch:	Standardized overhead trolley wire switches.
Submitted Sufficient Information:	Yes.
Design Speed:	46 miles per hour.
Reference Material Submitted or on Hand:	Brochure.

System Description

The use of trolley buses would be an adaptation of available equipment in a new grade separated right-of-way.

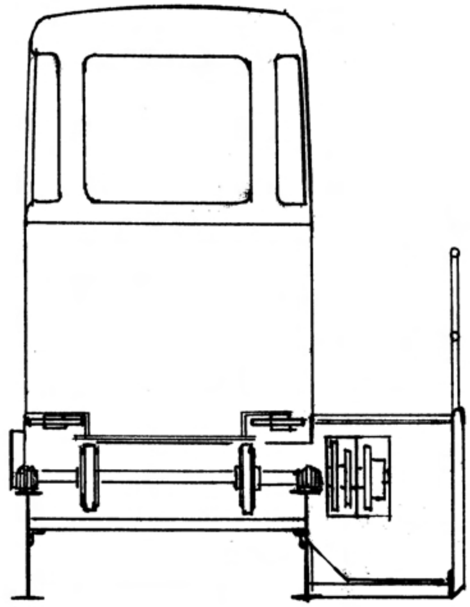
System Evaluation

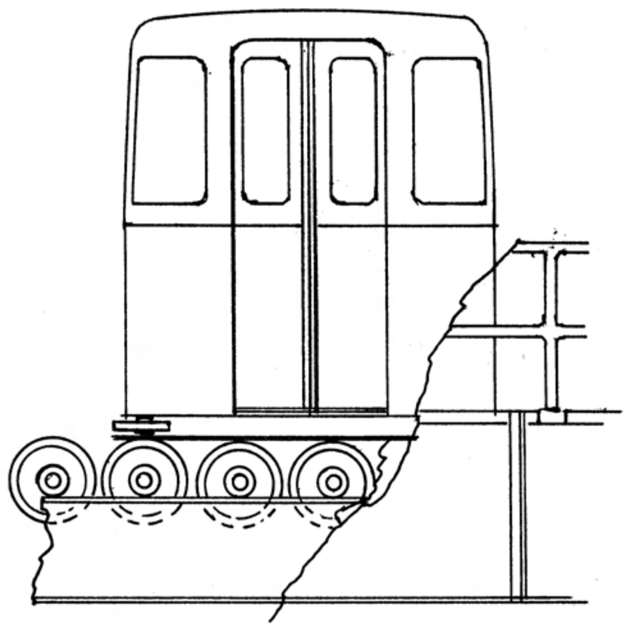
The cost of providing a catenary feeder line for high speed operation would be excessive for this system.

While an operation would be clean and quiet, the flexibility is limited as compared to a motor bus under similar conditions.

Recommendation

No further consideration should be given to this proposal for application in the LAMTA service area.





Type of System:	SUPPORTED AND ELEVATED TYPE
System:	"CARVEYOR" SYSTEM Stephens-Adamson Mfg. Co.
Proponent:	George P. Crank, S. E. Lunden & Associates
Existing Installations:	None
Type of Use:	For the L.A. Central Business District feeder line.
Development Engineering:	Yes.
Power System:	Electric current.
Propulsion:	Rubber belt and rollers.
Running Gear:	Skid and side thrust wheels.
Guidance:	Inherent guiding and taper rollers.
Type of Switch:	Not applicable.
Design Speed:	Up to 15 miles per hour.
Submitted Sufficient Information:	Sufficient information.
Reference Material Submitted or on Hand:	"Carveyor" brochure.

System Description

The system is an elevated rubber belt runway, with tapered roller arrangement for turning corners. Therollers are powered and speed synchronized with the main line belt.

Each station is provided with a decelerating runway consisting of varied size rollers which reduce the car speed progressively to match the parallel loading moving walk speed. When the relative velocity of the moving walk and the approaching car becomes zero, the car doors can be opened to discharge the passengers. The car proceeds at the relative zero speed for passenger pick-up or will continue unoccupied. At the opposite end of the station, the car enters on a series of progressively sped sets of rollers until it attains the synchronized speed of the main line belt upon which it enters on its continued duty cycle.

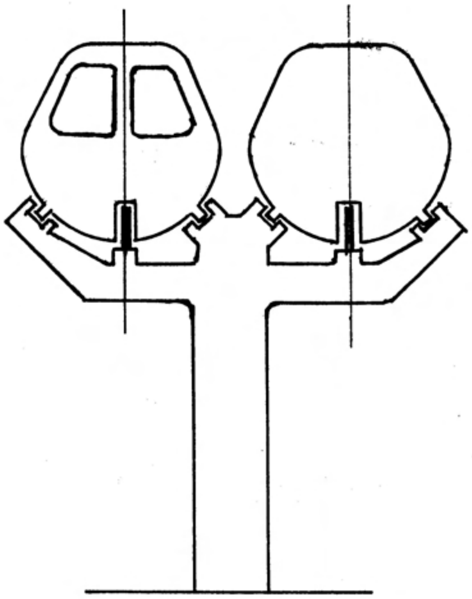
System Evaluation

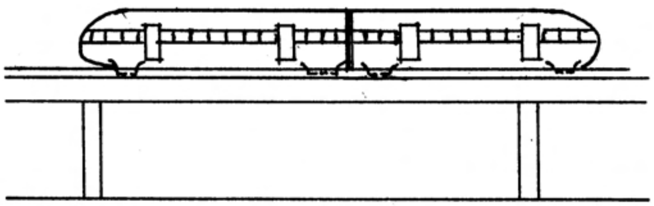
The carveyor system is adaptable for the central business district passenger traffic and can be operated on multiple pattern and a closed loop.

The system is safe, quiet in operation, and should prove to be economical in operation. It is a single purpose system for localized areas.

Recommendation

The system should be studied further for the central city secondary distribution system. It is completely automatic and requires no operators.





System Type:	AIR-SUPPORTED
System:	AIR RAIL TRANSIT SYSTEM
Proponent:	Ideonics Corporation
Existing Installations:	None.
Type of Use:	For use LAMTA Overhead System.
Development Engineering:	Not engineered - concept stage.
Power System:	Gas turbo-electric.
Propulsion:	Magnetic induction.
Running Gear:	Compressed air cushion without wheels (Signalling wheels provided for emergency).
Guidance:	Channel air reaction track (no guide wheels and no physical contact with the rail).
Type of Switch:	Special switch (transfer switch).
Design Speed:	60 miles per hour.
Submitted Sufficient Information:	Insufficient information for conclusive evaluation.
Reference Material Submitted or on Hand:	Ideonics Corporation proposal and photographs, verbal description.

System Description

A "Y" type structure, supporting two parallel channels mounted at the extreme "Y" arms are precision aligned to close tolerances.

Aluminum "pulling" rail is mounted centrally on axis of the beam. There is no outside source of power to the vehicle.

Car travels on a cushion of compressed air and the movement is frictionless. Car has no traction wheels, except retractable auxiliary rollers used for ground maneuvering at repair shops, classification yards and emergencies.

Each car carries 80 passengers with 60 seated in 40-50 ft. car length.

Train is made up of three cars and the train has four gas turbine generators.

The gas turbines drive electric 3 PH-AC generators each producing 150 HP. The exhaust gas drives an air compressor.

Each car is equipped with four "legs" designed to provide approximately eight square feet of reaction surface. These "legs" may be compared to conventional trucks. However, they do not have any traction capability and merely produce the reactive air lift necessary to sustain the car above the channel rails.

The turbine air compressor applies the necessary reactive energy via the air stream which is bled from the "leg" pads to maintain the car above the channel track at a nominal height approximately 1/4 inch to 1/2 inch.

The lateral oscillation of the car is restrained by a blast of air contained by the sides of the channel rails and prevents physical contact of the car "leg" with the channel.

Propulsion

The polyphase turbo-electric power units driven by gas turbines at constant speed, provides energy for magnetic induction straightline motor through interaction with the center "pulling" rail which is fixed to the supporting structure.

The only major factors effecting horsepower requirements are desired acceleration at rated gross weight and aero-dynamic resistance at top speeds.

Squirrel-cage type flat rotor motor of approximately four feet in length are mounted two per car.

Discussion

This new development, generally called a "ground effect vehicle" has been experimentally verified by the Ford Motor Company, the U. S. A. Army, and by fully developed equipment in Great Britain.

The Ideonics Corporation concept uses the same basic principle, except that it introduces another propulsion feature presently used by the Armed Forces at several high-speed test sled sites and also used for catapults on aircraft carriers.

Advantages

Full advantage of dynamic braking. (It is conceivable that in case of extreme emergency, the car could be caused to rest on the runway on runners as powerful sled brake).

Convertability of grade separated flat plate to utilize this concept.

Disadvantages

Fumes from gas turbine.

Noise from turbine.

Recommendation

We recommend that this revolutionary concept be studied in conjunction with conventional rail concepts.

B. TRANSIT SYSTEMS QUESTIONNAIRE

CRITERIA FOR LAMTA

EVALUATION OF EQUIPMENT

AND

STRUCTURAL REQUIREMENTS

The following information is furnished to all Proponents of mass rapid transit systems for guidance, to elicit the pertinent points of the proposed system; equipment, and its fundamental engineering.

The information desired from the various presentations will be classified for evaluation of the individual design status of the proposed system and equipment.

NOTE: All information furnished in response to this inquiry, which may be considered proprietary, will be held confidential.

DANIEL, MANN, JOHNSON, & MENDENHALL
Architects & Engineers

I. GENERAL CRITERIA:

A. No generalization in broad sense shall be presented for evaluation.

B. The interpretations in the evaluation study may be misleading and detrimental to the Proponent of the rapid transit system.

C. The proposed system may be above ground, underground, or surface transportation, or a combination of the above types.

D. Each specific question, shall be answered wherever applicable to system or equipment under consideration, as; brief description, including length, operating speeds, size of cars, etc., of any commercially operating installation or the type proposed.

E. In the absence of an installation, such as above, a brief similar description of any test installation and test procedures and components will suffice.

ANSWER: ______________________________

II. DEFINITION:

A. Operating Performance

1. What is the guaranteed acceleration from standstill to 50 miles per hour of a car with full seated load @ 140 pounds per passenger on straight level track with clean running surface?

ANSWER: ______________________________

2. Based on maximum number of train stops @ 90 second intervals, is the air compressor capable to sustain the air receiver pressure with ample safety margin?

ANSWER: ______________________________

3. Have you arranged for automatic fire protection to the running gear and how is this accomplished?

ANSWER: ______________________________

4. What is the guaranteed balancing speed under the same condition, as above in (1)?

ANSWER: ______________________________

5. What allowance in total train resistance is required for curve resistance? Test basis, if any, for determination of this allowance.

ANSWER: ______________________________

6. What are the guaranteed service and emergency braking rates under normal track or running surface conditions?

ANSWER: ______________________________

7. What factors of adhesion, over the operating speed range, can be expected under normal conditions and adverse conditions, such as rain and oil contamination of the running surface? Test basis of these figures, if available.

ANSWER: ______________________________

8. Submit speed-time, speed distance, and scheduled speed vs. length of run curves for a vehicle, under the conditions of (1) above. In calculation of scheduled speeds, a speed margin of 5 percent (5%) (time added over a no-coast run from start to standstill), shall be used. (20 seconds stop time).

ANSWER: ______________________________

III. VEHICLE:

A. What is the light, or empty, weight of the car, complete with drive and all attachments?

ANSWER: ______________________________

B. What is the seating capacity of the car and the area available for standees? (For structural consideration).

ANSWER: ______________________________

C. Describe the structure and materials providing the main structural strength of the car.

ANSWER: ______________________________

D. What design stresses are used for the above materials?

ANSWER: ______________________________

E. What buffing strength, expressed in longitudinal squeeze without causing permanent deflection, is the vehicle designed to have?

ANSWER: ______________________________

F. What are the nature and location of couplings between cars, the coupling strengths and impact absorbing characteristics?

ANSWER: ____________________

G. As presently considered, what are the number, size, control, and locations of doors, including end doors for communication between cars if considered feasible? How operated - electric, pneumatic - hydraulic, and what safety features are incorporated?

ANSWER: ____________________

H. What is the type of closure between cars? As a train, is access between cars possible or contemplated, and what safety precautions are the function of design?

ANSWER: ____________________

I. What level of illumination (foot-candles on a 45° plane 33 inches from the floor), is provided?

ANSWER: ____________________

J. What are the sources of power for normal illumination, emergency lighting and door controls?

ANSWER: ____________________

K. Describe the contemplated provisions for ventilation, and air conditioning, if included?

ANSWER: ____________________

L. Describe all safety devices concerning the car.

ANSWER: ____________________

M. Describe procedure and car securing mechanism to platform.

ANSWER: ____________________

N. Describe procedures in case of car break-down. How are passengers transferred from stalled train or car, etc?

ANSWER: ____________________

O. Please give switch cycle time.

ANSWER: ____________________

IV. BODY TO TRUCK CONNECTION, OR SUSPENSION:

A. Describe clearly, but briefly, the method of connections between the car body and trucks?

ANSWER: ______________________________

B. To what extent is body side sway permitted by the suspension or support system, and how limited?

ANSWER: ______________________________

C. Are provisions to prevent, or to limit, side sway during approach to a station platform, and during loading and unloading, considered necessary? If so, what provisions are made?

ANSWER: ______________________________

D. What are the horizontal and vertical locations of the center of gravity of a light car relative to the running surface, or rail?

ANSWER: ______________________________

V. TRUCKS (BOGGIES - POWER NACELLES):

A. Give a general description of the trucks, from the point of attachment to the car body to the running rail or surface.

ANSWER: ______________________________

B. What are the overall dimensions and wheel-base of the truck assembly?

ANSWER: ______________________________

C. What size and type of wheels are contemplated?

ANSWER: ______________________________

D. If wheels having steel rolling contact surfaces are contemplated, what noise prevention measures are contemplated?

ANSWER: ______________________________

E. If rubber tires are to be employed, describe the nature of the tire and its average and maximum loading per square inch, and state what increase over normal ambient noise level the tires of one car will produce at 50 miles per hour? What is the tire adherance?

ANSWER: ______________________________

F. How is guiding action of the truck obtained?

ANSWER: ____________________

G. What provisions are made for lateral stabilization of the truck, and the working strength of such provisions?

ANSWER: ____________________

H. As limited by vehicle and truck characteristics, what permissible speeds on tangent and representative curves are guaranteed?

ANSWER: ____________________

VI. PROPULSION SYSTEM:

A. What would be the continuous shaft horsepower rating of propulsion equipment per car?

ANSWER: ____________________

B. How many of the load-bearing wheels per car will be driven?

ANSWER: ____________________

C. What form of transmission and gearing is contemplated?

ANSWER: ____________________

D. Describe briefly the method of speed and direction control, stating the continuous duty gradations of control.

ANSWER: ____________________

E. What type of braking is considered, including provision against loss of normal service braking medium?

ANSWER: ____________________

F. What specific consideration has been given the adaptability of control and braking to the addition of automatic train control and of the functionally more inclusive automatic train operation?

ANSWER: ____________________

G. Describe the manner in which brakes are serviced. Are all brakes self-equalizing?

ANSWER: ____________________

H. What type of brakes are employed; shoe - disc - expanding - dynamic, etc?

ANSWER: ______________________________

I. What features, or special provisions, are contemplated to minimize noise, at the level of the trucks and propulsion equipment?

ANSWER: ______________________________

J. Describe briefly the propulsion medium characteristic - DC-AC motor, other electric motor types or internal combustion engines.

ANSWER: ______________________________

K. In the preferable instance of electric propulsion, what provisions (as to type and location) are made for energy collection?

ANSWER: ______________________________

L. What will be the energy consumption, electrically in watt-hours (at the point of energy collection) per car-mile; or for fuel propulsion, in B. T. U.'s per car mile under the conditions of ~~(A)~~ above? II-A-1

ANSWER: ______________________________

VII. SIGNALING AND CONTROL:

A. What form of signal display is contemplated - wayside, cab, or both?

ANSWER: ______________________________

B. What form of signal circuit is provided, and how arranged?

ANSWER: ______________________________

C. Is provision made for track-trippers, and if so, to perform what function?

ANSWER: ______________________________

D. What provisions, if any, have or can easily be made for automatic train control or operation?

ANSWER: ______________________________

VIII. COMMUNICATION:

A. What facilities for voice or signal communications are contemplated for the following:

1. Station to station;

2. Dispatcher to station;

3. Dispatcher to train;

4. Car to car;

5. Public announcement at stations and on trains.

ANSWER: ______________________________

IX. COST ESTIMATES:

A. State cost of operating train unit.

ANSWER: ______________________________

B. Cost of each car.

ANSWER: ______________________________

C. Estimate maintenance of system.

ANSWER: ______________________________

D. Estimate cost of trackage per mile.

ANSWER: ______________________________

X. PATENTS:

A. What are your patent identifications, and licensee affiliations?

ANSWER: ______________________________

XI. STRUCTURE:

A. What are design loads for supporting structures:

1. Vertical Loads 1. Beam 2. Column

ANSWER: ______________________________

2. Lateral Loads 1. Beam 2. Column

ANSWER: ______________________________

3. Torsion Loads 1. Beam 2. Column

ANSWER: ______________________________

4. Axial (Rail)

ANSWER: ______________________________

B. What combinations of loads are used in design?

ANSWER: ______________________________

C. Have the effects of dynamics been considered? How? What resulting design modifications?

ANSWER: ______________________________

D. What are dimensions of recommended support members? Are patents involved? Spacing of supports? Shape and materials used for support? Design stresses used? (Elevated, surface, sub-surface).

ANSWER: ______________________________

E. What are dimensions of switch? Materials?

ANSWER: ______________________________

F. What are suggested dimensions of switch support members? Materials? Method of operation? Time to operate?

ANSWER: ______________________________

G. What are maximum grades? (Straight & Curve)

ANSWER: ______________________________

H. What are speed-curve radius - super-elevation recommendations?

ANSWER: ______________________________

I. What maintenance yard facilities are required?

1. Support beams - size and span.

2. Beam support requirements.

3. Switch requirements.

4. Special car support requirements - bridge cranes, etc.

ANSWER: ______________________________

J. What are anticipated costs of support systems for straight and curved track, switching, etc?

ANSWER: ______________________________

K. What are outside dimensions of vehicle and clearances for safe operation?

ANSWER: ______________________________

L. What are power requirements? Voltages, frequencies, quantity?

ANSWER: ______________________________

C. <u>Rapid Transit Cars and Equipment</u>

Transit cars shall be of lightweight type. The conventional cars as manufactured today are considered too heavy for today's modern transport systems.

The possibility exists that the cars may be of the conventional type, suspended type or supported type. In any case, the weight is important, because it reflects excessive costs to the overhead structures, and as conventional type a lightweight car structure can reflect first initial cost and reduced maintenance and operating costs.

Cars shall be so designed as to allow their operation with minimum side sway, either suspended or supported.

<u>If suspended</u>, the natural sway in curves must not place torsional stresses in coupled car or cars following. The couplers must be of a design to allow for the preceeding car lateral displacement, and be automatic in function, self-locking with ability to attain electrical power interlock connection and the signal system.

The buffing strength of the car shall be 2.5 times the total and loaded capacity. Center of gravity shall be on the center of the supporting rail as possible to reduce the pendulum reaction to a minimum. This will result in sway damping mechanism with least corrective effort.

Seats shall be designed with passengers' comfort in mind with ample aisle width for easy and rapid ingress and egress. Doors shall be automatic with sensitive rubber edges and operable from the driver's cab.

Doors shall be securely locked in place and interlocked with controllers to prevent train from moving with any of the doors open. Emergency escape shall be provided for suspended cars. Cars shall be arranged for ventilation and heating.

Cooling by refrigeration is desirable. There are problems which must be resolved by further studies. In order to keep the C.G. of the car as close to the supporting rail as possible, the refrigeration unit shall be mounted on the traction bogie with flexible connectors tied to the evaporators mounted on the buffer beam of the car.

The hydraulic pump unit and the air compressors shall also be mounted on one of the traction bogies, with flexible connectors connected to the functional parts of the car to reduce the sprung weight of the car and increase the tractional effort of the traction wheels.

<u>Trucks</u> (Bogies - Suspended Split Rail)

The axles shall be full floating and subject to torsional stress only and drive through a differential.

The reduction gearing shall be of the spiral or helical type with shafting mounted in taper roller bearings with adjustable thrust feature.

Hypoid pinion and gear shall be the power take-off.

Every effort shall be made to reduce vibration and noise by proper selection of gear tooth form and gear back lash.

The propulsion motor shall be flange mounted; involute spline drive shaft shall have rubber disc drive.

Brake System;

Dynamic braking shall be employed in any system used. Friction brake shall automatically take over from 5 miles per hour to zero speed and also be used for parking.

Wherever automatic operational system is used, the braking shall be arranged to respond to all safety blocks as commanded, with manual override at driver's discretion.

Pneumatic rubber tired wheels may be used, provided each tire load, in the most unfavorable condition, meets with the tire manufacturer's recommendation and guarantee, at the specified balancing speeds, temperatures, and deceleration rates, with ample safety margin.

Steel wheels may be used on steel rails. Sound deadening in the high frequency spectrum is recommended as a requirement.

Industrial type rubber tires shall not be used for guide wheels if guide wheels are used.

Adhesion

The average conditions of adhesion should not affect controllable 3.5 miles per hour per second, with 4.5 miles per hour, per second available at all time for emergency braking deceleration.

The adverse conditions of adhesion include such factors as rain, tree leaves on rail or track, oil, etc., on fixed running surface.

Conventional Car Truck shall be of modern lightweight. The truck stress members should preferably be aluminum alloy forging, properly heat treated and normalized for its ultimate strength.

The hunting tendency of the truck shall be snubbed by friction pads and final restraint made by appropriate rubber bumpers in the lateral direction.

Vertical truck chassis displacement shall be snubbed and friction pads employed to dampen high frequency oscillations. Air springs and self-leveling air valve mechanisms shall be made use of together with torsional rods inbedded in rubber grommets.

The car shall be cradled in a ball joint self-lubricated thrust bearing, supported by a "rubber" ring encased in the bolster and cause rubber to be in shear.

Controls and Signals

The cars shall be fully controllable from either end, or if articulated car design is used, it shall also be driven in either direction from either end.

The controls shall respond to complete central automation and allow driver discretional overriding.

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Controls and Signals

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The controls shall respond to complete central automation and allow driver discretional overriding.

The signals shall be the standard block light system mounted on the car operator's dashboard.

<u>Communication</u> shall be by dispatcher's radio to each train and through telephone at each station, station-to-train, train-to-dispatcher, and to station.

<u>Car Automation</u>

On the basis of 50 miles of double track, 200 cars (40 five car trains), the estimated cost of complete train automation from a central control room and providing one spare computer and a black box element for each car, is 4-5 million dollars.

Standard block system for the same coverage as stated above; the cost estimate is 13 million dollars.

There will be one electronic black box per each individual car or each individual train. This instrument will relay track information to, and receive information from a digital computer, located at the central dispatcher's office.

Only the dispatcher will have the overriding capability over a <u>system</u>.

Each driver of the car will have discretionary overriding capability over his particular car or train.

D. Electric Power Applications to Rapid Transit Trains in Urban Areas

1. General

As an example of the power requirements of rapid transit service, one six-car rapid transit train weighing 165 tons requires 3500 kw (4700 horsepower) of power for a short time (about 5 seconds) during acceleration at a rate of 3 miles per hour per second until the speed is about 30 miles per hour, after which the power demand drops off gradually while the train's speed continues to increase, but at a less rate of acceleration until a free-running speed is reached, or until the speed must be decreased by coasting and braking and the train brought to a stop at the next station. Also, a smaller power demand, in addition to traction power, exists continuously because of electric lights, air compressors, etc., on the train. Longer trains would have proportionately larger power requirements. It is estimated that when trains follow one another on a 1-1/2-minute headway, the total power required is considerable, averaging 2600 kw per double-track mile during rush hours.

Both prime movers (self-contained sources of energy) and power-collecting electrical systems are considered in this discussion.

2. Prime Movers

a. Nuclear Power Units

Because of the large size and heavy shielding required for the only nuclear power generating units so far developed, nuclear power can be applied to the rapid transit system only by the Transit Authority building its own nuclear-steam-electric stationary power station and transmitting and distributing the electric power. This system is not recommended, however, because nuclear power plants have not yet been proven to be economical in the United States where cheap fossil fuels are available, and on account of high development costs. Previous experience in other cities have shown that, since the load factor of a transit system is low, a central power plant which supplies only a transit system would be uneconomical, as compared with a nearby power utility serving many diversified customers.

b. Jet Engines

The use of jet engines or power units on rapid transit trains in impractical because of low efficiency on account of the relatively slow speed of trains in higher-density atmosphere, as compared to airplanes where jet engines are efficient, and because of the large amount of fumes and noise emitted by the jets.

c. Other Internal Combustion Engines

The use of diesel engines and gasoline reciprocating engines to power rapid transit trains with high accelerating rates is impractical because of the size of the engine necessary to furnish sufficient power for high acceleration.

Diesel engines have been successful on locomotives and interurban trains with relatively low acceleration rates, but urban rapid transit with short runs requires high acceleration. Gas turbines using kerosene as fuel have been developed with sufficient horsepower and small size to furnish the requisite power, one turbine to a two-car unit, but the high temperature heat losses, poor efficiency at light loads and when idling, fumes, and danger of fire from kerosene tanks, make them impractical for multiple unit passenger service, especially if long subways are to be traversed.

d. Fuel Cells

Fuel cells are a new development in producing electric power by chemical means (similar to a flashlight cell, but more powerful and can be replenished continuously). So far, these cells have not been developed to have sufficient power for buses or rapid transit cars.

3. Power-Collective Systems

a. Electrical Source - General

The problem of obtaining power economically in an urban area can be solved by purchasing electric power from one or more of the local utilities. This power would be distributed over the utilities' circuits to traction substations spaced at intervals near the rapid transit tracks (see Figure IV-B-1).

These substations feed the current-collection system, trolley wires or contact rails, from which the trains obtain their power. In some localities, the Transit Authority now owns and operates a suitable power distribution system fed by the Southern California Edison Company.

The number of traction substations and their spacing, and whether contact rails can be used, depends on the voltage selected for the current-collection systems-- the higher the voltage, the fewer substations are needed.

It is seen that costs of substations and the current-collection system can theoretically be minimized by making the current-collection voltage as high as possible. There are certain technical considerations, however, which limit the current-collection voltage. Higher voltages require greater clearances because the insulators are larger and the arcing distances are greater. Some suburban electric railways have 11,000-volt (a-c) contact systems with substations 20 miles apart, and some have 3000-volt (d-c) contact systems with substations 10 miles apart, but these systems have overhead contact wires above the rails, (Figures IV-B-2 and IV-B-1 alternately). Most urban rapid transit systems, where overhead clearances would be costly because of the large tunnels which would be required, now use 600-volt (d-c) contact rails at the side of the track and are in tunnels as small as practical. (Similar to Figure IV-B-2, except low contact rails and no overhead wires). The substations are approximately 2 miles apart. Most of the rapid transit systems now being considered for the Los Angeles Metropolitan Area will also have close clearances for their contact systems and, therefore, must use a fairly low voltage current-collection system.

The question as to whether a-c or d-c voltage should be used will be decided by economic and technical considerations, also. Undoubtedly, the power purchased from the local power utilities will be a-c 3-phase at a frequency of 60 cycles per second and at a voltage of 34,500 volts or 16,500 volts which can be transmitted economically over the distances involved. This purchased 3-phase power will be transformed or converted in the traction substations to the voltage selected for current collection. It would simplify the substations if this 60-cycle a-c power could be merely stepped down by transformers for use by the trains.

Direct current (d-c) voltage has an advantage over the a-c voltage in that d-c traction motors are very well suited to rapid transit service with high acceleration rates.

This type of motor is well developed and successful, while if alternating current is used, the a-c traction motors for direct application have not been developed, except for special low frequency (25 cycles per second or less) or for wound-rotor 3-phase motors which are bulky, more costly, and require 3-phase conductors. Another 3-phase system has been proposed, however, which would be new in transit service, and which was considered once in previous reports for San Francisco's and Los Angeles' new rapid transit systems. This new a-c system would operate on 2300-volt 3-phase 60 cycles, using constant-speed squirred cage motors driving the train axles through a hydraulic "torque converter" variable speed device. So far, a car truck with torque converter and squirrel cage motor has never been built for train service, so it is not known how much space would be required and how much the equipment would weigh, and whether it can be used on some of the supported and suspended type railways being considered. The substations would be transformers and circuit breakers with reverse-power protection.

These power application systems will now be discussed in detail.

b. <u>Single-Phase, 25-Cycle, A-C System with Series Motors (Figure IV-B-2)</u>

The alternating current system of power distribution has two outstanding advantages: (1) simplification of substations which require only switching and, possibly, static transformers for lowering the voltage to a suitable voltage for the trains if clearances are limited, and (2) the possibility of using high voltage current collection with widely-spaced substations, where clearances are not difficult to obtain, as in "classical" railroads, with only transformer equipment and tap changers required on cars using 25-cycle series a-c motors. This 25-cycle a-c system is now being used on the large Pennsylvania Railroad and Reading Company's suburban services in Philadelphia and the New York, New Haven and Hartford suburban services out of New York.

The disadvantages are: (1) a large frequency changer is necessary at point of power supply, (2) slower acceleration in rapid transit service, (3) noise of starting, due to magnetic hum, and (4) necessity for transformers on the cars. Also, high voltage current collection would be practically impossible on low-clearance systems such as suspended systems and some "straddle" monorails. Last, and probably most important, the rapid transit operating authority probably would have to own its own 25-cycle power distribution system.

c. Three-Phase A-C System Using Fluid Drive (Figures IV-B-3 and IV-B-4

The 3-phase a-c system at the commercial frequency of 60 cycles would require a complicated current collection arrangement, including two insulated contact wires and the ground through the supporting structures, as the third phase, with 2300 volts between phases. Each truck on the train would have mounted on it one 200-horsepower (nominal rating) 3-phase 60-cycle squirrel-cage motor which will run at nearly constant speed whether the train is stopped or whether it is in motion, two fluid transmission systems (one per axle), and two or three collector shoes. The torque of the motor is transmitted to the axles of the truck through a type of fluid drive such as the torque converter which was developed primarily for automobile drives. The details of the torque converter application and its remote control, within the space limitations of a railway truck would have to be developed. A gear-shifting arrangement would be necessary for reversing the train.

The principal foreseen difficulties of this system are the high voltage drop due to the impedance of the circuit over the desired distances, the current collection at 2300 volts 3-phase, which is high for a comparatively inflexible trolley wire made necessary by the confined space available on suspended system and "straddle" type monorails, and the high losses during acceleration of a fluid transmission. Also, it would be difficult to design the traction equipment to be within the space limitations of a car truck.

The principal advantages are the simplification of power supply and of wayside substations which would be secondary-network transformers and their protective devices plus capacitor banks along the tracks to improve the voltage regulation. Because of the lack of experience with this electric application, extensive developmental testing of the torque converter should be made in the shop before it is adopted.

d. Three-Phase A-C System Using Variable Speed Induction Motors

This system is similar to the preceding 3-phase 2300-volt a-c 60-cycle except that the traction motors would be variable-speed wound rotor induction motors geared to the axles without a clutch or fluid drive. These traction motors would be much larger than squirrel-cage or series motors and would require heavy resistor grid and numerous contactors for varying the speed. It is quite doubtful if this system could be applied to a suspension system or "straddle" type monorail, because of the limited space available for the traction motors. Other disadvantages are high voltage drop, the necessity for a "hard" current collection system at higher voltage than is good practice heretofore, and heavy motors and control. The wayside substations would be simple, however.

e. Alternating Current System Using Rectifiers on the Cars (Figure IV-B-2)

This a-c system, using a high voltage (11,000 volt) current collection system has been successfully operated on conventional railroads, but would not be applicable to suspended systems and "straddle" type monorails because the limited space precludes the high-voltage current collection. However, it would be possible if the current collection voltage were reduced to 2300 volts or below. The advantages of this system are that low-voltage d-c traction motors could be used which are well suited to rapid transit service and the wayside substations would be comparatively simple. The serious disadvantages are the high cost of control (including transformer and rectifier equipment) on each car, the heavy transformer equipment requiring considerable space, and the high voltage drop of low-voltage a-c distribution.

f. Low-Voltage (600-Volt) Direct Current System (Figures IV-B-3 and IV-B-4)

This d-c system has been highly developed and is in successful operation in thousands of miles of rapid transit and surface lines. It is well suited to the high accelerations of rapid transit service. Also, like other systems using d-c motors, it is adaptable to dynamic braking which saves wear and tear of the wheels and trucks. The disadvantages include the frequent and more costly substations required for power distribution.

Also, where the running rails cannot be well insulated, there is a possibility of stray d-c currents in the earth and care must be taken to maintain rail bonding, rail insulation, etc., to minimize the stray currents. If space is available for the use of heavy iron rails for the contact system, as in the case of "classical" railroads, the power distribution cost would be low, since the use of iron rails on inexpensive low-voltage insulators is a comparatively low cost method of power transmission.

g. Fly-Wheel Energy Storage on Cars in Lieu of Continuous Current Collection System

The fly-wheel energy storage system would be a modification of the system above described using the desirable low-voltage direct current traction motors, and would considerably simplify current collection, which would take place only when trains are in a station area, where the fly wheels would be recharged. In this system, each car or two-car unit would be equipped with a motor-generator set directly connected to a fly wheel of sufficient inertia that energy can be stored in the turning wheel. At stations and other stopping points, contact shoes on the train would make contact with conductors energized with 2300 volts 3-phase 60-cycle current, causing the motor-generator fly wheel set to accelerate and run at near synchronous speed.

The generator on the m-g set would then supply accelerating power to the d-c traction motors when the train is started. The contact rails would extend possibly 200 feet or so, in the station so that the starting energy would come from them through the m-g set during most of the high-acceleration period. After the train leaves the vicinity of the station, the energy required by the traction motors would then come from the generators while being driven by the fly wheels, thus slowing down the fly wheels to some extent. When the train is slowed due to dynamic braking, some energy would be returned to the fly wheels by the generator acting as motors, and when the train reaches the station, the fly wheel would again be charged from the contact rails through the a-c motor of the m-g set.

This system has the advantage of a less expensive contact sytem. The disadvantages are the more expensive, bulkier and heavier electrical equipment on the cars, the more frequent substations (one at each stopping point), the gyroscopic effects of the fly wheels when the cars run onto vertical curves, and its need for considerable development work for application to rapid transit service. Also, if a train should have to stop between stations, for a considerable time, there would be danger of the fly wheel slowing down too low due to friction and the train would then have to be towed to the next charging point by a service car equipped with a prime mover for motive power.

4. Other Power Applications to Trains

a. Air Screw or Propeller System

This type of propulsion has been tried experimentally, but was not successful for high accelerations, and it had serious objectives due to noise, wind and inefficiency.

b. Electro-Magnetic Propulsion from a Long Motor Winding Laid Out Horizontally and Continuously Along the Rails of the Track (Figure IV-B-5)

The stationary winding would act magnetically on a motor "rotor" winding developed in a flat form underneath and attached to the train. The stationary winding would be energized by electric current and the train would move due to the magnetic action between the windings. Such a system would be very expensive and prohibitive in first cost.

c. Use of Compressed Air Traction Motors on the Trains Operating From Storage Air Tanks on the Trains Which Would be Recharged at Stations

This system would be very inefficient due to heat losses and low thermal efficiency of the air motors.

d. Dual Voltage (600/1200 Volts) Direct Current Systems (Figures IV-B-3 and IV-B-4)

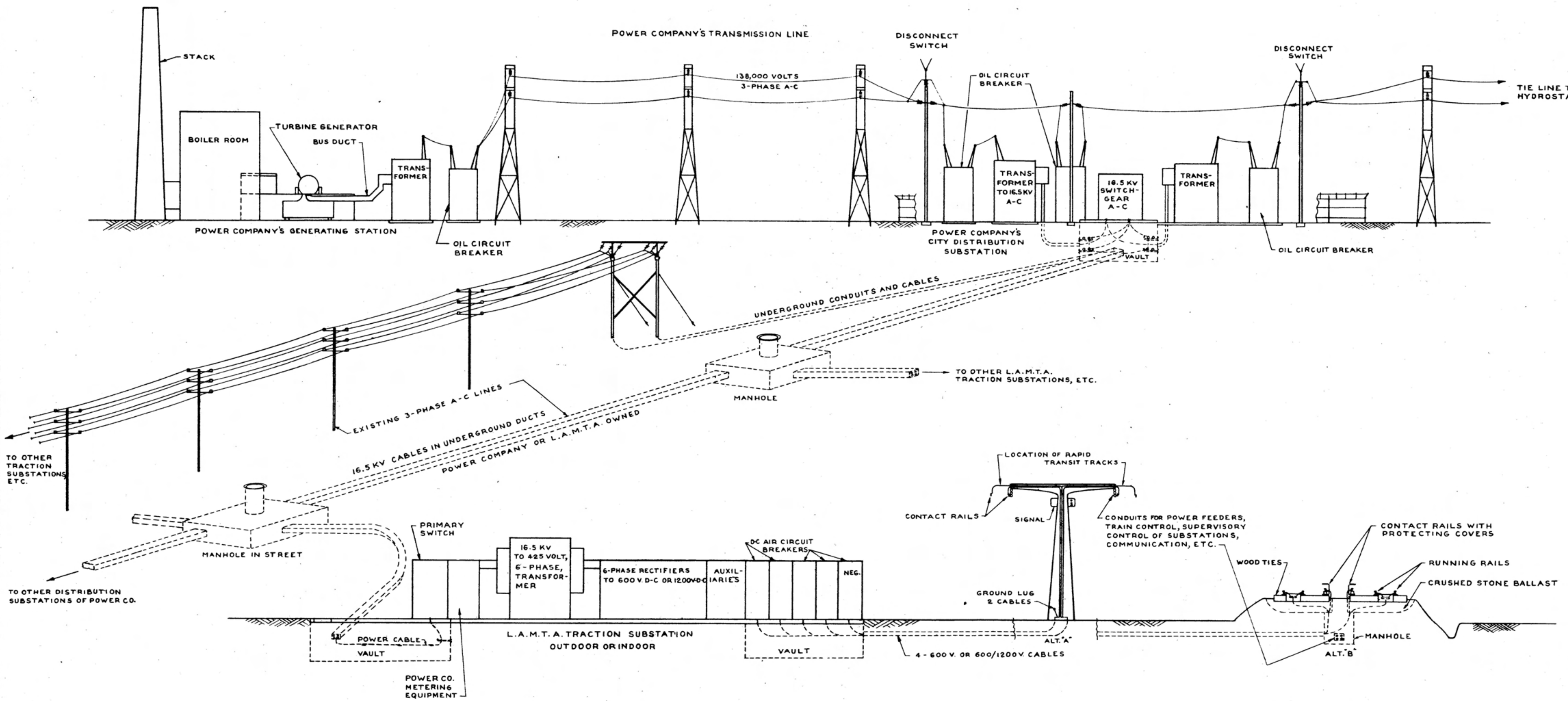
This d-c system is a modification of the low-voltage d-c system. The traction motors are rated 600 volts and the two motors on each truck are connected in series with an impressed voltage, on the pair, of 1200 volts d-c.

There are two contact rails, however, which are positive 600 volts on one rail and negative 600 volts on the other, making 1200 volts d-c between the two contact rails, but with a maximum of 600 volts to ground. The traction motors need only to be insulated for 600 volts, however, since the substations are grounded at the neutral point of this 600/1200 volt system.

The advantages of this system are that the substations can be spaced twice as far apart as in the case of the 600-volt system, and the danger of stray d-c currents and the corrosion resulting therefrom, is minimized.

The disadvantages, as compared with the 600-volt d-c system are that two separate contact rails are required, the traction motors must be slightly larger in diameter, and one extra rectifier is needed in each substation, so that the neutral can be brought out of the circuit. Also, the dynamic braking advantage is lost to some extent, and more reliance must be placed on friction brakes. The disadvantage of having two contact rails disappears if it is decided that the 600-volt d-c system also must have two contact rails in order to eliminate stray currents, as may be the case if the grounded structure would otherwise be used as a return path for the current to reach the substations.

conditional on a reconsideration of the 600/1200 volt d-c system before detailed design for construction of the initial phase of the rapid transit system begins. If it demonstrated that satisfactory dynamic electric braking can be obtained with both systems, the 600/1200 volt d-c system will be the preferred system because of its economy and elimination of stray d-c currents in the earth.



TYPICAL
POWER SUPPLY
TO
RAPID TRANSIT SYSTEM
(DIAGRAMMATIC)

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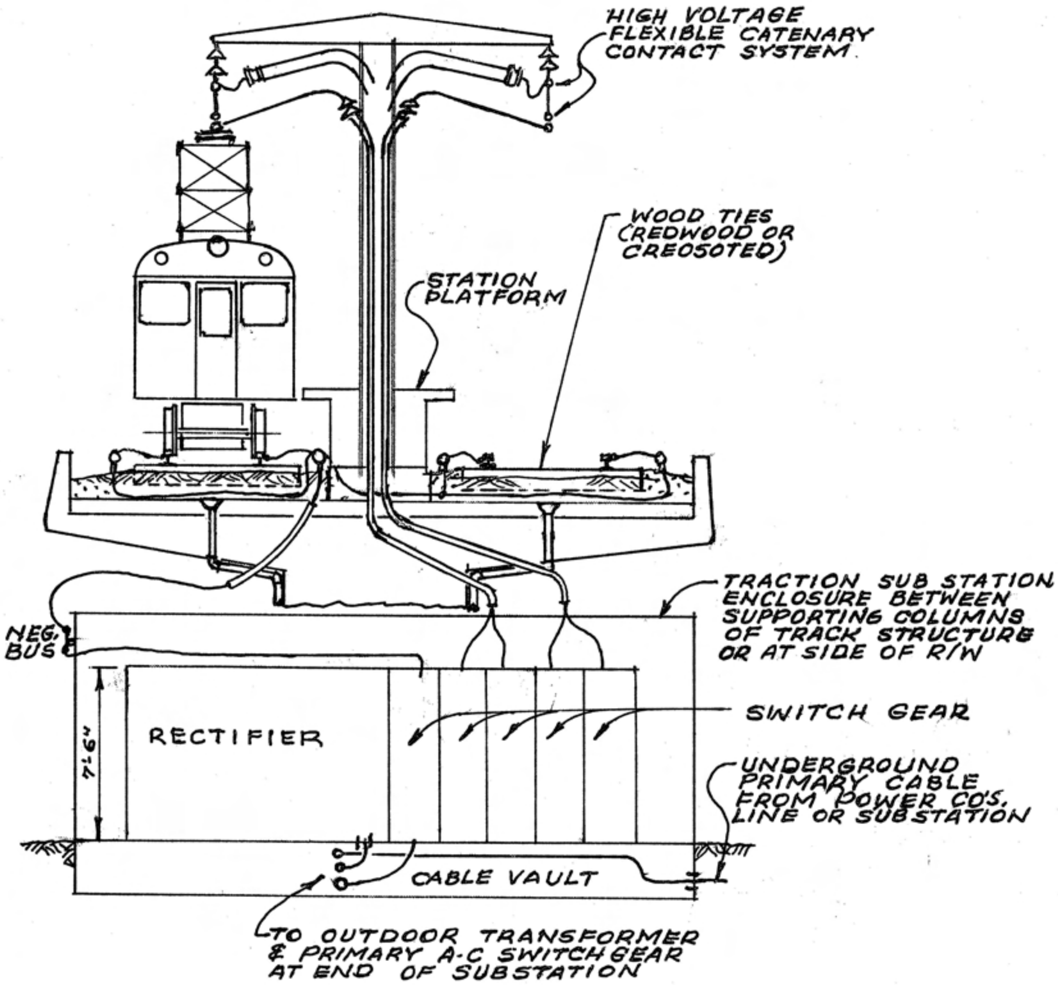
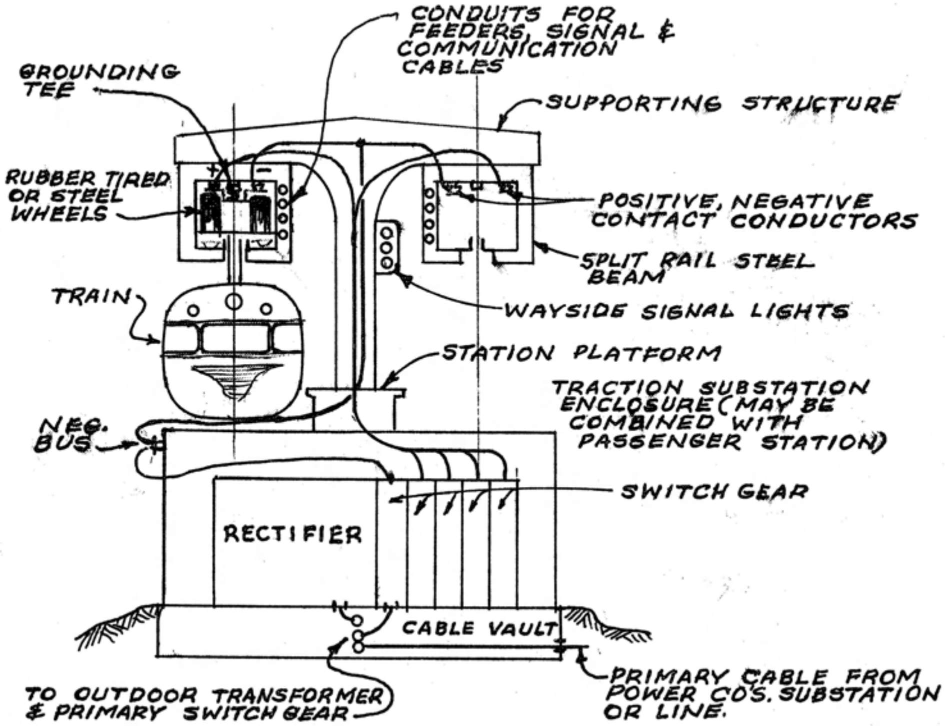
LAMTA RAPID TRANSIT PROGRAM
PRELIMINARY

DRAWN BY: L. Korda	JOB NO.: 626-1-1
CHECKED BY: W.T. [illegible]	SHEET NO.: FIG IV-B-1
APPROVED BY: F.W. [illegible]	DATE: JAN 25, 1960



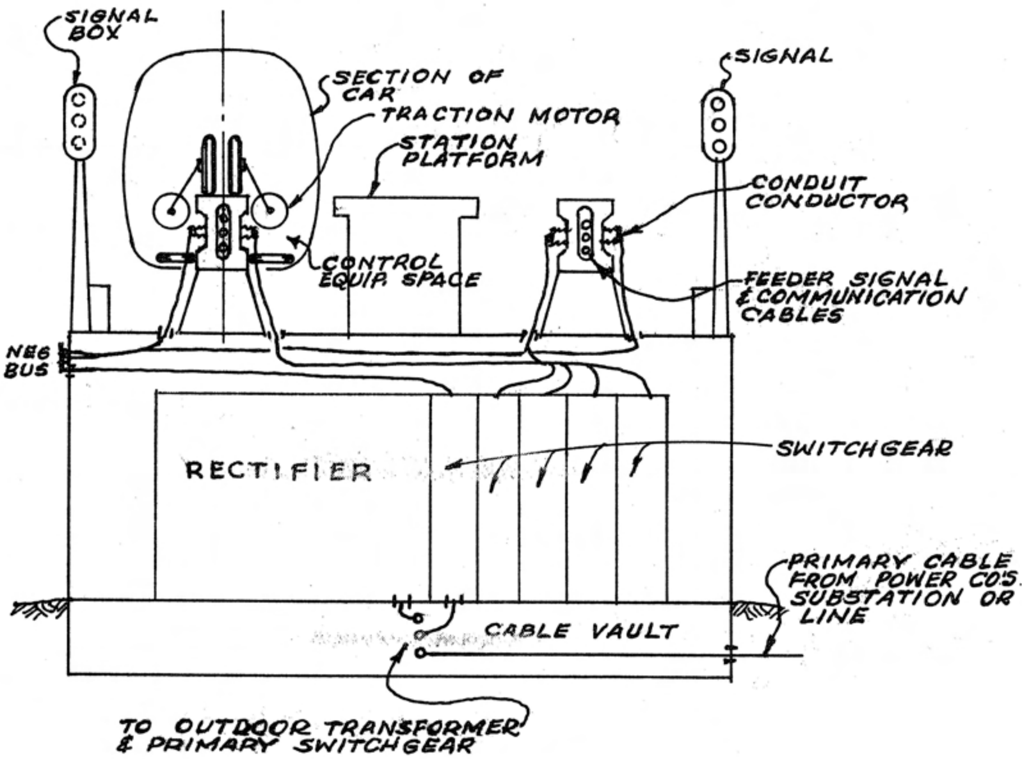
HIGH VOLTAGE D.C. TRACTION SYSTEM

FOR CONVENTIONAL RAIL SYSTEM



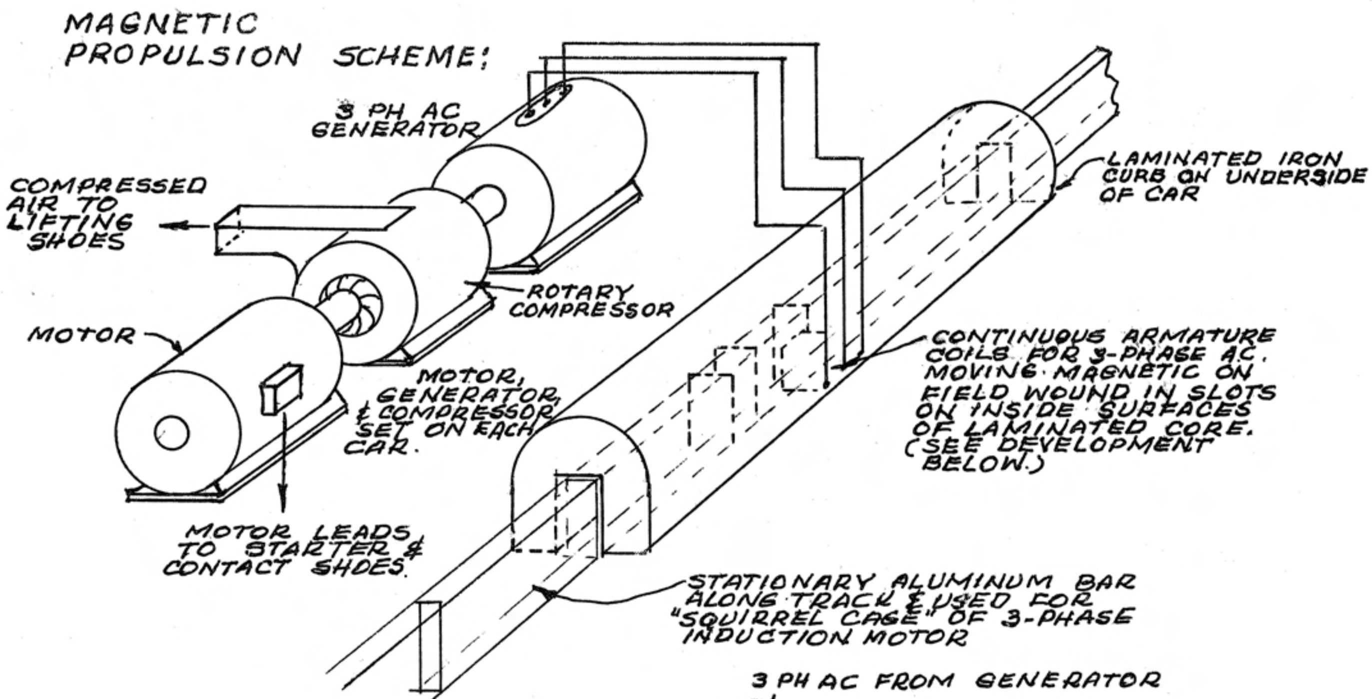
LOW VOLTAGE D.C. TRACTION SYSTEM

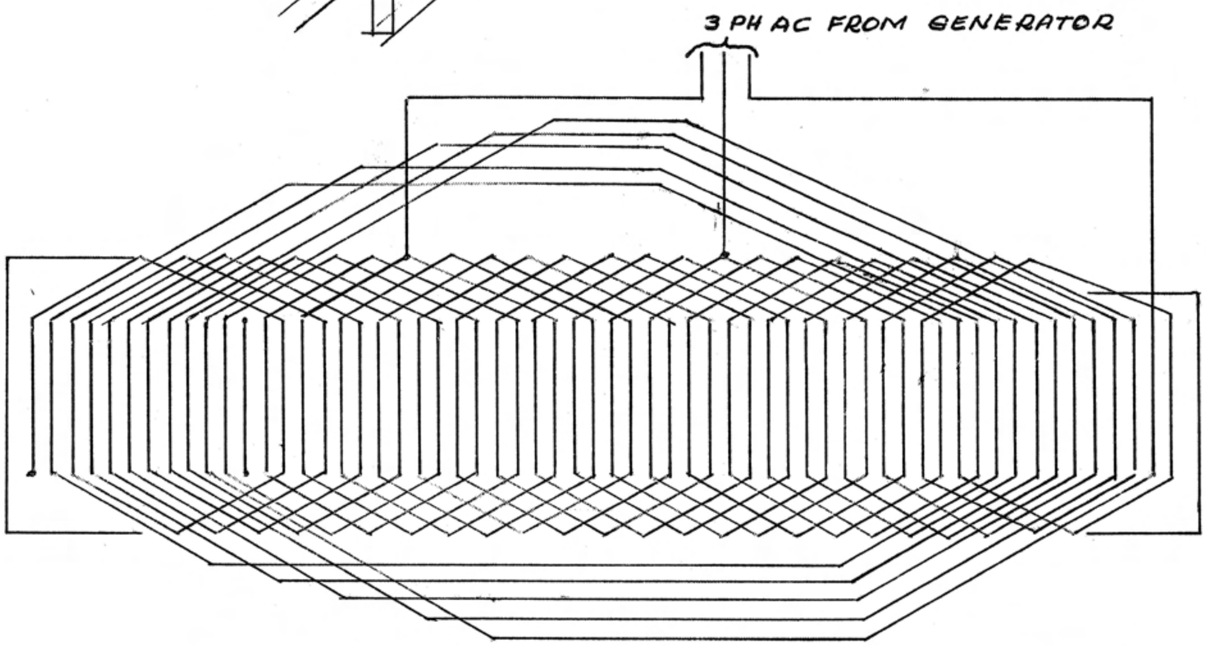
FOR SUSPENDED MONORAIL



LOW VOLTAGE D.C. TRACTION SYSTEM

FOR SUPPORTED MONORAIL





DEVELOPMENT OF WINDING ON ARMATURE

MAGNETIC PROPULSION

The sketch portrays the "ground effect vehicle" basic motive propulsion motor and its 3-phase stationary windings energize the stationary field which is integrally mounted with the car bottoms.

The propelling flat aluminum plate is the squirrel cage for the 3-phase induction member, which is fixed to the roadway.

E. AUTOMATIC TRAIN OPERATION AND SIGNALS

1. GENERAL

In urban rapid transit service, the trains or vehicles must run at high speed and with close spacing in order to transport the large numbers of passengers per hour who will travel from their homes to work at about the same time every week day and who go home at about the same time at the end of the work day.

Such close operation at high speed requires that great precautions be taken to prevent collisions and the resultant loss of life and injuries to passengers and attendants, in addition to equipment damage.

Nearly all existing railways use visual block signals along the tracks, which, if properly observed by train motormen, prevent accidents.

The recent rapid development of electronics, servo-mechanisms and ultra-rapid computing machines have made possible improvements to rapid transit train operation, and these will now be discussed as to their practicability.

2. AUTOMATIC TRAIN CONTROL

It now appears to be possible to control all trains on a rapid transit system from a machine located at a central point. The pattern of operations would be pre-determined and translated to a tape fed into the machine. The computer-like controller then sends impulses by alternating current of various frequencies through insulated wires along the track.

The computer is also connected to pick-up coils along the tracks, or other forms of transducers.

The trains have corresponding pick-up and sending coils under each operating cab, and the cab in use receives the impulses from the computer by magnetic induction and the control device in the operating cab then interprets the signal to cause the train to start, stop, slow down, or increase speed, depending on the meaning of the signals. Each train also sends out distinctive impulses and if a train stalls or gets ahead or behind schedule for any reason, the central computer, which automatically compares the transmitted train positions with the schedule, will send out the pre-determined necessary impulses to adjust the positions of all trains accordingly re-routing some, if required, or giving an alarm to maintainers if a stalled train does not respond to the impulses. Such a system has the advantages of increasing safety by eliminating human failures and utilizing the "closed loop" feature and saving of manpower. Supplementary way side signals can be added as a further safeguard.

Automation has the disadvantage of being new to transit service, though it is becoming common in machine tool control and other such applications. Also, the first cost may be considerable, and there will be much pre-calculation work in preparing the program for the computer, and specialists must be retained for changing the program from time to time to suit the traffic requirements.

3. SIGNAL SYSTEMS

a. Track Signals

Signals along the tracks have been highly developed for railroads for governing trains. The signals are controlled by low frequency or d-c electric currents in the running rails, and they indicate the presence of a train in any signal section continuously, thus signalling the following train not to enter the occupied section.

The relays for the track circuits must be quite sensitive and accurate, since the voltage impressed on the running rails is small for reasons of safety, and there is some leakage of current due to the rather low resistance between rails and from rails to the earth.

This signal system is fail-safe, current must be present in a relay coil to obtain any other signal than "stop". Therefore, a failure, such as a broken running rail or interrupted power supply, which results in no current, has the same effect as a train shunting the track circuit, namely, a "stop" indication.

b. Track Signals with Automatic Stops

Sometimes an automatic stopping device is added to the signal system to insure that trains do not pass a red signal due to the train operator not being alert. This mechanical device would be arranged to set a tripper at the location of the signal when the signal is red. Each car with a motorman's cab would have to be equipped with a trip valve in the air brake system located on each side of the car. When the track tripper makes contact with the car trip valve as it passes by, the valve would be tripped open and thus setting the emergency brakes which, in turn, would shut off power to the traction motors and the train would come to a stop.

This system has the advantage that it has been tried and is successful and would require only small, if any, development costs for railways having at least one insulated running rail. For systems without insulated tracks or with rubber tires, there would be some development work necessary because track circuits would have to be replaced by magnetic induction between coils on the train and wires and coils located near or under the track.

This system has the disadvantage that it depends on the human element to keep the trains running in a normal manner. The psysiological delay of the motormen acting on changing signals is not as fast as automatic devices.

C. Cab Signals

Railway signaling has now been developed so that the signals can be located in the motorman's cab on the train instead of, or in addition to, way side signals. Cab signals are made possible by the ability of the apparatus on the train to pick up the signal impulses by magnetic induction. This improvement speeds up traffic because of the continuous indication of a occupancy ahead of the trains; it makes possible shorter sections in the track for sensing track occupancy so that a train motorman knows more accurately what his safe speed is, and, therefore, closer headways are possible. Also, cab signals, eliminate the hazards of poor visibility due to fogs.

4. CONCLUSIONS

The apparent advantages of automatic train operation are so great that a detailed design and cost estimate should be made, along with other construction cost estimates to be completed in Phase II of the Rapid Transit Study. If automatic operation is found to be of reasonable cost for the service to be rendered, plans should be made using it on the initial rapid transit installation, with provisions for extension.

F. AUTOMATION

The complete automation of a car or train based on digital feedback system is not, at this time, in existence specifically for trains made up of one or more two-car sections. However, it appears possible to apply such a system to rapid transit service with the provision for one attendant per train.

The digital feedback system combines track to train control and automatic block signal control, and retains the manual over-ride feature.

Speed Distance Track Control

Tha automatic system can call for any speed or acceleration or deceleration within the car equipment and can be varied at will by dispatcher or by the automatic operation equipment in the control office.

Car Makeup

A minimum amount of equipment would be mounted permanently in a car. The leading axle on the front truck and the trailing axle on the rear truck of each car would be equipped with a simple, static device to indicate wheel revolutions.

A relay bank and cab signal would be located in each control compartment (two sets per car).

All other equipment would be contained in a small portable unit wherein only one would be required for any train, regardless of the number of cars.

Interlocks between cars would be provided on the digital feedback system.

Starting of Trains

In the digital feedback system, the starting of trains from a yard would be permitted by a signal from the motorman but would be instigated by the automatic control. Starting of trains at station stops would be done automatically after door closure, but subject to delay by the attendant. Starting, after emergency stops initiated either manually or automatically, would be permitted by the motorman but accomplished by the automatic features.

The starting of trains can be accomplished at any desired acceleration rate that is obtainable by the car equipment. The train would be under the control of the automatic system during and after the automatic start and does not have to travel a certain distance before the operation comes under the automatic control.

Stopping of Trains

The stopping of trains at a point in a passenger station, or any other desired location at the option of the central office dispatcher, will be accomplished automatically from the central office of the digital system.

The procedure described for the block system, requiring local devices, would be handled automatically from the central office logic equipment of the digital feedback system. Various degrees of accuracy in spotting trains can be attained, as required.

Announcing Train Arrival at Stations

The functions described in this section for the block system can be easily accomplished by the digital feedback system. The information required for arranging these displays would be inherent in the central office logic system.

Station Program

The station program for the digital feedback system would be handled from the central office, automatically, and would take into account the correct positioning of the train, door opening, the desirable interval which could be based upon the number of passengers waiting to load, and would include automatic door closing and restarting of the train. The central dispatcher, the motorman, or the station dispatcher would delay door closing if desired.

Dispatching from Terminals

Dispatching from terminals would be carried out by the digital feedback system in much the same manner as by the block system, except that the pre-arranged programs setting the times for trains to depart would be stored in the central office logic system memory where the central dispatcher would have flexible manual control or manual override. Starting the train from the terminal would be essentially the same as starting the train from any other location. However, it would require, as in the block system, the permissive action of the attendant.

In addition, the train would leave over a section of track arranged to calibrate the distance traveled in a given number of revolutions of the front and rear axles of the train so that the central office system can generate a factor for interpreting wheel revolutions as distance. Furthermore, recalibration and correction stations of a very simple nature could be occassionally spotted along the wayside to eliminate any errors due to wheel slippage or creepage. This calibration and correction would be done automatically without manual attention.

Train Identification

The digital feedback system incorporates simple provisions for reporting the location of all trains in the system every one or two seconds and this information further includes the exact identity of the train for each such report. No wayside equipment is involved; the identity is inherent in the transmission of data to and from the train.

Line Supervision

The digital feedback system would provide all that information enumerated for the block system deemed desirable, and in addition, such further information as speed and acceleration for selected trains. The recording of data would be done using modern techniques such as magnetic tape, visual plots, visual displays and printed data. The digital feedback system is inherently more flexible in initiating manual operations by the central office dispatcher and in the collection, storage, use, display and recording of pertinent data concerning the entire operation.

Correction of uneven service would be accomplished automatically by the digital feedback system, the results of which can be manually altered by the dispatcher if he so desires. Re-routing can also be handled either automatically or manually.

Any emergency stop would be reported automatically to the dispatcher including information concerning the exact location and identity of the train and the subsequent automatic actions taken to slow down, stop or re-route following trains. The various details of such a central dispatching office can be specified, as desired, with regard to the functional requirements.

Switching

Automatic switching would be provided by the digital feedback system and would be coordinated in the central dispatching office automatically, but would include safety interlocking features on the switching devices themselves.

Block Signal System

The digital feedback system differs from the block system in a very basic manner. Instead of using block occupancy as the information upon which safe minimum headway is based, the digital feedback system utilizes the actual location of the front and rear ends of the trains in question, as well as train speeds, acceleration, and deceleration. The safe minimum headway between two trains is then, more realistically, a function of the leading train and the speeds and accelerations or decelerations of both trains. The digital feedback system makes use of a continuous-loop type of information transmission between each train and the central office. The information from the train to the central office includes the train's identity, the location of both ends of the train, the signal aspect being displayed in the cab, and the automatic operation instruction being utilized. The transmission from the central office to the train contains the train's identity, the signal aspect to be displayed in the train, and the automatic operation instruction to be utilized by the train. Receipt of this data aboard the train causes the train to transmit its data to the central office. The receipt of the data in the central office causes the central office to transmit its data to the train, and so on. If any component or part of this digital information loop fails, or if the loop is accidentally or intentionally interrupted, all data transmission stops. The train, after a suitable time delay, would execute an emergency stop, thereby accomplishing fail-safe operation. The central office receives this type of data from all trains and utilizes the data in determining cab signal aspects and automatic operating instructions to be sent to each train in order to maintain safe minimum headways while automatically operating each train in the system. The logical functions performed by the system, to provide safe headway between trains, would be performed in a self-checking, high-speed digital computer, in the central office, provided with adequate machine standby and automatic safety features in its program. The same automatic logic system can be made to handle other problems such as switch operation, train dispatching at terminals, execution of pre-determined schedules by automatic operation, automatic revision of such schedules as desired, passenger station train announcing and other related functions.

Communications

The digital feedback system would provide essestially the same communication facilities, if required, as the block system described.

G. SPACE AND STRUCTURAL REQUIREMENTS FOR POWER SUPPLY AND AUTOMATIC TRAIN OPERATIONS FACILITIES ON RAPID TRANSIT RIGHT-OF-WAY

1. Traction Substation

Traction substations receive the power utility's high voltage 3-phase power circuits, which bring electric power to the rapid transit system, and convert this power for use by the traction motors on the trains. Fig. IV-B-1 shows the position of the traction substation in the electric circuit of the power supply and shows the more important equipment making up the substation.

The substation should be automatic and unattended. This equipment should be enclosed and it can be located in the same unified structure as houses a passenger station in many cases. The equipment can be strung out in a line, as indicated in the figure and located underneath the elevated rapid transit tracks, and no more land need be used than must be acquired in any event for a double track elevated railway.

The transformers for the substation could be in a ventilated fireproof room if they are oil-filled. Dry type or askavel-filled transformers are more expensive but would require no such vault. All equipment must have ample access space for maintenance and for repairing any piece of equipment, and must be protected from tampering by non-authorized persons.

Supervisory control by the Dispatcher and including alarms to the Dispatcher would be provided by remote control from the Dispatcher's office.

2. Electrical Equipment on Track Structures

The traction substation would be connected by cables to the railway contact system, and supplementary feeder cables, when required, must be mounted on the track-supporting structures and run parallel to the track, tapping into the contact system at intervals.

Wayside signals and relays, or automatic train operation inductive equipment, must also be mounted at intervals on the track structures, with connecting cables, preferably in conduit or suspended from messenger wires, paralleling the track.

Summarizing the cables and equipment along each track would be:

a. Cables Along Each Track

2 bare hard-drawn copper or high-conductivity iron contact conductors mounted on porcelain insulators, 3 to 8 feet spacing.

2 or more aluminum or copper traction power feeder cables, 2" to 3" in diameter, insulated for 600 volts (nominal), when necessary.

1 multi-conductor insulated control cable for wayside signals.

1 multi-conductor insulated control cable for substation control.

1 telephone type cable for telephone or communication.

1-4-conductor 4160 volt 3-phase 4-wire insulated copper or aluminum auxiliary power distribution cable to supply power to auxiliary transformers at signal lights, signal relay cabinets, etc.

2 (minimum) co-axial high-frequency cables for transmitting control and supervision impulses to and from trains, and connecting to induction coils along the track, for automatic train operation. (Note: These co-axial cables may be omitted if automatic train operation is not used).

1 insulated stranded wire for relaying radio communication signals to train attendants (only in subways and along depressed track with many overhead viaducts and other shielding structures).

b. Equipment Along Each Track

1 signal standard every 500 to 2,000 ft., including box with three or more colored signal lights, relay cabinet, single phase small transformer with high-voltage fused cut-outs.

2 wayside induction coils at each signal standard location, one for transmitting and one for receiving low or high frequency impulses to and from trains.

1 wayside telephone plug-in station, near each signal and at each passenger station, located within reach of train attendant, and to be used if radio communication fails.

Miscellaneous cat walks on structures where electrical and signal maintainers must reach equipments for periodic testing, inspection and maintenance.

H. CAR STORAGE AND MAINTENANCE YARDS

1. General

The car storage and maintenance yards shall be preferably located on:

Low cost real estate.

In a zone remote from heavy main line traffic, to preclude traffic interference while switching.

Possibly located to utilize the ground level for auto parking.

On presently owned LAMTA property.

Over present surface bus storage.

The storage tracks for suspended system shall be the open type, of the most economical and functional design.

There shall be "cat" walk to facilitate ingress at any point of storage for inspection.

Fire extinguishers shall be placed in strategic locations on the "Cat" walk.

Night illumination shall also be provided.

2. Car Maintenance Center.

There shall be a limited space under roof, for the servicing of truck tires if pneumatic tires are used, with full complement of tire tools, compressed air supply, wheel balancing device, and necessary jacks and air or electric wheel nut torque wrenches.

Second Station shall consist of brake adjustment and replacement with all special tools located at strategic places.

Dynamic brake testing wheels, shall be placed in the track for brake inspection and control inspection card log kept.

Third Station shall facilitate the propulsion motor maintenance, (commutator turning and polishing, brush replacement and motor oiling).

Fourth Station tooled up for the servicing of the car suspension mechanism and the allied hydraulic system. (Check hydraulic oil level, change oil cleaner cartridges, bleed air from the hydraulic system, make adjustments to valves, etc.

Fifth Station will inspect and service car doors and the automatic mechanism. If operated by air, drain water from system.

Sixth Station - Electronic equipment check out, and parts replacement.

Seventh Station pantograph tension adjustment, and shoe replacement.

Eighth Station clean air inside and vacuum floors. Wash outside of car and report car number to control station for service or storage.

Truck inspection and repair equipment.

Provide "Walkie-Talkie" radios for the track and car inspectors.

The maintenance stations will be under cover with three (3) operations in line. This will expedite the movement of the finished cars to the next operation or to the storage track.

The yard will have the following buildings:

General Yard Office

General Yardmaster's Office

Crew Dispatcher's Office

Garage

An analog computer (which is a self-checking punch card, perforated tape, or magnetic tape unit,) for automatic switching on the multiple yard tracks and for the main line operation shall be installed in the General Yardmaster's Office. (Allow space for future expansion).

A machine shop shall be provided for hardware repair and replacement. (Pipe shop - air compressor room - spray paint booth).

Train-car spare parts room shall be maintained and an inventory system installed to avoid delays and car down-time.

3. <u>Main Line Servicing Equipment</u>:

   1. Service self-propelled suspended car for electrical equipment, repair on main line or spare line use.
   2. Special service ground surface track, with elevator for mechanical servicing of disabled cars.
   3. Self-propelled suspended car for repair of mechanical troubles.
   4. Self-propelled suspended car for overhead switch maintenance.

APPENDIX B

LEROY CRANDALL & ASSOCIATES
CONSULTING FOUNDATION ENGINEERS
1619 BEVERLY BOULEVARD
LOS ANGELES 26, CALIFORNIA
MADISON 9-3661

L. LEROY CRANDALL
CIVIL ENGINEER
FREDRICK A. BARNES
LEOPOLD HIRSCHFELDT
RUSSELL C. WEBER
CIVIL ENGINEER

January 22, 1960

Daniel, Mann, Johnson & Mendenhall
3325 Wilshire Boulevard
Los Angeles 5, California

Attention: Mr. David R. Miller,
Project Manager

Gentlemen:

Our "Preliminary Review of Foundation Conditions, Rapid Transit Program, for the Los Angeles Metropolitan Transit Authority" is herewith submitted.

The scope of the study was planned in collaboration with Messrs. David R. Miller and William D. McEwen of your firm. The purpose of the study was to develop sufficient general soils information to permit you to make a realistic comparison of the costs of constructing the several alternate transit systems.

Anticipated soil and water conditions in the Central Business District and four routes under consideration for the proposed transit system are presented in the report. Based on our experience with numerous foundation studies we have made in the area, the soil conditions have been related to the feasible foundation types for the various types of construction anticipated. We have also correlated the soil conditions with the problems involved in tunnelling and in making open excavations. The information presented is not, of course, sufficiently accurate for design use, but we believe it to be adequate for comparative construction cost estimates.

Respectfully submitted,

LeROY CRANDALL & ASSOCIATES

by LeRoy Crandall
LeRoy Crandall

LC-RW/pc

LOS ANGELES METROPOLITAN TRANSIT AUTHORITY
RAPID TRANSIT PROGRAM

PRELIMINARY REVIEW OF FOUNDATION CONDITIONS IN THE LOS ANGELES CENTRAL BUSINESS DISTRICT AND IN THE FOUR TRANSIT CORRIDORS

January 22, 1960

Prepared for

Daniel, Mann, Johnson & Mendenhall

by

LeRoy Crandall & Associates
Consulting Foundation Engineers

TABLE OF CONTENTS

PRELIMINARY REVIEW OF FOUNDATION CONDITIONS

RAPID TRANSIT PROGRAM

FOR THE

LOS ANGELES METROPOLITAN TRANSIT AUTHORITY

SCOPE

This report presents our evaluation of the soil conditions in the Central Business District of the City of Los Angeles, and along four routes being considered for the construction of a mass rapid transit system. The purpose of the study was to provide a general guide as to the soil conditions likely to be encountered within the specified areas, thus permitting a realistic estimate of the cost of foundation construction.

The soil conditions and other pertinent information covering five specific areas are discussed in this report. These five areas are designated the Central Business District, the San Bernardino Corridor, the Long Beach Corridor, the San Fernando-Cahuenga Pass Corridor, and the Wilshire Boulevard Corridor. In addition, in accordance with your later request, we have included a brief description of the Elysian Park area, which we understand is also being considered as a possible access to the Central Business District. The general locations of the various areas discussed are shown in relation to the Los Angeles Basin on Plate 1, Map of Metropolitan Los Angeles.

Logs of test borings, which define typical soil conditions at several locations along each of the planned corridor routes, have been reproduced and included in this study. The various sources of information utilized in the preparation of this report are discussed in the final section of the report. Probable foundation types for support of the proposed installations, which we understand will impose relatively high lateral forces as well as downward loads, are discussed for each of the planned corridors. These recommendations are, of course, necessarily general, and must be considered as average conditions rather than applying to specific locations.

Seismically, all of the Los Angeles Basin is an active area. However, the only recognized fault located in the areas studied is the Cherry Hill fault, which intercepts the Long Beach Corridor roughly 1½ miles south of Del Amo Boulevard. Although this and other lesser faults may cross the proposed system, normal seismic design criteria will be sufficient since the chances of a slip across the line are extremely remote, and could not be protected against in any event.

CENTRAL BUSINESS DISTRICT

The extent of the Central Business District, as defined by your personnel, is shown on Plate 1. In general, this area includes all of downtown Los Angeles, for an area roughly three miles by four miles in plan. The surface geology, general character of the various geologic divisions, and groundwater conditions are presented in plan on Plate 2, Anticipated Soil Conditions, Central Business District, Plan. Plates 3-A through 3-D, Sub-surface Sections, show typical sections through the Central Business District, and define the general characteristics of the soils at various locations. It is possible that underground facilities may be employed in the development of the Central Business District. Tunnels would extend from 50 to 100 feet below the present ground surface.

Basically, the Central Business District under consideration includes three major geologic conditions. The northwesterly portion, roughly west of Main Street, consists of the Puente Shale, except for the Figueroa Street Channel and localized alluvial channels. Within the area shown, the shale lies near the ground surface as shown by the cross sections on Plates 3-A through 3-D. This material is stratified, and is moderately firm to firm. The surface is generally weathered to a depth of five to ten feet. Minor water seepage may be encountered within the upper 20 feet of shale, and perched water is generally found above the upper surface in any overlying overburden soils. While the material is firm to very firm, excavation with conventional equipment is feasible. Except where the stratification dips adversely, vertical cuts will stand safely in the shale. The material may be classified as excellent for tunneling, with few, if any, problems. Permissible foundation pressures in the shale may vary from 8,000 to 15,000 pounds per square foot.

East of the Los Angeles River, firm older soils are again exposed. This material consists of Continental Terrace deposits of Pleistocene age. The deposits are composed of poorly sorted clays, sands, and gravel. Also encountered in this higher ground is the Puente Shale which underlies the continental deposits, which may be found in outcrops at some locations. The continental deposits are moderately to well cemented, and contain occasional water seepage in the sandier strata. Except for localized conditions, the walls of open excavations in the continental material will stand nearly vertically. Excavation with conventional equipment is definitely feasible. Tunneling through this material will be generally good, with possible minor problems where uncemented sand or very firmly cemented materials may be encountered. Permissible bearing pressures in this material vary from 4,000 to 10,000 pounds per square foot.

Adjacent to the Los Angeles River, along Figueroa Street, and spreading out in the southwest portion of the Central Business District, recent alluvial deposits are encountered. Within the majority of the Central Business District, these alluvial deposits generally consist of sand and gravel, with a tendency to become siltier to the south. Immediately adjacent to and beneath the Los Angeles River Channel, the alluvium is known to extend at least 100 feet below present ground surface. To the west, the depth of the alluvium decreases until the underlying Puente Shale outcrops in the Civic Center area. Spot elevations at which the older soils were encountered beneath the alluvium during explorations in the area are shown on Plate 2.

The alluvium contains zones of minor water seepage, which may become considerable in quantity in local channels, and is fairly uniformly found perched over the older soils. The alluvium is predominantly granular, with little or no cohesion. Open excavations in this material will require shoring, or unprotected slopes must be permitted to slough back to at least ½:1 embankments. Excavation of the material is no problem, and conventional equipment will suffice. Tunneling through the alluvium may be classified as fair to good, but continuous lagging must be provided. Although predominantly granular, few if any areas of clean sand which will flow into tunneling excavations are anticipated. Foundations at ground surface, for heavy loads as are anticipated, may consist of drilled-and-belled caissons where the older soils or extensive deposits of clean sand and gravel are encountered, or drilled cast-in-place concrete piles where such desirable conditions do not exist.

SAN BERNARDINO CORRIDOR

As defined on Plate 1, the San Bernardino Corridor will generally follow the existing San Bernardino Freeway from the downtown area to West Covina. The area is defined to a larger scale at the top of Plate 4-A, Anticipated Soil Conditions, San Bernardino and Long Beach Corridors. Also shown on Plate 4-A are the ground surface contours, the surface geology, and the groundwater conditions along this route.

From the Santa Ana Freeway to west of San Gabriel Boulevard, geologically older soils will be encountered. These consist of both marine and continental deposits of Pleistocene age, as well as some of the Puente Shale. From the Santa Ana Freeway to roughly Atlantic Boulevard, the terrain is rough and hilly. From Atlantic Boulevard to San Gabriel Boulevard, the topography slopes fairly uniform downward to the east. Except for some local perched water conditions east of Atlantic Boulevard, the groundwater is at least 50 to 75 feet below the present ground surface. Foundations at ground surface for heavy structural loads will be either conventional spread footings, or drilled-and-belled caissons for resisting major upward or lateral loads.

East of San Gabriel Boulevard to West Covina, the soils consist of alluvial deposits eroded from the San Gabriel Mountains by the Rio Hondo and the San Gabriel River. Both these rivers are known to have meandered throughout most of this area, and the alluvial deposits consist of primarily sand and gravel. Typically, weathered silty sand overburden overlies the sand and gravel. The ground surface slopes downward from San Gabriel Boulevard to the Rio Hondo, and upward fairly uniformly toward the hills east of West Covina. The groundwater is at a depth of approximately 20 feet at the Rio Hondo, roughly 60 feet at the San Gabriel River, and at greater depths to the east. Except for very favorable conditions, conventional spread footings will not be feasible for support of heavy structural loads. The most likely foundation types will consist of drilled-and-belled caissons extending through the silty sands, and founded on the sand and gravel, or drilled piles where extensive deposits of sand and gravel are not encountered. In the immediate vicinity of the Rio Hondo and the San Gabriel River, driven piling may be required.

Typical soil conditions for the San Bernardino Corridor are represented by Borings 1 through 4, Plates 5-A through 5-D.

LONG BEACH CORRIDOR

The location of this Corridor is described on Plate 1; a more detailed defining is shown on Plate 4-A. Geologically, the majority of this Corridor is within the alluvial plain of the Los Angeles River. This condition is prevalent from the downtown area to the vicinity of Del Amo Boulevard. The alluvial soils consist of predominantly sandy material in the northerly portion, grading siltier to the south. The groundwater level is at least 50 feet below present ground surface, except for the central portion of the Corridor north of Del Amo Boulevard. In this area, groundwater may be encountered within 30 to 40 feet below present ground surface. The ground surface slopes uniformly downward from the Civic Center area to Del Amo Boulevard. Within this alluvial area, likely foundation types consist of drilled-and-belled caissons founded on the underlying sand from the Civic Center south to the vicinity of Slausen Avenue. South of Slausen Avenue to Del Amo Boulevard, drilled cast-in-place concrete piles are the most likely foundation type.

South of Del Amo Boulevard, the Corridor includes the westerly portion of the Signal Hill area, which approaches the Los Angeles River within the Corridor. The older soils of Signal Hill consist of marine terrace deposits which are composed of predominantly firm silts and clays in the northerly portion, becoming sandier as San Pedro Bay is approached. The groundwater level is fairly constant at Elevation -10 south of Del Amo Boulevard, with the depth below ground surface varying with the variations in the ground surface contours. Channels draining westward from the Signal Hill area are likely to contain seepage water. Probable foundation types will vary from conventional spread footings or drilled-and-belled caissons in the older soils to drilled or driven piles in the alluvial area adjacent to the Los Angeles River.

The attached Boring Logs 5 through 8, Plates 5-E through 5-H, typify the soil conditions which will be encountered in the Long Beach Corridor.

SAN FERNANDO - CAHUENGA PASS CORRIDOR

This Corridor is located on Plate 1, and in more detail on Plate 4-B, Anticipated Soil Conditions, San Fernando - Cahuenga Pass and Wilshire Boulevard Corridors. From the westerly end near Reseda

Boulevard to the Los Angeles River, near Lankershim Boulevard, the soils consist of alluvial deposits of the Los Angeles River. This material was eroded from the north from the San Gabriel Mountains. These alluvial deposits are primarily cohesive silts and clays in the westerly portion, becoming more sandy to the east toward the River. The ground surface is essentially level throughout this portion of the Corridor. The groundwater is approximately 15 to 20 feet below ground surface near Reseda Boulevard and gradually becomes deeper to the east. Likely foundation types will consist of driven piling to the west, where the groundwater is high, changing to drilled cast-in-place concrete piles where sufficient depth can be obtained before the water is encountered.

The geology and soil conditions from the Los Angeles River through Cahuenga Pass to Franklin Avenue are quite complicated. For this reason, a separate report covering this area was prepared by the firm of Bear and Kistler, Consulting Geologists. A copy of this report, which describes the geology, excavation and tunneling conditions, and general physical considerations is attached.

From Franklin Avenue south to Santa Monica Boulevard, recent alluvium which has eroded off the south side of the Santa Monica Mountains is encountered. The ground surface slopes fairly steeply downward to the south. The soils consist of predominantly cohesive silts and clays. The water level is at a depth of 75 feet or greater below the ground surface. Likely foundation types consist of drilled piles, with possibly drilled-and-belled caissons where the firm older soils are encountered within foundation depth.

From Santa Monica Boulevard to Beverly Boulevard, older continental alluvial deposits are situated. The ground surface slopes downward toward the south at a slightly lesser slope than the area to the north. Groundwater is at a considerable depth below ground surface. The soils are primarily cohesive, with some layers of more sandy material. Likely foundation types consist of drilled-and-belled caissons, or possibly deep spread footings extending through the surface weathering of the older material.

Logs of Borings 9 through 12, which typify the soils anticipated along this Corridor, are shown on Plates 5-I through 5-L.

WILSHIRE BOULEVARD CORRIDOR

The location of the Wilshire Boulevard Corridor, which is centered by Wilshire Boulevard from the Ocean to the Central Business District, is shown on Plate 1, and at the bottom of Plate 4-B. From the Ocean to slightly west of the intersection of Wilshire Boulevard and Santa Monica Boulevard, the soils consist of older continental alluvial deposits, which have been cut by drainage channels sloping south from the south edge of the Santa Monica Mountains. Within these channels, recent alluvial soils have been deposited. The channels through which Sepulveda Boulevard, La Cienega Boulevard, and La Brea Boulevard are situated are notable major channels. Both the older deposits and the recent alluvium consist of poorly sorted clays, silts, sand and gravel. Although the groundwater level is indicated at depths in excess of 50 feet below the ground surface, both seepage water and perched water will likely be encountered above this level. Likely foundation types consist of drilled-and-belled caissons in the continental deposits, and drilled piles where the recent alluvium is encountered at ground surface. Within the larger recent alluvial channels, the use of driven piling may become necessary.

From Santa Monica Boulevard east to approximately Fairfax Avenue, the recent alluvium is fairly continuous for the Corridor under consideration. Within this area, the use of drilled piles or driven piles appears most likely.

From roughly Fairfax Avenue to the downtown area, the older soils, consisting of continental deposits to about Vermont Avenue and Puente Shale to the east, will likely be encountered within foundation depth. However, north-south channels have been cut in this area, and may be expected at isolated locations. The ground surface generally slopes upward to the east, toward the downtown area. The groundwater is a minimum of 50 feet below the present ground surface. However, water perched on the surface of the Puente Shale is likely to be encountered. Foundation types in this area will generally consist of drilled-and-belled caissons extending into the older deposits or to the shale.

MacArthur Park, which includes a lake of considerable extent, is located just west of Alvarado Street on Wilshire Boulevard. The lake was formed by the damming of a major drainage channel which sloped downward to the southwest. The soils beneath the lake are believed to consist of moderately soft to moderately firm alluvial deposits to a depth of 40 to 50 feet, below which the Puente Shale should be encountered.

Typical soil conditions of this Corridor are shown by Borings 13 through 16, on Plates 5-M through 5-P.

ELYSIAN PARK

Elysian Park, located just north of the downtown Los Angeles area, is extremely rugged terrain, consisting of hills and deep valleys with variations in elevation of up to 350 feet. Geologically, the material is composed of Puente Shale and Puente Sandstone, with deep valleys containing alluvium. Tunneling through this material should be excellent, provided the tunnel is situated below the alluvial deposits.

A location map of this area is presented to the left of Plate 6, Elysian Park Route. Also shown on Plate 6 is a cross section which defines the existing topography through a typical area through Elysian Park, and the various soils which will be encountered.

SOURCES OF INFORMATION

In addition to previous field explorations performed by LeRoy Crandall & Associates, from which the boring logs were taken, and which form the majority of the specific soils information discussed, many agencies and sources contributed to the information. The geology is primarily based on "Geology of the Los Angeles Basin" which is a part of Bulletin 170 of the Division of Mines, State of California. Extensive groundwater information was obtained from the Los Angeles Flood Control District. The geologic study of Cahuenga Pass area, attached as an Appendix, was performed by the firm of Bear and Kistler, Consulting Geologists. Other basic data were obtained from the California

State Division of Highways, the U. S. Corps of Engineers, and public agencies of the City of Los Angeles.

-oOo-

The following Appendix and Plates are attached and complete this report:

Appendix	Geology through Cahuenga Pass by Bear & Kistler
Plate 1	Map of Metropolitan Los Angeles
Plate 2	Anticipated Soil Conditions, Central Business District, Plan
Plate 3-A	Anticipated Soil Conditions, Central Business District, Sub-surface Section, First Street
Plate 3-B	Anticipated Soil Conditions, Central Business District, Sub-surface Section, Wilshire Boulevard - Seventh Street
Plate 3-C	Anticipated Soil Conditions, Central Business District, Sub-surface Section, Grand Avenue
Plate 3-D	Anticipated Soil Conditions, Central Business District, Sub-surface Section, Main Street
Plate 4-A	Anticipated Soil Conditions, San Bernardino and Long Beach Corridors
Plate 4-B	Anticipated Soil Conditions, San Fernando - Cahuenga Pass and Wilshire Boulevard Corridors
Plates 5-A thru 5-P	Logs of Borings
Plate 6	Elysian Park Route

TED L. BEAR PHILLIP S. KISTLER
CONSULTING GEOLOGISTS
816 W. FIFTH STREET
LOS ANGELES 17, CALIFORNIA
MADISON 4-6964

December 30, 1959

LeRoy Crandall & Associates
1619 Beverly Boulevard
Los Angeles 26, California

Attention: Mr. Russell Weber

Dear Sir:

At your request we have made a cursory examination of the geology along the freeway route through Cahuenga Pass. This includes the area from Franklin Avenue in Hollywood to Ventura Boulevard in the San Fernando Valley. The general geology of the Santa Monica Mountains was mapped by Harold W. Hoots for the United States Geological Survey in Professional Paper 165, 1925. In addition to the published information, we spent some time in the field inspecting the geology along the proposed route. Several recent steep road cuts lend some suggestion to the stability of the anticipated rock types.

The Topanga formation of Middle Miocene age outcrops over the proposed route from Franklin Avenue to Ventura Boulevard, except for the canyon bottom which is filled with Recent alluvium. However, over a portion of the freeway most of the alluvium has been excavated due to the construction of the Cahuenga Freeway. All heavy foundations from Dark Canyon south to Franklin Avenue should be excavated to the Topanga formation, while those north of Dark Canyon will be on the Recent alluvium.

The Topanga formation consists of Basalt igneous rocks, conglomerate, sandstone, and shale. From Franklin Avenue to the Hollywood Bowl the surface exposures are flat north dipping sandstones and shale, and coarse unconsolidated gravels in the lower ravines. Tunneling and good foundation support will present very little problem in this area. The alluvium gravels will need support and in most cases their depth will be less than 100 feet. From the Hollywood Bowl northward 3,500 feet, the bedrock consists of basalt flows and intrusives. The basalt is well exposed along the west side of Cahuenga Pass. The basalt flows are easily weathered and do not appear extremely hard. The intrusives are very hard and will need no support when tunneling, however, the basalt will be difficult to excavate since it is very hard, and appears to be very massive below the zone of weathering. Approximately 65% of the 3,500 feet consists of hard intrusive basalt. The road along the west side of the Pass is cut out of the basalt and fresh samples can be obtained which should be representative of the rock expected at a depth of 100 feet.

From the northern limit of the basalt to Dark Canyon is approximately 4,000 feet. In this area the sandstones and conglomerates outcrop with only a very minor amount of alluvium. The conglomerates are hard and well indurated, however, the sandstones and minor shales appear only moderately hard and easily eroded. The bedding strikes northwest-southeast and dips 50° to 70° northeast.

From Dark Canyon northward to Ventura Boulevard the valley is filled with alluvium to an estimated depth of 100 to 200 feet. The underlying section is Topanga sandstones and shales which appear to be only moderately hard and easily eroded. This section should be easily excavated in open pit and tunneling. The exact route of the project is not known, therefore it is impossible to estimate the exact rock types to be expected. However, no real difficult section should be encountered along the northern portion of the route.

Near the entrance to Cahuenga Pass along the south edge of the Hollywood Bowl is a fault with considerable displacement. This is probably part of the fault system along the south edge of the Santa Monica Mountains. Two minor faults cross Cahuenga Pass at the summit. These faults were mapped in the U.S.G.S. Bulletin by Harold Hoots. Other very minor faults were observed in the field, but these would be of no concern.

The basalt from the Hollywood Bowl northward 3,500 feet is the only real disturbing section to be encountered in tunneling. More than half of the 3,500 feet will be extremely difficult to excavate. However, the remainder of the proposed route should not encounter any excavation or stability hazards.

Respectfully submitted,

BEAR & KISTLER

Ted L. Bear

Ted L. Bear

TLB:b

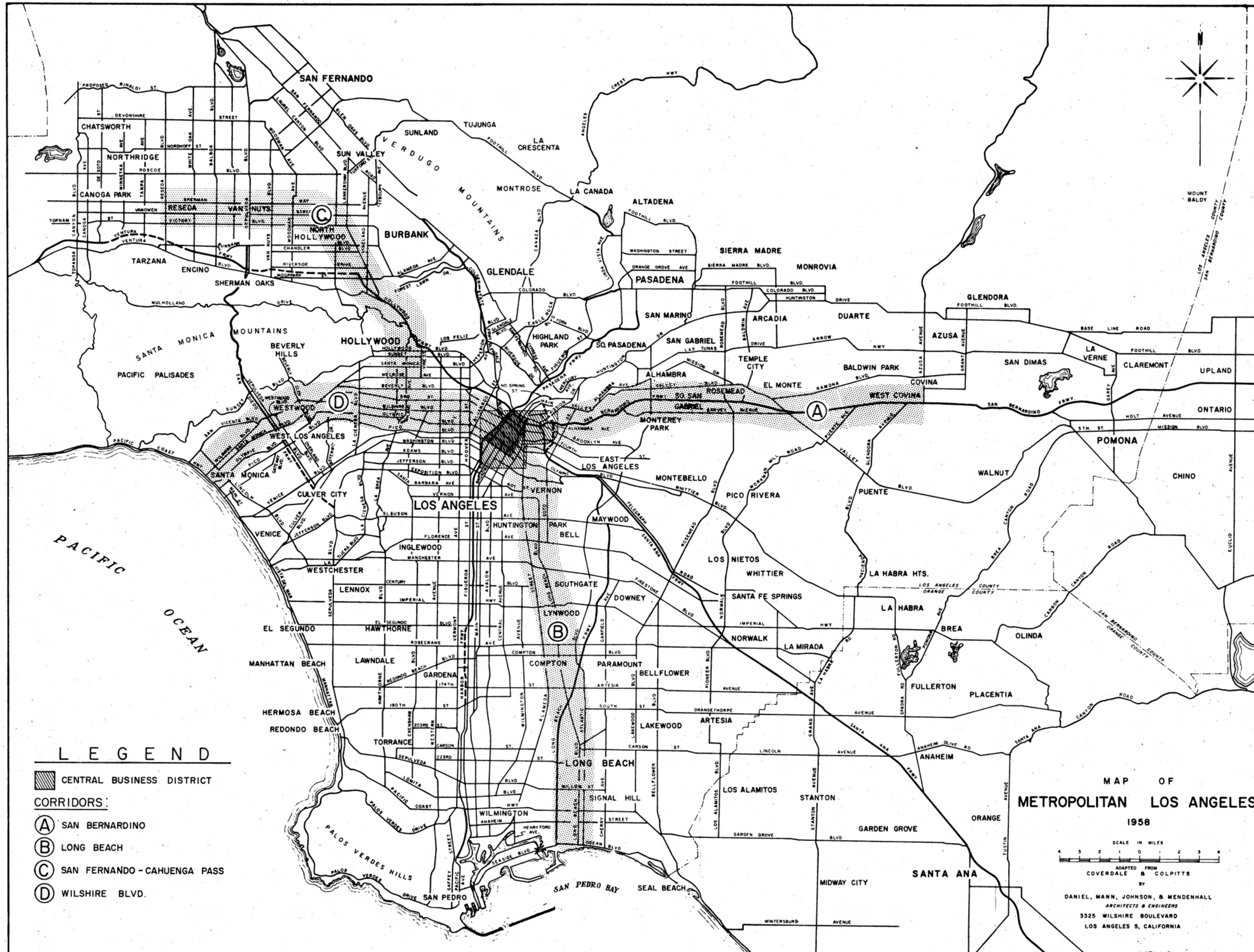
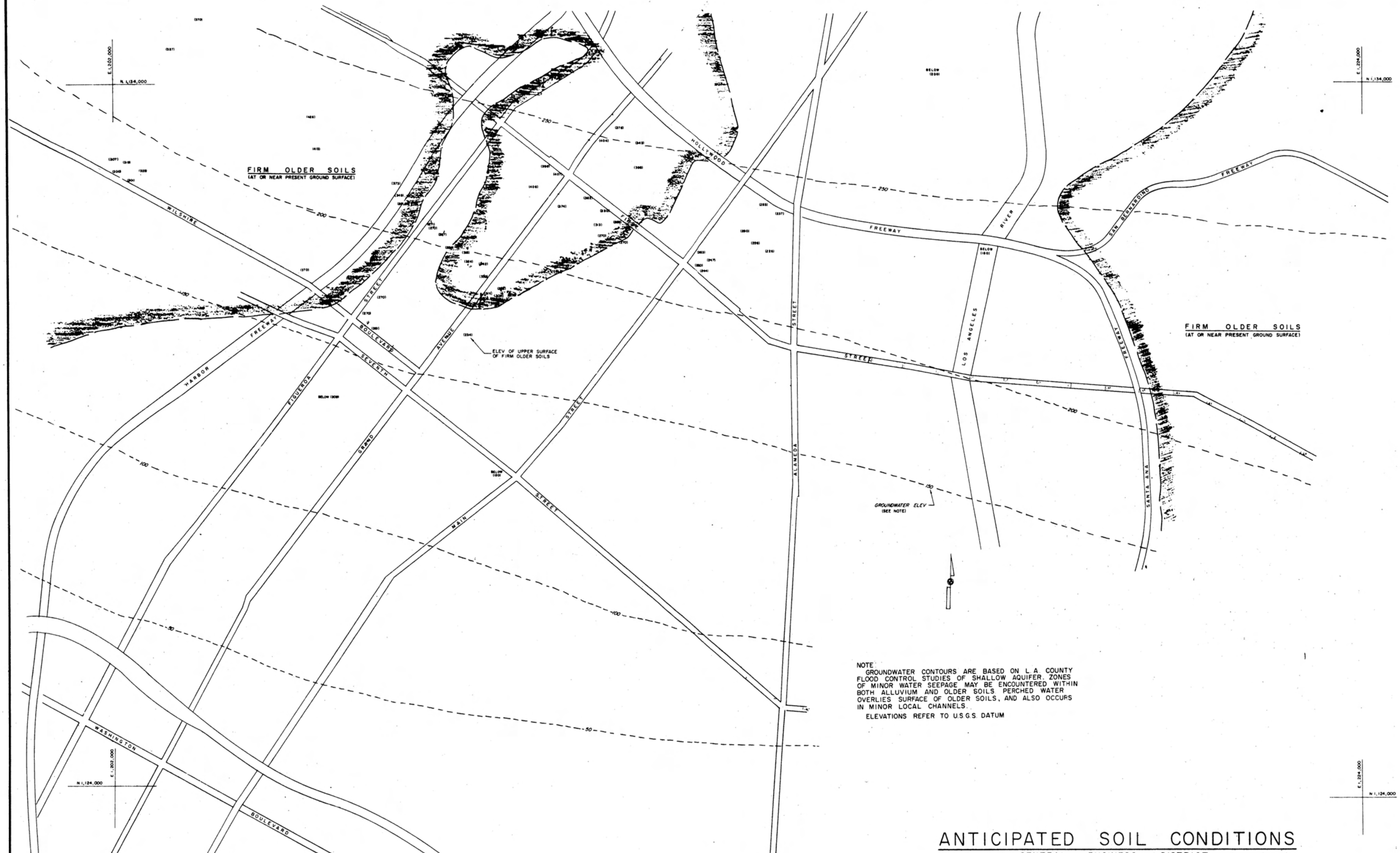

LEGEND
CENTRAL BUSINESS DISTRICT
CORRIDORS:
(A) SAN BERNARDINO
(B) LONG BEACH
(C) SAN FERNANDO - CAHUENGA PASS
(D) WILSHIRE BLVD.
MAP OF
METROPOLITAN LOS ANGELES
1958
SCALE IN MILES
ADAPTED FROM
COVERDALE & COLPITTS
BY
DANIEL, MANN, JOHNSON, & MENDENHALL
ARCHITECTS & ENGINEERS
3325 WILSHIRE BOULEVARD
LOS ANGELES 5, CALIFORNIA
LEROY CRANDALL & ASSOCIATES

PLATE I



ANTICIPATED SOIL CONDITIONS
CENTRAL BUSINESS DISTRICT
PLAN

SCALE IN FEET
2000 0 2000 4000

LeROY CRANDALL & ASSOCIATES

PLATE 2

59528 1-18-60 FRL


440
400
360
320
280
240
200
160
ELEVATION IN FEET
GRAND AVE
FIGUEROA ST
HARBOR FRWY
REC. ALL.
MAIN ST
ALAMEDA ST
GROUND SURFACE
L. A. RIVER
SANTA ANA FRWY
GROUNDWATER
FIRM OLDER SOILS
Puente Shale (some siltstone)
Stratified – may contain few strata of sandstone
Local minor channels (such as Glendale Blvd., Union Ave. etc) may contain shallow alluvium and/or fill
Zones of minor water seepage
Cohesion of 1,000 p s f or greater
Excavation with conventional equipment – blasting not required
Vertical cuts in open excavations, except where beds dip adversely
Generally excellent for tunnelling
ANTICIPATED SOIL CONDITIONS
CENTRAL BUSINESS DISTRICT
SUB – SURFACE SECTION
FIRST STREET
HORIZONTAL 1" = 400'
VERTICAL 1" = 40'
RECENT ALLUVIUM
Primarily sand and gravel, grading more silty to south
Overlies older soils. Quite deep in and adjacent to L. A. River, and variable in depth in minor local channels
Zones of minor water seepage – perched water over older soils, and in local low areas
Low cohesion – predominantly granular
Open excavtions will require shoring, or 1/2:1 unprotected slopes
Excavation with conventional equipment
Fair to good for tunneling – continuous lagging generally required
FIRM OLDER SOILS
Continental Terrace Deposits of Pleistocene age
Overlies Puente shale, which outcrops at some locations
Poorly sorted clay, sand and gravel
Moderate to good cementation
Occasional water seepage in sandy strata
Widely varying cohesion – nearly vertical cuts in open excavation
Excavation with conventional equipment – blasting not required
Generally good to excellent for tunneling
LeROY CRANDALL & ASSOCIATES

PLATE 3-A

ANTICIPATED SOIL CONDITIONS

SAN BERNARDINO AND LONG BEACH CORRIDORS

LeROY CRANDALL & ASSOCIATES

PLATE 4-A

ANTICIPATED SOIL CONDITIONS
CENTRAL BUSINESS DISTRICT

SUB - SURFACE SECTION

MAIN STREET

HORIZONTAL 1" = 400'
VERTICAL 1" = 40'

SEE PLATE 3-A FOR DESCRIPTION OF SOIL CHARACTERISTICS

LEROY CRANDALL & ASSOCIATES

PLATE 3-D

ANTICIPATED SOIL CONDITIONS
CENTRAL BUSINESS DISTRICT

SUB - SURFACE SECTION

GRAND AVENUE

HORIZONTAL 1" = 400'
VERTICAL 1" = 40'

SEE PLATE 3-A FOR DESCRIPTION OF SOIL CHARACTERISTICS

LeROY CRANDALL & ASSOCIATES

PLATE 3-C

ANTICIPATED SOIL CONDITIONS
CENTRAL BUSINESS DISTRICT

SUB - SURFACE SECTION

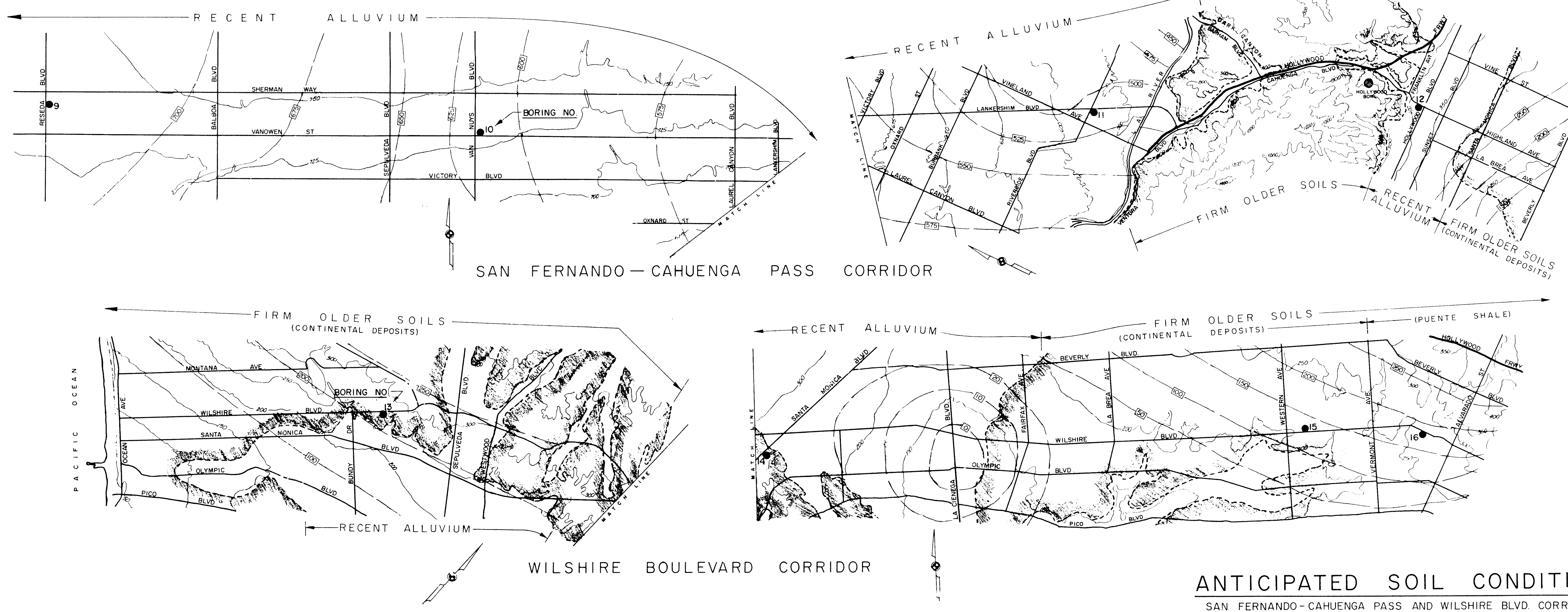
WILSHIRE AVENUE — SEVENTH STREET

HORIZONTAL 1" = 400'
VERTICAL 1" = 40'

SEE PLATE 3-A FOR DESCRIPTION OF SOIL CHARACTERISTICS

LEROY CRANDALL & ASSOCIATES

PLATE 3-B



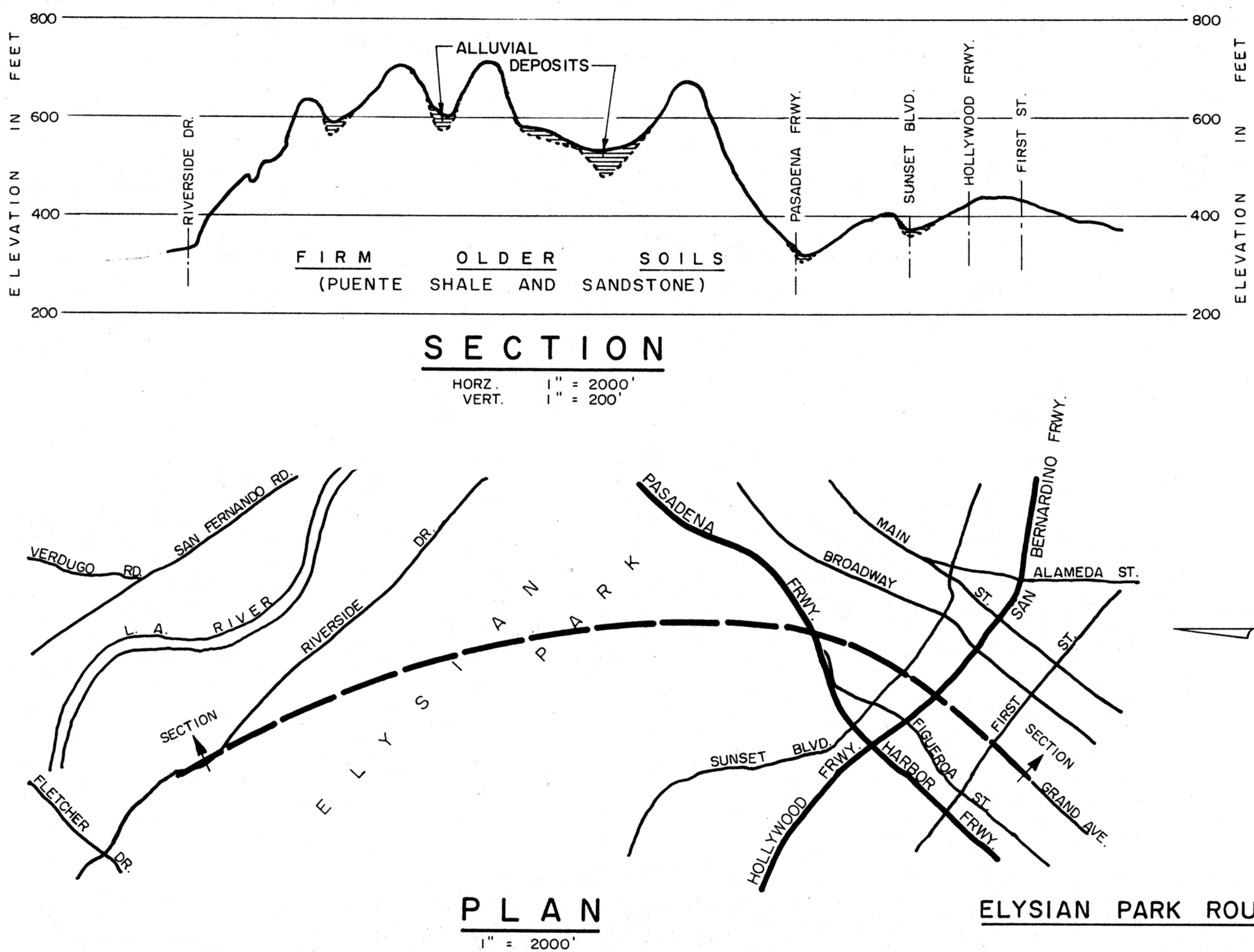
ANTICIPATED SOIL CONDITIONS

SAN FERNANDO-CAHUENGA PASS AND WILSHIRE BLVD. CORRIDORS

SCALE IN FEET
2000 0 2000 4000

LeROY CRANDALL & ASSOCIATES

PLATE 4-B



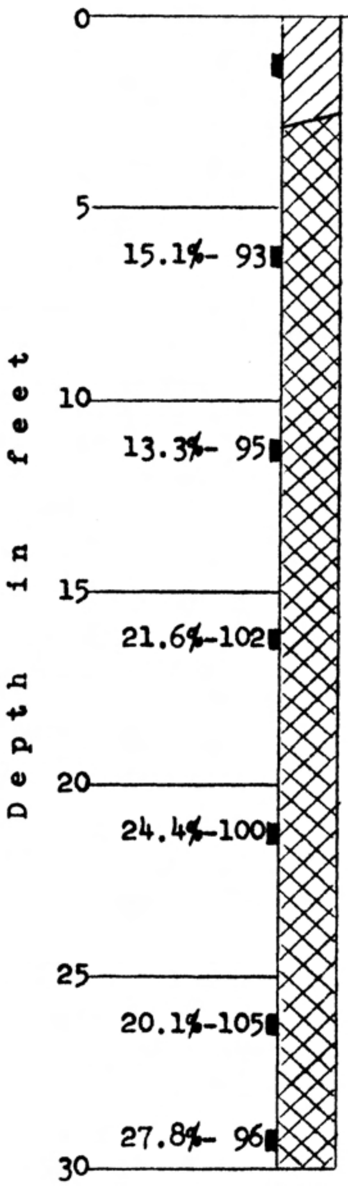
ELYSIAN PARK ROUTE

LeROY CRANDALL & ASSOCIATES

PLATE 6

PUENTE SHALE

LOG OF BORING 1



LEAN CLAY - contains small amount of silt, small amount of fine sand, porous, fractured, dark brown

WEATHERED SHALE - jointed, mottled light brown and yellowish-brown

Less weathered, less jointed

Greyish-brown with small patches and spots of yellowish-brown

Very thin laminations of silt, yellowish-brown

Thin laminations

NOTE: Groundwater not encountered; no caving

KEY:

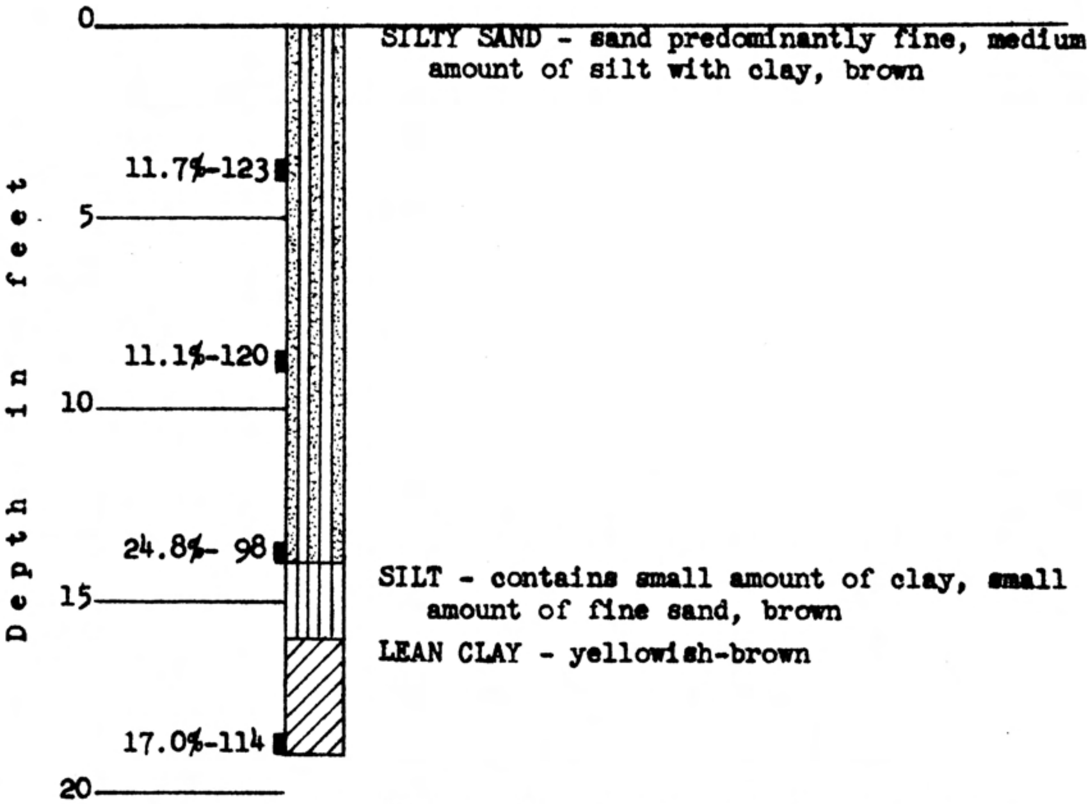
27.8%- 96 — Indicates depth at which undisturbed sample obtained

- 96 — Dry density in lbs./cu.ft.
- 27.8% — Field moisture content in percent of dry weight

Soils classified in accordance with the Unified Soil Classification System.

CONTINENTAL DEPOSITS

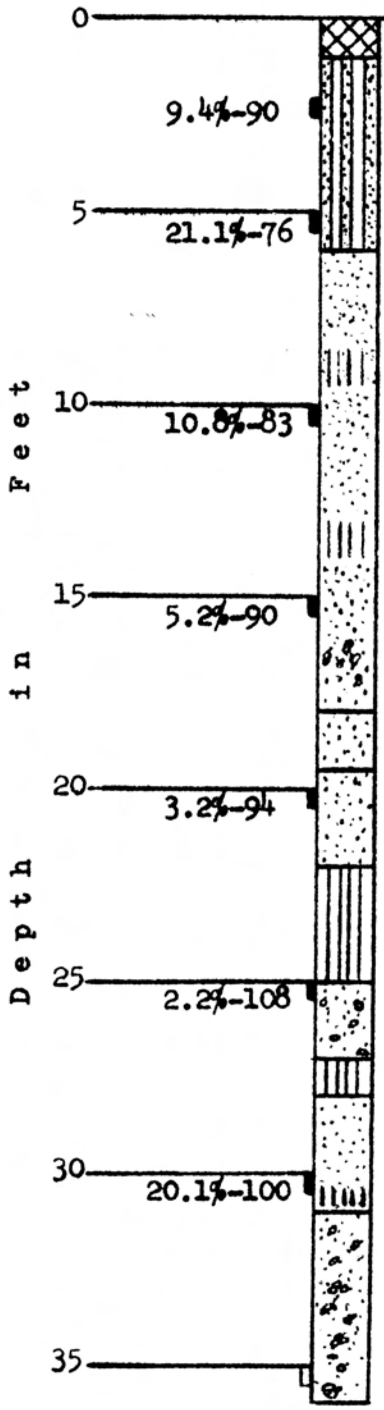
LOG OF BORING 2
16"-Diameter Rotary Bucket Hole
Drilled May 12, 1958



NOTE: Groundwater not encountered; no caving.

RECENT ALLUVIUM

LOG OF BORING 3



AC paving and base

SILTY SAND - sand fine, medium amount of silt, dark brown

lenses of SILT

POORLY GRADED SAND - fine, trace of silt, streaks of black, dark grey

thin lenses of SILTY SAND

lumps of SILT

contains slight amount of gravel

WELL GRADED SAND - contains slight amount of silt, few gravel, dark grey

POORLY GRADED SAND - fine, trace of silt, streaks of black, dark grey

SILT - slight amount of fine sand, mottled brown

WELL GRADED SAND -contains about 10% gravel, clean light brown

SILT - slight amount fine sand, mottled brown

POORLY GRADED SAND - fine, contains trace of silt, slight amount of gravel, dark grey

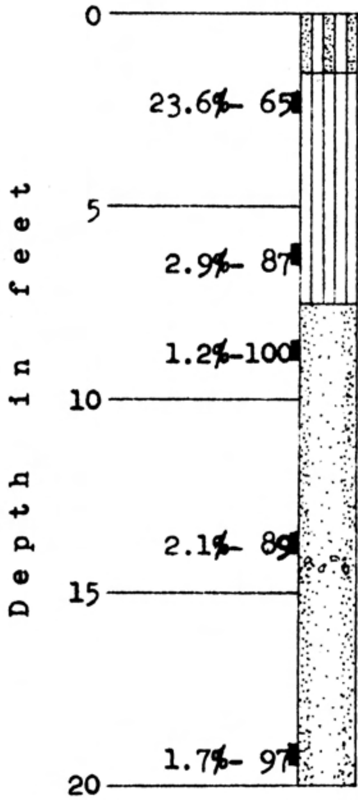
lens of SILT

WELL GRADED SAND - contains about 10% gravel, trace of silt, reddish brown

Groundwater not encountered; slight caving below 31'

RECENT ALLUVIUM

LOG OF BORING 4



SILTY SAND - sand predominantly fine, medium amount of silt, brown

SILT - contains medium amount of fine sand, light brown
Grading siltier

POORLY GRADED SAND - predominantly fine, clean, light brown

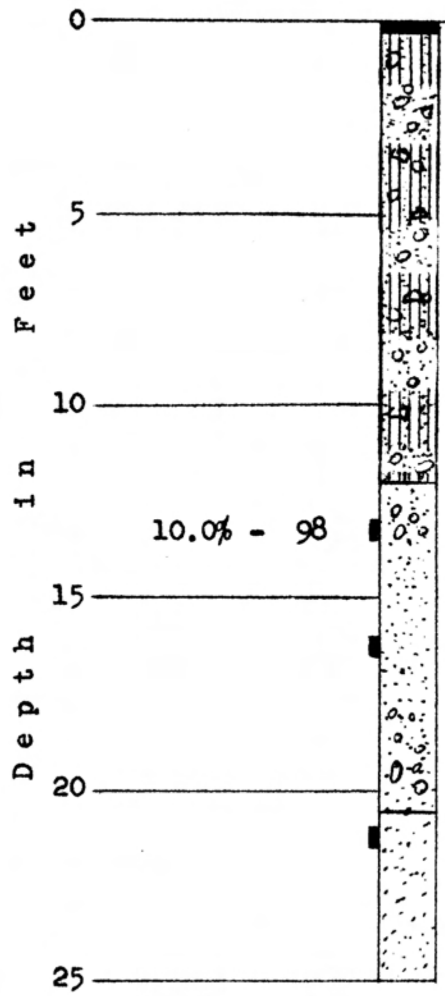
Lens of WELL GRADED SAND - contains approximately 5% well graded gravel

Laminations 6" of well graded sand, contains approximately 15% gravel, well graded

NOTE: Groundwater not encountered; caving below 7½'

RECENT ALLUVIUM

LOG OF BORING 5



4" A.C. Paving

FILL - SILTY SAND & POORLY GRADED SAND - sand fine to medium, contains large amount of silt, some clay, brick, concrete and wood, foundry slag, dark brown

POORLY GRADED SAND - fine to medium, contains large amount of silt, some cobbles, brown

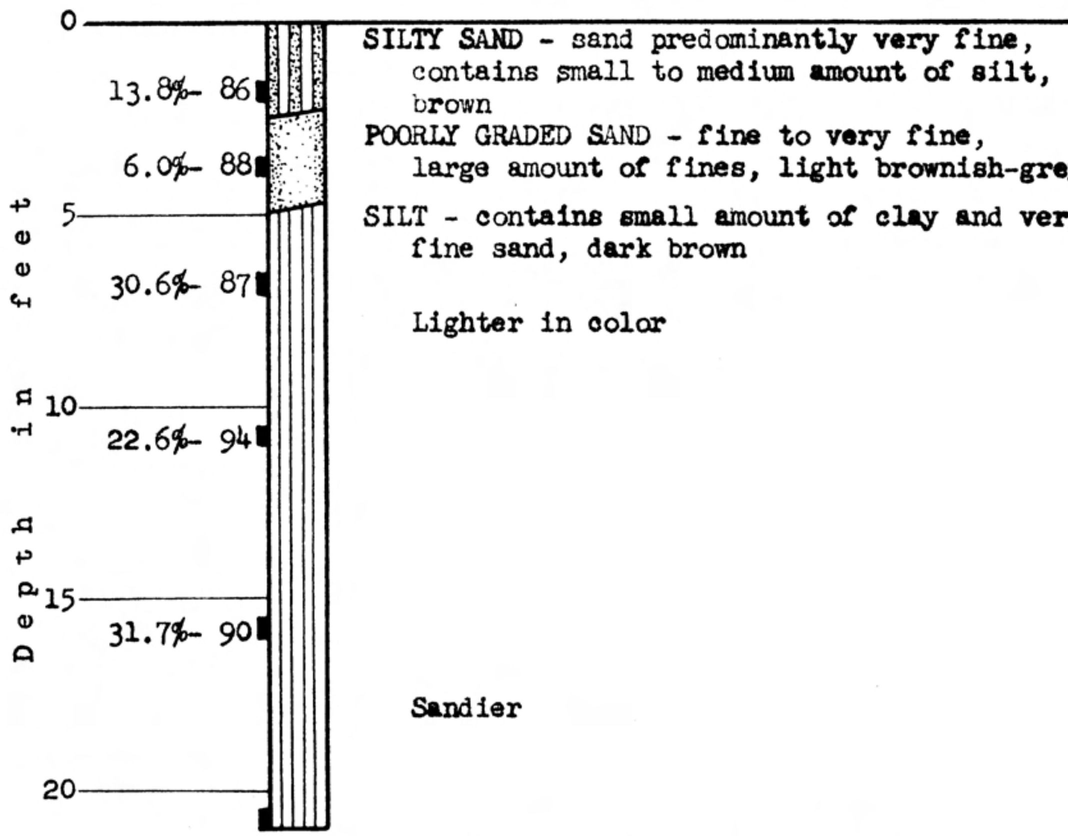
contains about 10% gravel and cobbles up to 4"

WELL GRADED SAND - clean, light brown

Groundwater not encountered; no caving

RECENT ALLUVIUM

LOG OF BORING 6
16"-Diameter Rotary-Bucket Hole
Drilled June 18, 1958



SILTY SAND - sand predominantly very fine, contains small to medium amount of silt, brown

POORLY GRADED SAND - fine to very fine, large amount of fines, light brownish-grey

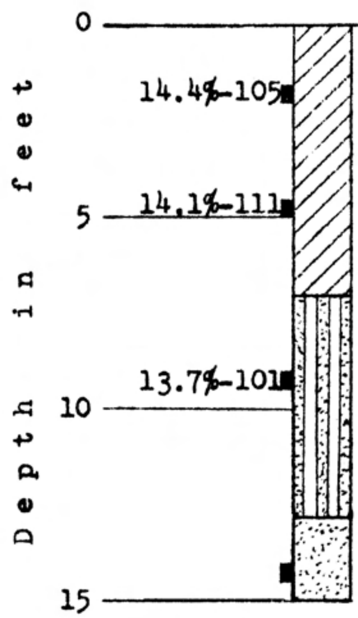
SILT - contains small amount of clay and very fine sand, dark brown

Lighter in color

Sandier

NOTE: Groundwater not encountered; no caving.

LOG OF BORING 7



LEAN CLAY - jointed, contains small amount of silt, dark brown

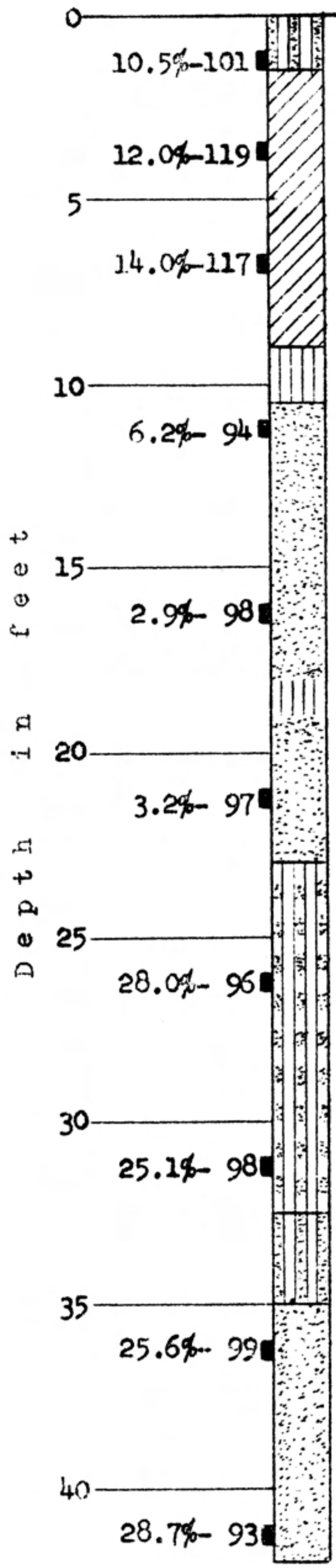
Grading to reddish-brown

SILTY SAND - sand predominantly very fine, medium to large amount of silt, moderately cemented, light brown

POORLY GRADED SAND - predominantly fine, some silt, light brown

NOTE: Groundwater not encountered; no caving.

LOG OF BORING 8



SILTY SAND - sand predominantly fine, medium to large amount of silt, brown

LEAN CLAY - contains small amount of fine sand and silt, reddish-brown

SILT - contains small amount of fine sand, reddish-brown

POORLY GRADED SAND - predominantly fine, contains small to medium amount of silt, light reddish-brown

Grading cleaner

Clean, grey in color

Layer of SILT

Layers of SILT and SILTY SAND - predominantly fine, light brown

Contains some clay

SILTY SAND - sand predominantly fine, medium amount of silt, brown

Yellowish-brown

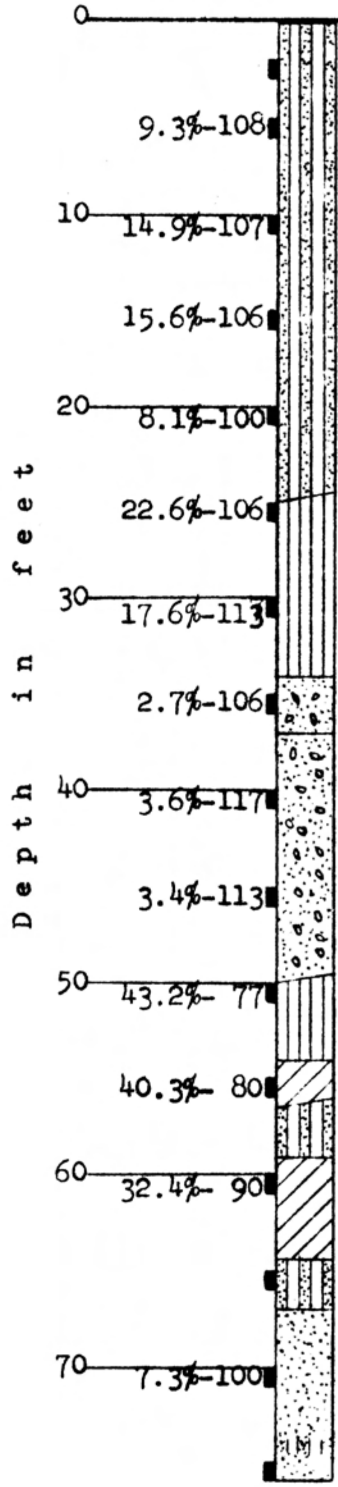
POORLY GRADED SAND - predominantly fine, contains small amount of silt, grey

Grading cleaner

NOTE: Groundwater encountered at $27\frac{1}{2}$'; caving badly at 35'

RECENT ALLUVIUM

LOG OF BORING 11



2" A.C. PAVING

SILTY SAND - sand predominantly fine. medium amount of silt, brown

Dark brown; siltier

Large amount of silt, small amount of clay

Brown

Medium amount of silt, light brown

SILT - contains small amount of clay, small amount of fine sand, brown

Layer of silty sand

POORLY GRADED SAND - predominantly fine, contains small amount of gravel, light reddish-brown

WELL GRADED SAND - contains some silt, approximately 15% gravel, occasional cobble to 8", mottled reddish-brown

Contains approximately 25% well graded gravel

Grey

SILT - contains large amount of clay, small amount of fine sand, brown

Bluish-black; thin lens of organic silt

LEAN CLAY - contains small amount of silt, thin streaks of organic matter, bluish-grey

SILTY SAND - sand predominantly fine, medium amount of silt, bluish-grey

LEAN CLAY - contains small amount of silt, bluish-black

SILTY SAND - sand predominantly fine, medium amount of silt, reddish-brown

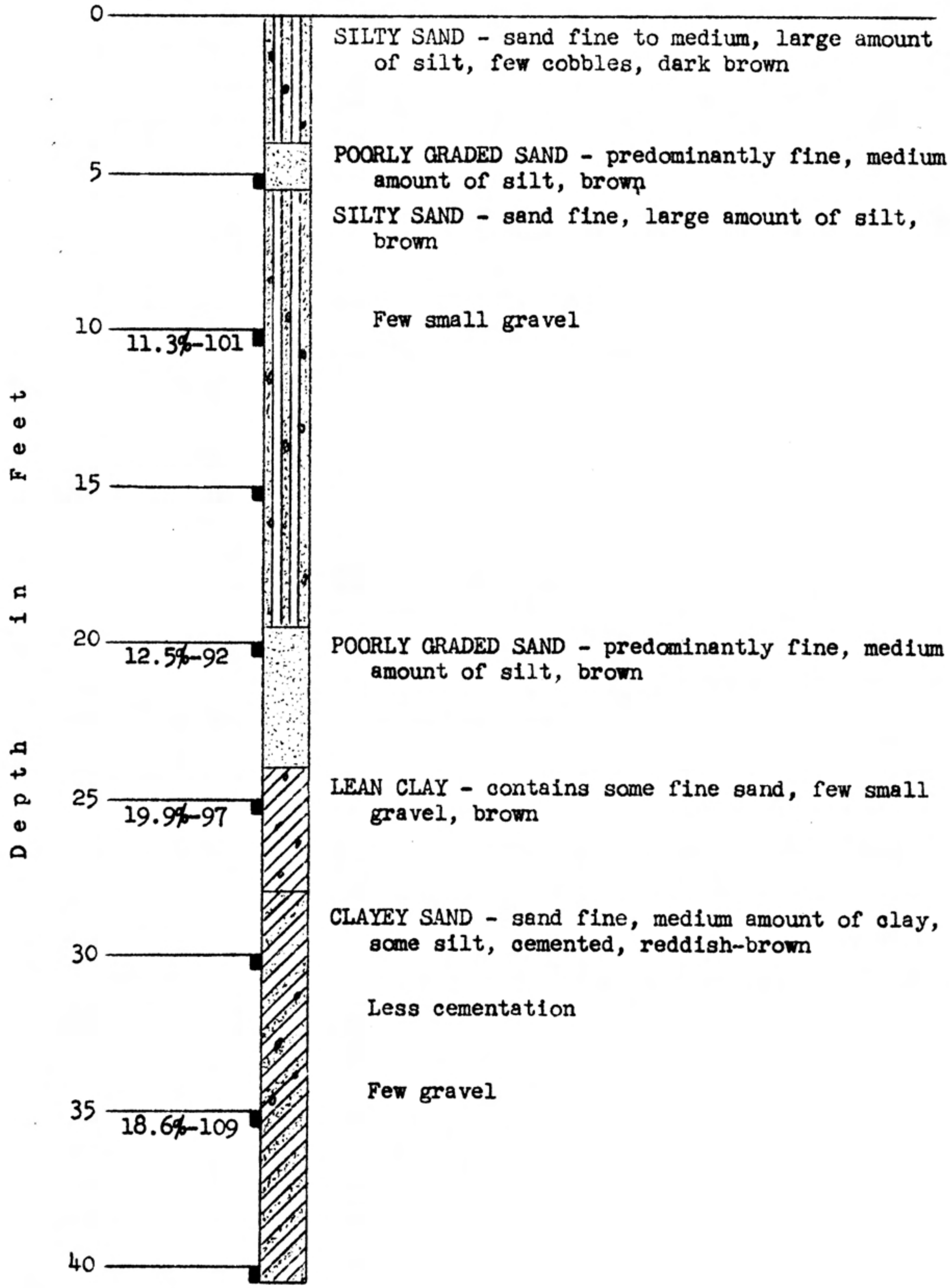
POORLY GRADED SAND - predominantly fine, clean, grey

Lens of SILTY SAND

NOTE: Groundwater not encountered; caving from 34' to 50'

RECENT ALLUVIUM to 28'
CONTINENTAL DEPOSITS below 28'

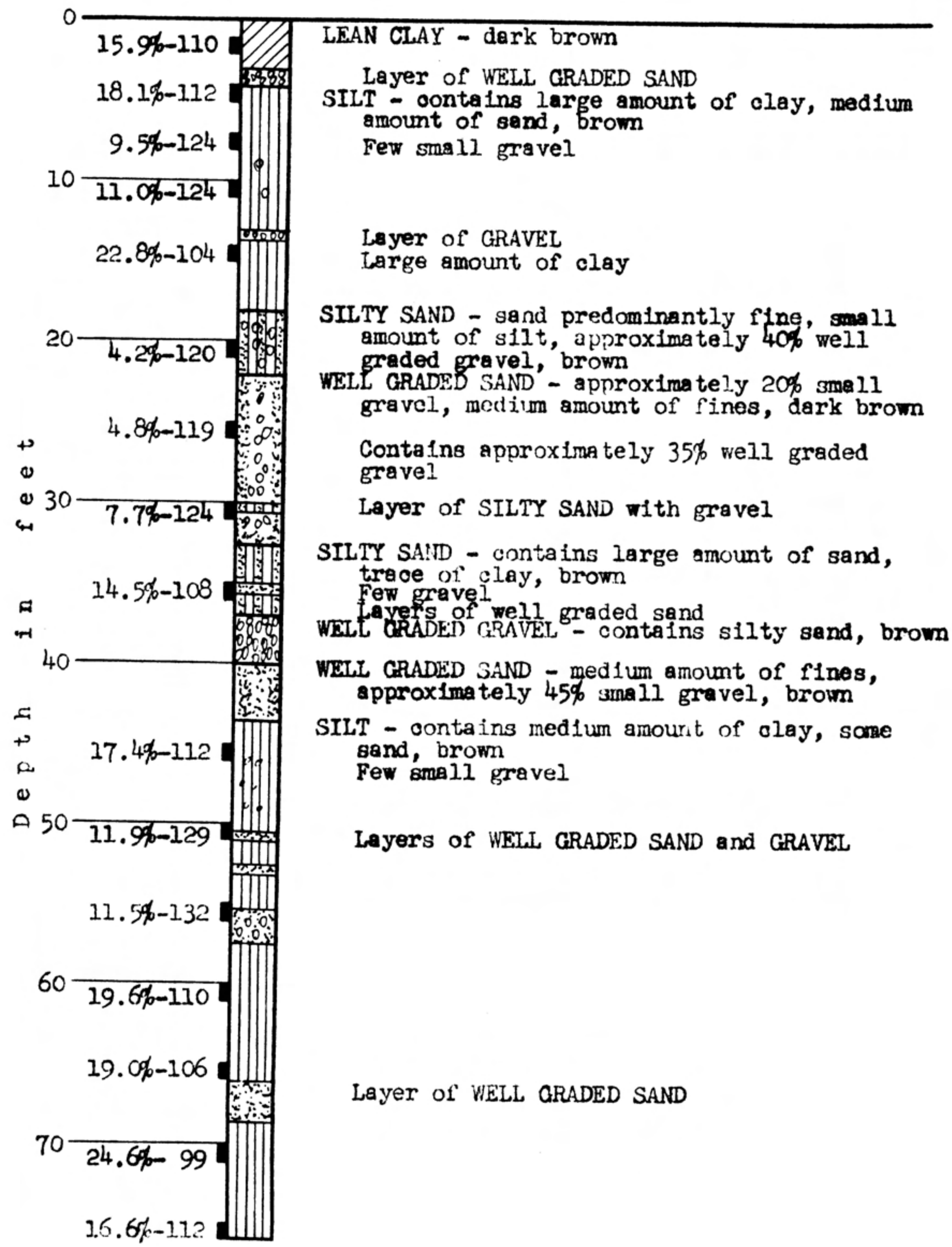
LOG OF BORING 12



NOTE: Groundwater not encountered; no caving

CONTINENTAL DEPOSITS

LOG OF BORING 13
18"-Diameter Rotary Bucket Hole
Drilled November 18, 1959



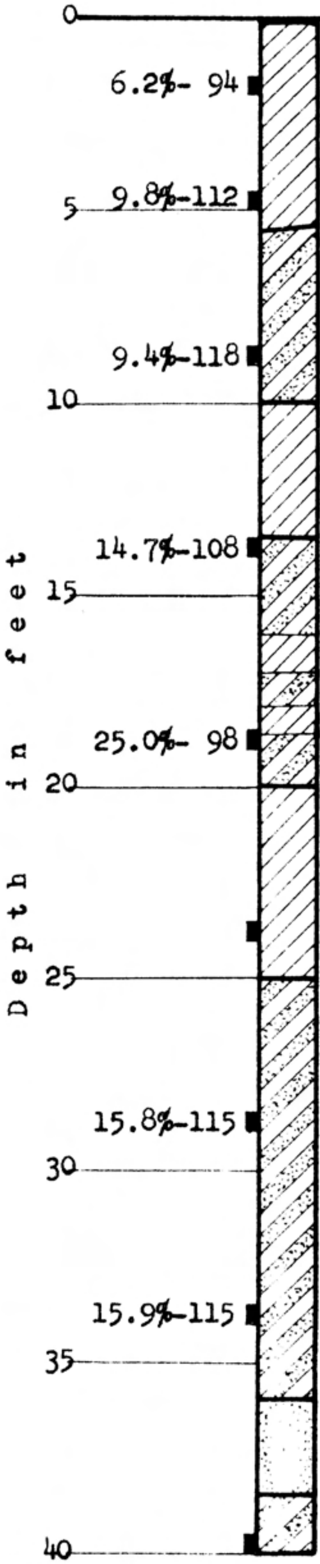
NOTE: Groundwater first encountered at 40' and remained at 40' overnight; no caving.

CONTINENTAL DEPOSITS

LOG OF BORING 14

16"-Diameter Rotary-Bucket Hole

Drilled September 23, 1958



1½" ASPHALTIC PAVING

LEAN CLAY - contains large amount of very fine sand and silt, reddish-brown

Less silt

CLAYEY SAND - sand predominantly fine to very fine, contains large amount of clay, large amount of slate gravel, cemented, reddish-brown

LEAN CLAY - brown

CLAYEY SAND - sand fine, large amount of clay and silt, brown

Layers of LEAN CLAY

LEAN CLAY - contains small amounts of silt and very fine sand, brown

CLAYEY SAND - sand fine to very fine, contains medium amount of clay and silt, brown

Grading to mottled reddish-brown

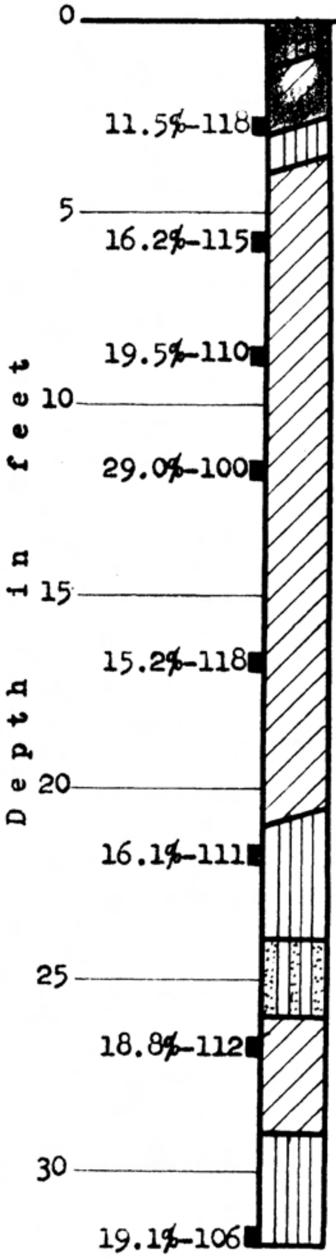
Small amount of silt with few small slate gravel

POORLY GRADED SAND - predominantly fine to medium, contains few coarse sand and small slate gravel, small amount of fines, brown

CLAYEY SAND - sand predominantly very fine, contains large amount of clay, brown

NOTE: Groundwater not encountered; no caving.

LOG OF BORING 15
18"-Diameter Rotary-Bucket Hole
Drilled December 18, 1958



FILL - SILTY SAND - sand predominantly fine, medium amount of silt, few roots, brown

FILL - LEAN CLAY and SILT - contains medium amount of sand, mottled brown

SILT - contains large amount of sand, dark brown

LEAN CLAY - contains small amount of sand, brown with streaks of darker brown

Contains medium to large amount of sand, large amount of silt, cemented, light brown

Sandier

Contains small amount of silt, brown

SILT - contains small to medium amount of sand, small amount of clay, brown

SILTY SAND - sand predominantly fine, medium to large amount of silt, brown

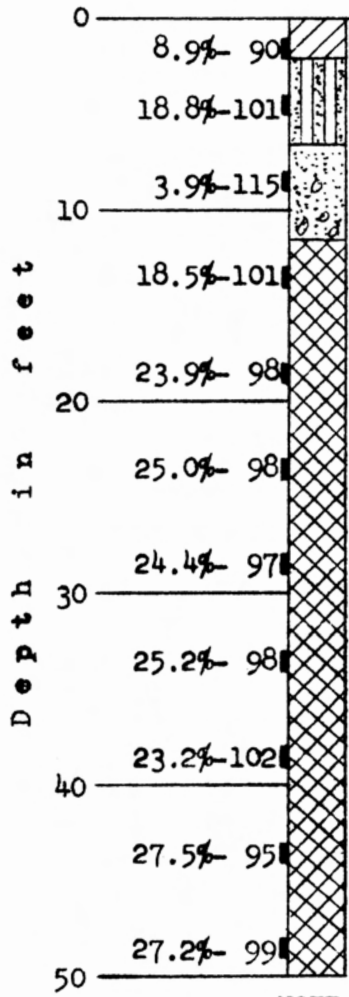
LEAN CLAY - contains small amount of sand, brown

SILT - contains medium amount of sand, light brown

NOTE: Groundwater not encountered; no caving.

PUENTE SHALE

LOG OF BORING 16



LEAN CLAY - contains medium amount of sand, large amount of roots, brown

SILTY SAND - sand predominantly fine, medium amount of silt, mottled brown; cemented

POORLY GRADED SAND - predominantly fine, saturated with asphalt, plastic, black
Few gravel; lens of cemented silty sand

SHALE - laminated, laminations of asphaltic sand, greenish-brown
Hard cemented layers

Very thin nearly vertical lenses of asphaltic sand

Thin streaks of silty sand
Large layers of silty sand

NOTE: Very slight water seepage at 28'; no caving.

APPENDIX C

Mason & Hanger-Silas Mason Co., Inc.

ENGINEERS AND CONTRACTORS
FOUNDED 1827

Los Angeles
668A SO. LAFAYETTE PARK PLACE
57

January 23, 1960

Daniel, Mann, Johnson, & Mendenhall
3325 Wilshire Boulevard
Los Angeles 5, California

Gentlemen:

We herewith submit our report on the construction of underground rapid transit subways in the Los Angeles area, in accordance with our agreement to act as your consultant in this field.

The scope of our effort was established by preliminary negotiation and by your continuing direction to our staff engineer in your office. The content, in text and reference, is compatible with and conforms to the balance of your progress report to be submitted to the Los Angeles Metropolitan Transit Authority on February 2, 1960.

Very truly yours,

MASON & HANGER-SILAS MASON CO., INC.

Francis Donaldson

Francis Donaldson
Vice President

FD:kt

LOS ANGELES METROPOLITAN TRANSIT AUTHORITY

RAPID TRANSIT PROGRAM

PRELIMINARY REVIEW

OF

UNDERGROUND CONSTRUCTION CONSIDERATIONS

FOR

SUBWAYS IN THE LOS ANGELES AREA

JANUARY 25, 1960

PREPARED FOR

DANIEL, MANN, JOHNSON, & MENDENHALL

BY

MASON & HANGER-SILAS MASON CO., INC.

ENGINEERS AND CONTRACTORS

TABLE OF CONTENTS

REPORT ON UNDERGROUND CONSTRUCTION FOR LOS ANGELES RAPID TRANSIT SYSTEM

Among those who have studied the Los Angeles traffic problems, it is the consensus that on account of its' high cost, underground railway construction should be confined to the more closely built and congested areas of the city and beyond these, some other type of construction should be seriously considered. This report confines itself to the underground work.

The general plan assumed for this report provides for a section of four-track conventional subway in the heart of the city, fed by three radial, two-track lines extending respectively into the Wilshire-Reseda, the Long Beach, and San Bernardino Corridors. A four-track downtown loop was considered, but it is believed that this plan would involve too many difficulties, both in construction and operation. The alternative now proposed is to build feeder lines to two or more of the stations on the four-track section; these feeders to consist of belt transporters hereinafter termed distributors, constructed in tunnel in the intersecting streets. Such distributors will operate at lengths up to $1\frac{1}{2}$ miles, and since they are entirely independent of the subway structures, they may be constructed simultaneously or added as required.

In recent years, tunneling methods have been developed which make it possible, in the Los Angeles soils, to drive tunnels of the size required for a subway train economically without causing ground settlement. It is, therefore, proposed to construct in tunnel the subway between stations, thus obviating the necessity of driving soldier beams, of street decking, and of other disturbances to traffic and to the public peace of mind.

For the stations beneath city streets, however, there is no alternative to conventional open-cut subway construction beneath decking.

This combination offers an advantage in operation, in that the track at the stations may be kept at a relatively high elevation and then dipped between the stations, thus permitting gravity to accelerate outgoing and retard incoming trains. This saves power and wear on brakes.

Under Bunker Hill, where cover is too deep for open-cut, the proposed stations will be constructed entirely in tunnels. These will require escalators to carry passengers to and from the surface.

Standard rail transit was assumed for this report to facilitate comparison of costs with existing systems. It is recognized that structural criteria, and thus cost, will differ among the various proposed transit systems.

Accompanying this report are plans and a summary of estimated costs based on these plans using 1959 labor rates and prices. Also enclosed are the detailed cost estimates and a discussion of pertinent construction parameters.

It should be noted that labor rates continue to rise. On the assumption that work will be started in three years, 10% must be added to the total cost to cover escalation. Also, note that only direct structural construction costs have been included. Costs of rail, signal, and power installation were omitted as constants regardless of structure.

SUBWAY COSTS PER MILE

AND

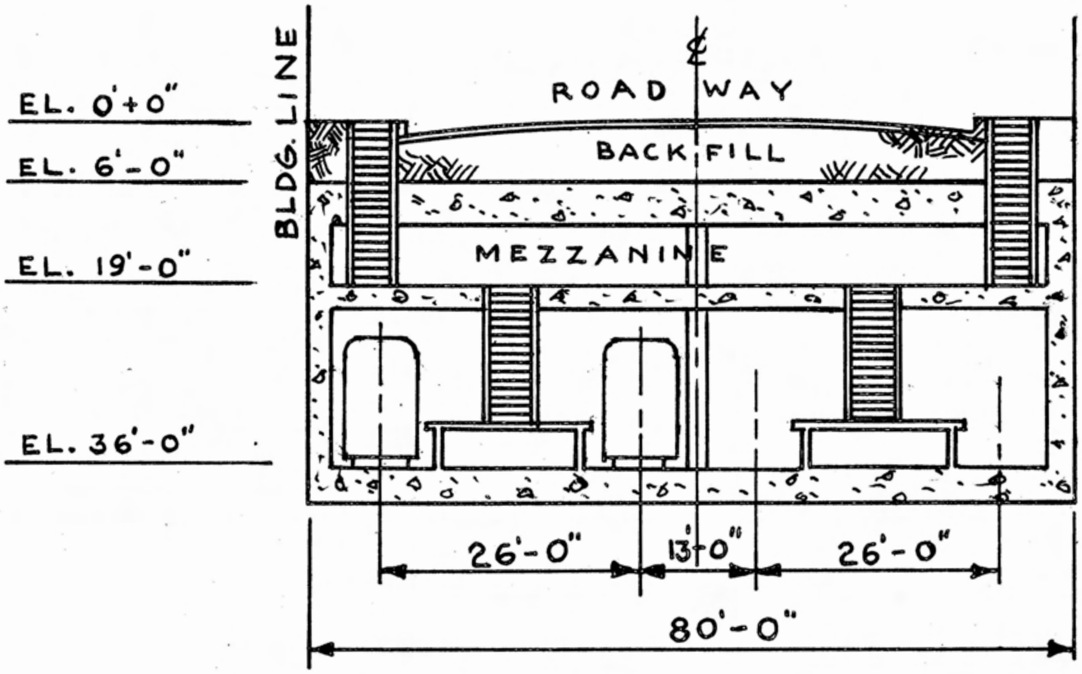
COMPARISON WITH NEW YORK SUBWAY COSTS

Construction Costs

Structure	Length Feet	Miles	Cost M$	
Two Track Subway	12,000	2.28	15,900	
Two Track Stations	1,200	0.23	3,309	
Two Track Totals	13,200	2.51	19,209	
Cost Per Mile Two Track Subway:			Los Angeles	$ 7,650,000*
			New York	$10,500,000**
Four Track Subway	6,500	1.23	19,675	
Four Track Stations	800	0.15	5,106	
Four Track Totals	7,300	1.38	24,781	
Cost Per Mile Four Track Subway:			Los Angeles	$18,000,000*
			New York	$17,800,000**
Distributor Tunnels	13,900	2.66	7,297	
Distributor Stations	320	0.60	1,003	
Distributor Equipment	---	---	16,200	
Distributor Totals	14,220	3.26	24,500	
Cost Per Mile Distributor:			Los Angeles	$ 7,540,000
			(No New York Comparison)	

* Los Angeles costs based on assumed layout in downtown district.

** Based on 1959 figures furnished by the New York Board of Transportation.



TYPICAL FOUR TRACK SUBWAY STATION
IN 80' RIGHT OF WAY
Scale 1" - 20'-0"
Construction Procedure - Cut and Cover
Note - Ends of Platforms tapered to allow Tunnel Configuration shown below.

TYPICAL FOUR TRACK SUBWAY TUNNEL
IN 80' RIGHT OF WAY
Scale 1"-20'-0"
Construction Procedure - Excavate and Line Tunnels #1 and 3. Then Excavate and line tunnels #2 and 4.

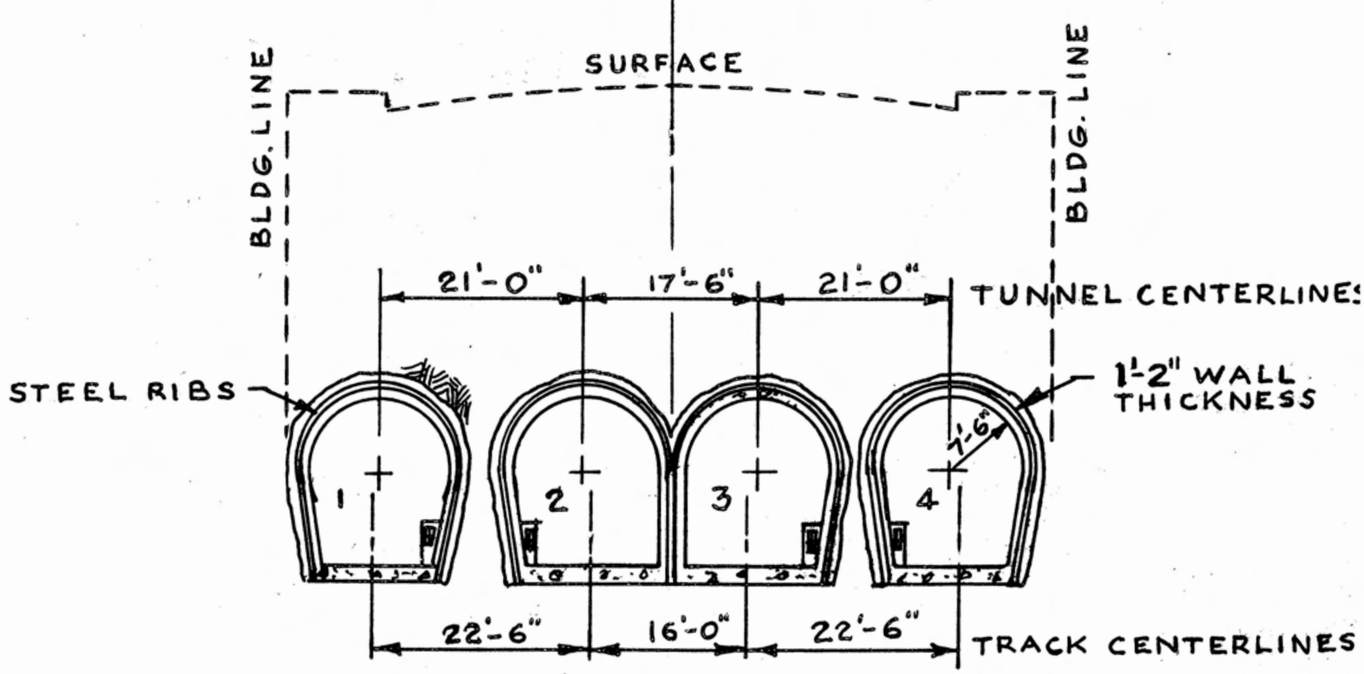
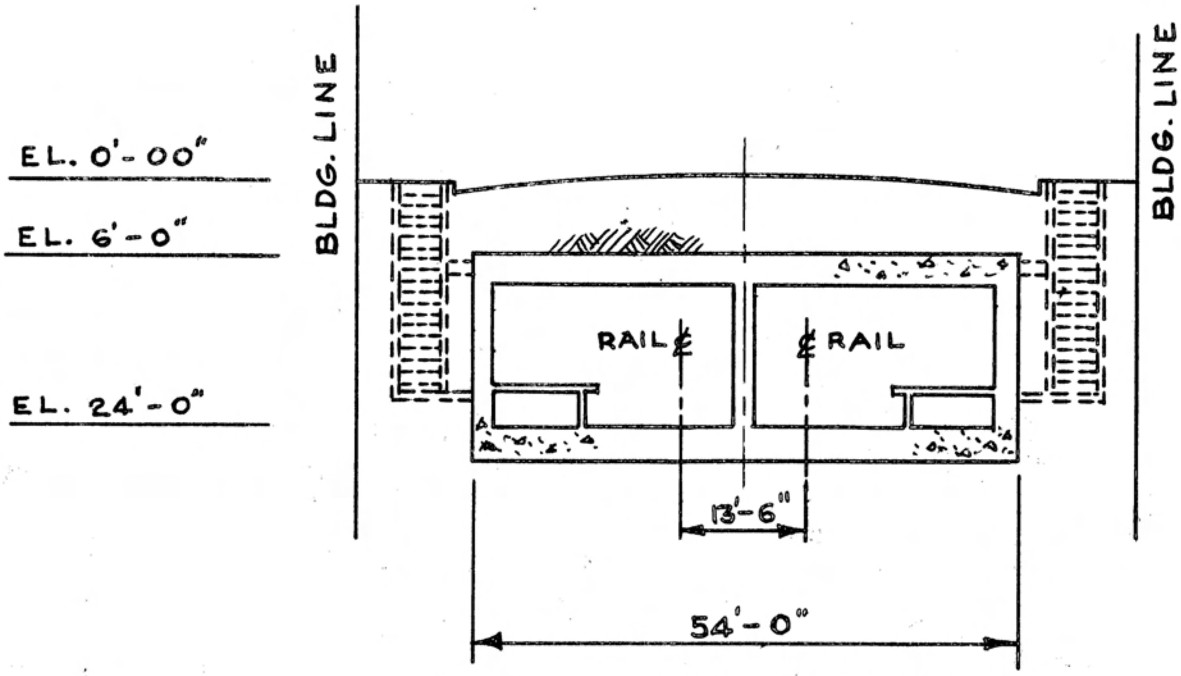


PLATE I
LA Rapid Transit Study
Matson & Hanger -
Silas Mason Co.



TYPICAL TWO TRACK CORRIDOR STATION
Scale 1"-20'-0"
Constructed by Cut and Cover Method
Note: Platforms tapered at ends of station to allow tunnel separation

TYPICAL TWO TRACK SUBWAY TUNNEL

Constructed by Mechanical Excavation Behind Partial Shield. Erection of Steel Rib Temporary supports (and wood lagging in earth) ribs jacked or wedged against earth to exert active pressure on overlying ground and placement of concrete lining.
Note - Separation of tunnel decreased at stations.

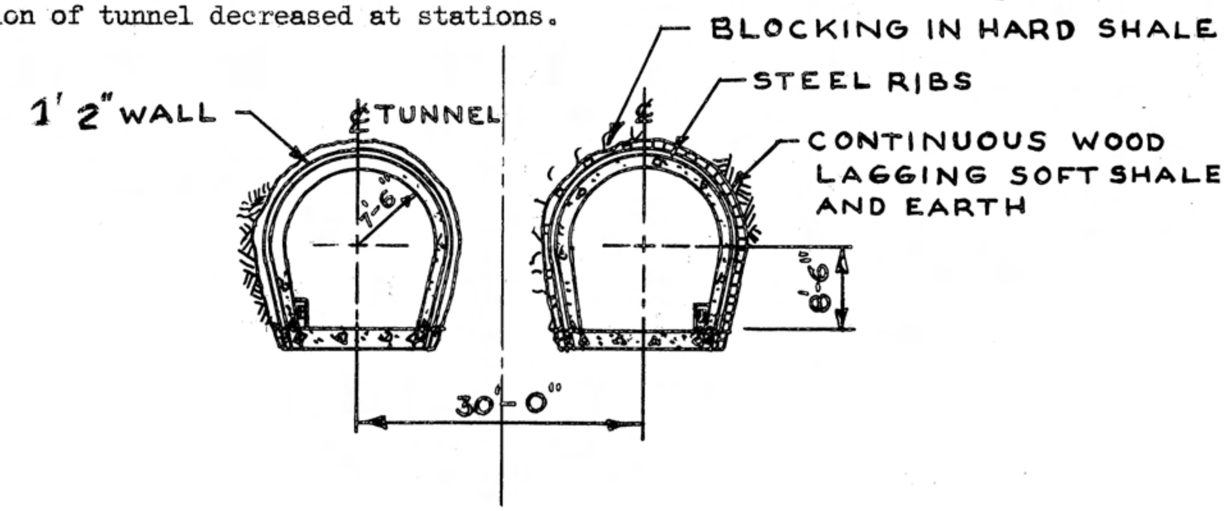
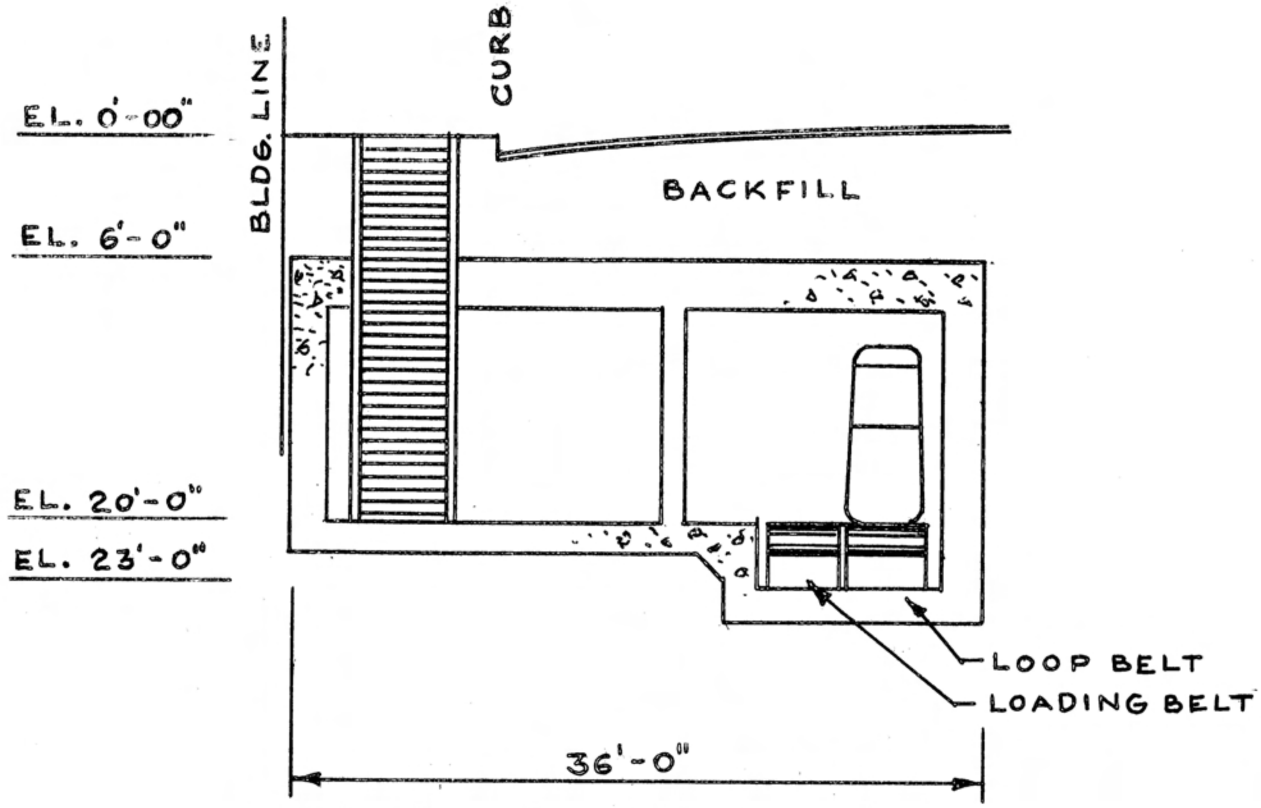


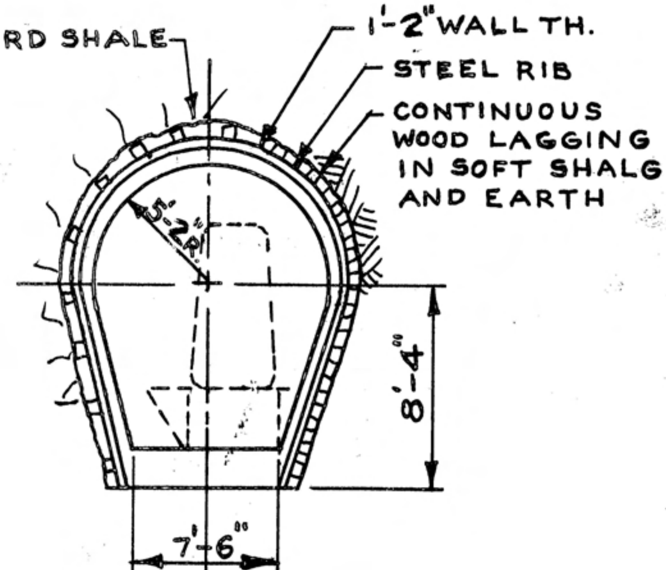
PLATE II
LA Rapid Transit Study
Mason and Hanger - Silas Mason Co



TYPICAL BELT DISTRIBUTOR SYSTEM STATION
SCALE 1"-10'-0"

Constructed by Cut and Cover Method-Station Length 40'-0". Deep Stations Beneath Bunkerhill excavated with tunneling methods by enlargement of through tunnel.

Constructed by Mechanical Excavation behind partial shield; erection of steel rib temporary supports and blocking or lagging; (Ribs jacked or wedged against earth to exert active pressing on overlying ground) and placement of concrete lining.



TYPICAL BELT DISTRIBUTOR SYSTEM TUNNEL
Scale 1"-10'-0"

PLATE III
LA Rapid Transit Study
Mason & Hanger-Silas Mason Co.

TYPICAL DISTRIBUTOR STATION - SHALLOW

Excavation - 36' x 23' x 40'	1,225 c.y.	@	20.00	$ 24,500
Decking - 20' x 40'	90 s.y.	@	20.00	1,800
Concrete	250 c.y.	@	60.00	15,000
Steel	25 tons	@	400.00	10,000
				51,300
Finish				10,200
Total for One Station				$ 61,500

TYPICAL DISTRIBUTOR STATION - DEEP

Excavation	1,800 c.y.	@	40.00	72,000
Concrete	500 c.y.	@	60.00	30,000
Escalator				200,000
Finish				15,000
Total for One Station				317,000

TYPICAL FOUR TRACK TUNNEL (Plate-1)

Excavation including grouting	11 c.y.	@	30.00	330.00
Ring Beams	300 lbs.	@	.25	75.00
Lagging	80 ft.BM	@	.10	8.00
Concrete	3.3 c.y.	@	60.00	200.00
Reinforcing Steel	400 lbs.	@	.25	100.00
Total, Each Tube				713.00
Total, Four Tubes				2,852.00
Ducts, Etc.				20.00
Miscellaneous				78.00
Total per Lineal Foot of Four Track Tunnel				2,950.00
Additional costs - $500,000 for ventilation structures etc., for 6,500 LF				77.00
				$3,027.00/LF

TYPICAL TWO TRACK TUNNEL (Plate-2)

Excavation including grouting	10.8 c.y.	@	27.00	291.50
Ring Beams	200 lbs.	@	.25	50.00
Lagging	80 ft.BM	@	.10	8.00
Concrete	3.3 c.y.	@	55.00	181.50
Reinforcing Steel	330 lbs.	@	.25	82.50
Total, Each Tube				613.50
Total, Two Tubes				1,227.00
Ducts, Etc.				10.00
Miscellaneous				13.00
Total Per Lineal Foot of Two Track Tunnel				1,250.00

Additional costs - $500,000 for ventilation structures, etc.
$400,000 for construction complications at corridor intersections
$900,000 for 12,000 LF — 75.00

1,325.00

DISCUSSION OF UNDERGROUND CONSTRUCTION

METHODS AND DESIGN

I. GEOLOGY

A. The geologic features of the central Los Angeles area which affect the construction parameters of underground structures are described in detail in the study by LeRoy Crandall also incorporated in this report. The shale, or "older firm soils", indicated near the surface in the Bunker Hill area and further out the Wilshire Corridor is excellent material for excavation. It is not a hard rock requiring heavy blasting procedures, yet it will, in general, require only light temporary support during construction. (A surface cut on a near vertical slope, not subject to superimposed loads, may be left unbraced.)

One document, referring to this material in reporting construction of the Pacific Electric Hill Street Tunnel calls it blue shale clay; its characteristics are that of a hard clay or soft rock. The sandstone and shale east of the Los Angeles River, near the central business district, have properties similar to those stated above.

The Los Angeles River has eroded a channel through the shale and sandstone base and deposited a great depth of sand, gravel, silt and clay. The majority of the central business district is founded on this material. Essentially, loose material is, of course, difficult to maintain in position during excavation and requires continuous total support.

Tunneling in this material is relatively easy, although care must be taken to protect existing structures from foundation damage caused by displacement of underlying soils due to construction operations.

The alluvia are generally well graded (i.e., there is a wide variation of particle size); a characteristic which stabilizes the soil itself and allows for simple methods of groundwater removal. This is important because presence of water intensifies the problem of ground support. The groundwater level is generally below grades considered for subway construction, but local areas requiring de-watering must be anticipated.

Tunneling directly under the Los Angeles River would present the most difficult construction problems. Larger quantities of ground water would be encountered and would, with seasonal surface run-off, complicate construction and increase the complexity and cost of the final structure.

B. The area near Cahuenga Pass represents the only other route locality currently considered for possible installation of underground structures. The Santa Monica Mountains here are composed of faulted basaltic fock formations, considerably harder than the shale, alternated with the shale and conglomerate rock. This material is more difficult to mine than the previously discussed shale, and faulted, broken rock could present support problems.

II. CRITERIA FOR UNDERGROUND STRUCTURES

A. Right-Of-Way Structures

Tunnel configuration is a function of the construction methods employed, and thus of the subsurface geology; and of the number of parallel tracks. In this instance two and four track lines are planned.

Tunneling in shale or alluvia predicates horseshoe cross-section to most efficiently provide temporary bracing to resist ground loads. Continuous mining methods if utilized in shale, and complete lining in very difficult ground, are more adaptable to a circular cross-section.

Parallel single track structures make more complete use of excavated volume than double track structures of these cross-sections, and are much more readily excavated and supported.

Single track structures of circular cross-section would necessarily be 16 feet in diameter for conventional rail. A larger vertical clearance, and hence larger diameter would be required for monorail systems in a circular tunnel. Horseshoe shapes of 15 foot width with varying clear height for the different support systems could be used. All tunnels should incorporate emergency walkways at the elevation of car door sills for access to stations or exit structures.

Open cut methods, based on trenching, favor a rectangular cross-section. The flat roof line minimizes depth of cut. Center columns between the "tracks" aid in transmitting roof loads (and rail loads of suspended systems).

Based on 10'-0" car width, the center-to-center spacing of adjacent "tracks" is established at 13'-6". The 3'-6" resultant clear space allows for center support columns, signal equipment installation, and adequate safe space for maintenance crews during passage of a train. Total clear width of approximately 28'-6" is required to provide emergency walkways adjacent to each track.

Cross-overs between the two parallel rights-of-way would increase the flexibility of operation and assure continuous service in case of breakdowns. Their installation would, however, increase construction costs, particularly between separate single track structures.

If more than two parallel "tracks" are to be installed in any section of the right-of-way, the soil characteristics, construction methods, and side clearance would govern selection of either multiple level or side-by-side arrangement.

Note that the monorail systems require increased vertical clearance due to supporting structures. This would be reflected in increased construction costs.

Nominal lighting, as well as auxiliary lighting in case of power failure should be installed for emergency and maintenance situations.

Ventilation of shallow right-of-way structures would be a combination of natural draft through shafts to grade at approximately 500' intervals abetted by the piston action of moving trains. Deeper structures may require forced draft ventilation installations. From 5 to 8 air changes per hour are necessary.

Emergency exits are required along the underground right-of-way. These facilities could possibly be incorporated with the ventilation shaft construction.

It is more practical to plan for drainage of underground systems rather than predicate design on completely water proof structures. A general arrangement of stations as highpoints in the route to aid both acceleration and braking would locate drainage points between stations. Again, incorporation with ventilation and exit structures is a possibility. Pumping to existing city storm drain facilities would result in optimum positive removal of ground water.

B. Subway Stations

The important relationship of appealing, convenient stations to public acceptance of a transit system has been stated previously in this report. The general criteria discussed are also valid for sub-surface structures.

The general four track station arrangement would provide for street level access down to a mezzanine ticketing area and concourse; and then down again to the platform. Two track stations in the various corridors do not require the mezzanine, as transfers are not essential. This allows shallower, cheaper, stations. Entries from the sidewalk and arcades in private buildings are suggested to provide optimum access as street and sidewalk widths, and above-ground structure usage varies. Entry to private buildings may result in benefit to the property owner as well as decreased construction costs and convenience to the public.

Of prime importance to the inducement of people to below-ground are the lighting and ventilation of public areas.

The use of effective indirect lighting, and installation of tile or other bright, easily cleaned and maintained surfaces reinforces the benefit of ample light quantity.

Two separate phases of ventilation are important: (1) adequate flow of clean, fresh air, and (2) elimination of discomfort due to air turbulence caused by train motion.

The supply and distribution of clean air is best maintained by mechanical ventilation. A minimum of eight air changes per hour of outside air should be supplied. Air entering inlet structures (grated rectangular boxes beneath the sidewalk) would be delivered by fans through ducts to registers beneath and over the passenger platforms. Several air handling units at one station would provide integral standby capacity and allow reduction of airflow in early morning hours. Exhaust would be up through passenger exits, through exhaust structures located at tunnel entries to the station, and along these tunnels.

The exhaust structures at the tunnel inlets would serve the second function of deadening the wind "blast" built up ahead of an incoming train. Large openings in the tunnel wall, connected through open ventilating structures to grated areas in the sidewalk above will allow dispersal of this moving air mass.

This problem, maximized by single track tunnel construction, would decrease with train streamlining and with the increase of the ratio of tunnel size to train cross-section.

Basic ventilation of a typical two-track station (380 feet long x 48 feet wide x 14' high) at ten air changes per hour could be accommodated by three 5-horsepower fans. Distribution ducting would logically be placed in the "dead" space beneath platforms.

C. Engineering Design Criteria

Detailed determination of the loads applied to underground structures by the surrounding soil or rock is a function of specific investigation of particular locations. However, the following data is incorporated in this report as a guide to establishment of specific values.

Rectangular Sections - (Shallow Structures)

Roof design is based on dead weight of the fill, or earth, above, plus live loads applied to the surface. Below are summarized the live loads employed by the New York Board of Transportation for subway design to avoid any limitations to surface usage of thoroughfares above shallow subways.

1) Superimposed load on sidewalks and roadways - 600 psf
2) Or, a local concentrated load of 200,000 lbs. on 4 wheels spaced 12'-0" between axles a 6'-0" gauge. Each wheel concentrated in 24" square at the pavement and acting on a 1 to 2 slope to the tunnel roof.
3) Minimum total roof load assumed as 1500 psf, which equals live plus dead loads for 9'-0" depth of cover.

Sidewalls in earth are designed for total earth (and water) pressure plus transmission of roof loads to invert.

The invert in earth is to be designed for complete distribution of the roof loads to decrease settlement and offset possible ground water uplift pressures.

The design loads for shallow structures in rock would be similar to those stated above. However, rock pressure on the walls would be decreased in proportion to the quality of the rock, and invert loads would be limited to internal loads, roof loading being transmitted to the rock through wall foundations.

Loads on deep tunnels in shale or alluvium are direct functions of lotal formations and soil mechanics.

III. SUBWAY CONSTRUCTION METHODS

A. Tunneling, General

Tunneling is the method of underground construction which creates the least disturbance to the general public. Construction incorporating modern excavation procedures, methods of temporary support, and permanent lining designs, will not disrupt the activities, nor damage the structures of, neighbors immediately overhead.

Surface activities are limited to plant areas for offices, temporary material storage, ventilation equipment, spoil handling, concreting, maintenance and power equipment.

Plants for short tunnels are generally located at adits. For a longer tunnel, operations are also carried forward from intermediate shafts preferably located at a station site where permanent surface access is required. Increased costs of plant duplication must be balanced against the compressed progress schedule. Plant space must be on appropriated public property, acquired private land, or incorporated in permanent station areas.

Hauling of excavated spoil and supply of construction material is generally accomplished over public streets in urban areas.

Tunneling problems vary with the type of ground penetrated. The shale formations underlying the area north and west of the central business district and the Wilshire Corridor is, as previously stated, an excellent material for tunneling operations - fairly soft, yet capable of at least temporary self-support. More care must be taken to support the Los Angeles River alluvium, however, similar tunneling methods may be used.

B. <u>Recommended Method</u>

A tunneling procedure which may be applied to both types of ground has been developed in the Los Angeles area, and is here recommended.

A shield is employed to protect the workers and support the overhead ground at the tunnel face. The shield is an open-bottom horseshoe shaped steel frame with a steel plate skin that conforms to the tunnel section. It is moved ahead by means of hydraulic jacks as tunneling progresses.

The temporary tunnel lining - horseshoe shaped steel ribs and wooden sheathing - is erected inside the tail end of the shield. An advantage of this lining configuration is the ability to jack or wedge it up against the ground to exert active pressure and prohibit subsidence.

Complete sheathing may not be required in the harder shale. Then the ribs are intermittently blocked against the shale to provide support. It is possible that light blasting might be required to loosen this hard formation.

Mechanical excavators are usually employed to dig and load most of the "muck". Some hand mining is required around the shield periphery. The spoil is hauled by battery or trolley powered mine trains.

Rate of advance of a tunnel heading by this method is estimated at fifty feet per three shift day.

Placing of the permanent concrete lining should be accomplished soon after tunnel excavation to minimize possibility of surface subsidence and damage. Concrete is placed by pumping methods into forms which may be moved and re-used through the entire tunnel length.

The closely spaced tunnels in the four track section of the subway present a construction problem. To avoid damage to a tunnel by subsequent excavation of one adjacent to it, it is proposed that tunnels 1 and 3 (see Plate 1) be excavated and concrete lined prior to excavation of tunnels 2 and 4.

The cost estimates in this report are based on tunneling both the alluvium and shale by this method.

C. Continuous Mining

Completely mechanized continuous mining methods have been recently successful in shale-like formations at several localities. The prime examples of this equipment are the "Moles" employed to excavate outlet and power tunnels appurtenent to Oahe Dam near Pierre, South Dakota. The material excavated is Pierre shale, similar to local shale.

The entire face of the tunnel is cut by a rotating cutter-head driven by large electric motors. Built into the "Mole" is equipment which collects excavated material and conveys it to hauling equipment.

Three such machines have been employed at the dam site. Excavated tunnel size varies between 26 and 30 feet diameter. Costs of the rigs vary between $350,000 and $500,000.

Progress rate with these machines has averaged over 50 feet per day.

Another continuous mining machine has been employed in California. At Vandenberg Air Force Base, north of Santa Barbara, a machine known as the "Badger" drilled 1300 feet of 10 foot diameter tunnel through blue shale. The machine, though not nearly as complex as the "Mole", does embody spoil handling and conveying equipment and a shield to protect workers in the unlined portion of the tunnel. Rate of advance with proper muck removal methods, could approach an average of two feet per hour.

Mr. Lawrence L. Morris, of Whittier, developer and owner of the "Badger" states that a machine with comparable capabilities could be developed for up to 22 foot bores. The rig would cost approximately $150,000.

Other isolated instances of continuous mining in shale have been successful. For example, coal mining equipment designed to work in rectangular drifts was adapted to cut a 12 foot diameter sewer tunnel in Euclid, Ohio (1953), when neighbors complained about the blasting nuisance.

An attempt to continuous mine small bore sewer tunnels at Pittsburgh was abandoned recently. A mixture of sandstone with the shale presented a variation of cutting conditions not economically met by this method.

It is noteworthy that continuous mining methods are best adapted to circular cross-section tunnels - a less efficient configuration for transit service than horseshoe sections.

Also, the large tuhnels successfully mined by continuous methods are nominally constant diameter. Stations, ventilation structures, emergency exit structures, and other appendages to the nominal smooth bore of a subway would not lend themselves to this method.

Maximum tunnel diameter practicable for continuous mining is governed by several factors. The height of free standing vertical face of the material excavated is critical. The power consumed by the large machines, and the incumbent temporary power transmission costs, as well as their initial design and development costs will also control.

Because subway tunnel lengths must economically be kept to a minimum; and because the majority of these tunnels will be located downtown, in river alluvium not suited for continuous mining; it is not deemed probable that the application of this method would effect appreciable savings to the program. Hence, the cost estimates have been based on the use of the shield method for all tunnels.

D. Hard Rock Tunneling Methods

Cahuenga Pass has been mentioned as the possible site of a tunnel for reason of grade and lack of right-of-way space over the pass. The hard rock formations in this locality would predicate use of the time honored tunneling procedure of drilling the tunnel face, loading these holes with explosives, blasting, removing loosened rock, installing temporary support in the freshly excavated area, and then repeating the cycle. Cost figures projected by the

California Department of Water Resources indicate construction costs for a double track tunnel in this material to be $8,000,000 per mile.

E. Cut and Cover Construction

Cut and cover is an alternate approach for construction of underground transit structures in urban areas.

The method is summarized as the excavation of a trench, construction of a rectangular cross-section subway tunnel, and restoration of the surface.

Problems are apparent. Blocking of urban streets must be minimized. Structures along the right-of-way must be protected. The myriad of subsurface utility lines in downtown areas must be maintained operational.

The problems have been recognized and overcome in the long development of this method. The procedures currently in common use are as follows:

1. Underpin adjacent structures

   Underpinning is defined by an excerpt from a standard subway contract of the New York Board of Transportation in Underpinning by Prentis and White as: "Such method of construction as will transmit foundation load directly through the underpinning structure to such lower level as necessary to secure the buildings and which will relieve the adjacent ground and the (railroad) structure from undue lateral pressures. The underpinning shall be designed to furnish a safe and permanent independent support for each building and structure. To accomplish this result, the contractor shall use such methods of underpinning, pneumatic or otherwise, as special conditions may require and the Engineer shall approve."

Methods vary with types of foundation and soils but generally involve preliminary support of the structure while piles, piers, caissons, (large open piles, sometimes constructed under air pressure in poor water bearing ground) or a combination thereof, are constructed; and then wedging of the new foundations to those existing to transfer the building loads. As a rule, only the foundations of the building beneath the wall facing the excavation are underpinned.

In some cases where the excavation is to be at some distance from the structure only lateral protection in the form of a cut-off wall is required.

All underpinning operations are preceded by inspection of existing structures to determine what damage, if any, is actually incurred during excavation. Usually representatives of the engineers, contractors, and building owner conduct the examination.

The local Los Angeles statutes must be investigated to determine the legal responsibility of the MTA contractor and for damage due to such excavation.

Generally both parties are liable for damages due to contracted work; the contractor is liable to damages due to negligence in performance of this work.

Cost of underpinning varies greatly with the type of structures along the right-of-way, width of right-of-way and depth of excavation.

2. Excavate Trench, Providing Temporary Roadway and Supporting Subsurface Utilities

These tasks are inter-related and conducted simultaneously as the job progresses along the route. Methods have changed with the evolution of construction materials and equipment to a fairly standard procedure.

First, H-beam piles are driven to below subway subgrade at approximately 10-foot intervals along the net excavation lines on each side of the subway. Shallow pits are sometimes excavated prior to pile driving to avoid piercing underground utilities.

Then the street is excavated to a depth varying from 3 to 12 feet. This phase of excavation is done by careful use of power equipment and by hand, again to avoid disturbance of utilities. At the same time, transverse girders are installed between piles and a timber decking installed. The framework is designed, if possible, to span the entire excavation to allow open work space. It must carry normal traffic loads plus any loads applied during construction operations. Special framing and bracing must be employed where street railway traffic is maintained. Utilities are supported from this falsework.

Decking and excavation are generally scheduled to continuously maintain traffic on at least half the roadway width; particularly for fire and other emergency equipment. An exception to this rule was the procedure followed during construction of the first increment of the Toronto subway. All traffic was totally detoured from two to four blocks for short periods; this greatly simplified the contractor's operations.

The various utilities are maintained by methods consistent with their characteristics. Gas lines are temporarily routed through by-passes laid at curb level, with bridging at intersections, to avert possible leakage in the excavated area. Lightweight pipe flumes, substituted for heavy sewer lines, are hung with the other smaller, lighter utilities and later replaced. Manholes are either destroyed and rebuilt or supported. This work is usually carried out by the owners of private utilities and by the contractor under the supervision of various city departments. Large storm drains transverse to the subway are rerouted under the structure by inverted siphons.

The remainder of the excavation is then carried to sub-grade beneath the deck. Small power shovels of tunnel type mining machines load directly into trucks which exit through ramps to grade. As the depth of cut increases, horizontal sheeting is installed between the piles to support the earth and additional cross bracing is installed as required.

3. Tunnel Construction

The permanent way structure construction is done by standard methods, and is considerably simpler than the preceding underpinning and excavation operations.

Structures of this type have generally been steel frames at five-foot spacing with concrete jack (shallow) arches between frames. This design has evolved from closely spaced cross-tunnel bracing necessary when timbering rather than steel was used, but remains competitive with reinforced concrete designs. One advantage of the closely spaced bents is the comparatively small size and weight of the structural and reinforcing steel which must be handled and placed in the cramped quarters beneath the decking.

Lack of adequate space for a construction plant usually predicates use of transit mix concrete whichis placed by gravity through openings in the deck.

4. Restoration of Utilities and Roadway

After completion of the tunnel, the space above the structure is backfilled, the utilities replaced, and the street and sidewalk restored. Again, these operations must be scheduled for minimum disturbance to normal traffic.

Where cut and cover methods are followed in a populated area, the turning radius of transit equipment will necessitate location of the right-of-way outside the limits of public right-of-way beneath existing structures. Where this is necessary, alternate procedures may be followed; either underpinning of the buildings in a manner allowing tunneling below them; or condemnation, demolition, open cut excavation, and construction of a subway structure capable of supporting future buildings on the site.

The cut and cover method just described is used where ground conditions are not favorable for tunneling operations. In such cases the increased tunneling costs offset the nuisance and complication of utility and traffic maintenance.

It is applicable in Los Angeles station construction where the final structure extends to the surface.

E. Los Angeles River Crossing

The subway portion of the system could be extended beneath the Los Angeles River bed. However, the construction problems entailed by the presence of considerable groundwater in the sand and gravel alluvium would make such an operation far more expensive than bridging. Another factor increasing the tunneling costs would be maintenance of the rail traffic on both sides of the river.

Bridge construction could clear the rail operation. A pier or piers within the river channel would decrease the individual spans and bridge cost. The only apparent adverse requirement for bridge construction is the acquisition of real estate west of the river for "daylighting" of the right-of-way.

APPENDIX D

January 28, 1960

Daniel, Mann, Johnson & Mendenhall
3325 Wilshire Boulevard
Los Angeles 5, California

Attention: Mr. David Miller

Gentlemen:

In accordance with our recent discussion concerning the relation of the Los Angeles "central city" to mass rapid transit, we herewith submit our thoughts on the subject.

Before discussing the central city-rapid transit relationship, it is important that everyone concerned be apprized of the assets and present potential of the central city.

- The central city has the greatest concentration of people in the entire Los Angeles metropolitan area; at one time or another there are 750,000 people in the central city on a typical business day.

- The central city has four major department stores and over 1600 other retail establishments, causing it to be the largest shopping center in the west.

- The central city is fortunate in having as one of its major tenants an integrated civic center housing Federal, State, County and City agencies.

- The central city is the financial center of the region. Main offices of the six largest banks in Los Angeles are located downtown and more than one-third of all bank deposits in Los Angeles County are in the central city.

- The central city contains more than one-half of the class A hotel rooms in the Los Angeles area.

- The central city is the cultural and entertainment center of the region.

- The central city contains over 10,000,000 square feet of office space.

- INDEPENDENT OF PROPOSED MASS RAPID TRANSPORTATION, THE CENTRAL CITY IS A TRANSPORTATION CENTER ACCOMMODATING RAILWAY AND INTER-CITY BUS TERMINALS.

- THE CENTRAL CITY INCLUDES ON ITS NORTHWESTERN PERIMETER THE LARGEST URBAN RENEWAL PROJECT IN THE UNITED STATES. THE $315,000,000 PROJECT IS PRESENTLY IN THE EXECUTION STAGE AND LAND PURCHASES ARE ANTICIPATED BEFORE THE END OF 1960.

- THE STRATEGIC CENTRAL LOCATION OF THE CENTRAL CITY IN RELATION TO THE LOS ANGELES REGION CAUSES IT TO BE A FOCAL POINT OF INVESTORS.

- THE EXISTING AND PROPOSED FREEWAY SYSTEMS ARE DESIGNED TO GIVE EXCELLENT SERVICE TO THE CENTRAL CITY.

- THE CENTRAL CITY IS FAR FROM DORMANT IN TERMS OF NEW CONSTRUCTION; 3,860,000 SQUARE FEET OF OFFICE SPACE HAS BEEN CONSTRUCTED SINCE 1948. NINE MAJOR OFFICE BUILDINGS, VARYING IN HEIGHT FROM 12 TO 20 STORIES AND IN FLOOR AREA FROM 150,000 TO 1,000,000 SQUARE FEET, HAVE BEEN CONSTRUCTED SINCE 1950. A 1300-ROOM MAJOR HOTEL, THE STATLER, WAS CONSTRUCTED DOWNTOWN IN 1953. THE TISHMAN REALTY AND CONSTRUCTION COMPANY HAVE INDICATED THEIR FAITH IN THE FUTURE OF THE CENTRAL CITY BY CONSTRUCTING A 20-STORY, 275,000 SQUARE FOOT OFFICE TOWER DOWNTOWN. MILLIONS OF DOLLARS HAVE BEEN SPENT IN RECENT YEARS AIR CONDITIONING, REFURBISHING AND UPGRADING OFFICE BUILDINGS.

WITH THESE ELEMENTS ALREADY EXISTING, THE CENTRAL CITY HAS THE POTENTIAL, IF PROPERLY GUIDED, TO REMAIN THE HUB OF A GREAT METROPOLIS. A CENTRAL BUSINESS DISTRICT MUST CONTINUALLY PROMOTE ITSELF, UPGRADE AREAS AND IMPROVE SERVICES JUST TO MAINTAIN ITS STATUS QUO. FOR A CENTRAL AREA TO BECOME MORE PRODUCTIVE REQUIRES MEASURES ABOVE AND BEYOND DOLLAR DAYS, EXPANSION OF PARKING FACILITIES, FACE-LIFTING, ETC. THE GREATEST SINGLE INFLUENCE TENDING TOWARD HIGHER PRODUCTIVITY AND INSURING CONTINUED GROWTH AND PROSPERITY, IS AN INCREASE IN ITS EFFICIENCY, AND ONE OF THE MOST EFFECTIVE MEANS OF INCREASING EFFICIENCY DOWNTOWN IS THE INTRODUCTION OF MASS RAPID TRANSPORTATION.

EFFICIENCY IS INCREASED BY MINIMIZING AREAS WITHIN THE CENTRAL CITY DEVOTED TO VEHICLE CIRCULATION AND STORAGE, AND THE LAND LIBERATED FROM THE AUTOMOBILE CAN THEN BE PUT TO A HIGHER AND MORE PRODUCTIVE USE. REDUCING VEHICULAR TRAFFIC DOWNTOWN MINIMIZES THE AUTOMOBILE-PEDESTRIAN CONFLICT AND A SUPERIOR LIVING ENVIRONMENT CAN BE CREATED. THE EXISTING AND PROPOSED

FREEWAY SYSTEMS ALONE CANNOT PROVIDE ADEQUATE ACCESS TO THE CENTRAL CITY AND A SUBSIDIARY SYSTEM OF MASS RAPID TRANSPORTATION WILL IMMEASURABLY IMPROVE INGRESS AND EGRESS, GENERATING MORE INTEREST AND ACTIVITY IN THE CENTRAL AREA. A TRANSIT SYSTEM PROVIDING SERVICE TO ALL POINTS WITHIN THE CENTRAL CITY WILL PERMIT SURFACE PARKING FACILITIES TO BE RELOCATED ON THE PERIPHERY OF DOWNTOWN IN LOW PRODUCTIVITY AREAS, FREEING LAND PRESENTLY USED FOR PARKING IN THE HEART OF THE CITY FOR A HIGHER USE. BY INCREASING EFFICIENCY, APPEAL AND PRODUCTIVITY ARE INCREASED AND A CYCLE IS STARTED THAT SPIRALS UPWARD, SETTING AN ECONOMIC TREND MOST BENEFICIAL TO THE CITY.

MASS RAPID TRANSPORTATION CAN BE VERY EFFECTIVE IN INCREASING CENTRAL CITY EFFICIENCY BY CAUSING WORKERS, SHOPPERS, AND VISITORS DESTINED FOR THE CENTRAL CITY TO LEAVE THEIR CARS AT A POINT REMOVED FROM THE CENTRAL AREA AND TO UTILIZE MASS RAPID TRANSPORTATION.

PARKING RATES IN PERIPHERY LOTS SERVING RAPID TRANSIT WILL BE LOWER THAN DOWNTOWN RATES AND THE EASE AND SPEED BY WHICH ONE MAY TRAVEL TO THE CENTRAL CITY ARE IMPORTANT FACTORS THAT WILL CONTRIBUTE TO THE SUCCESS OF A RAPID TRANSIT SYSTEM, BUT THESE FACTORS ALONE WILL NOT INSURE ACCEPTANCE OF THE SYSTEM. A PERSON WILL ABANDON HIS CAR AND UTILIZE THE SYSTEM ONLY IF HE CAN TRAVEL WITH EASE AND COMFORT TO HIS ULTIMATE DESTINATION. HE MUST BE QUICKLY AND COMFORTABLY TRANSPORTED TO HIS DESTINATION FROM THE MAIN LINE WHICH BROUGHT HIM TO DOWNTOWN, AND HE WILL MOST CERTAINLY REJECT THE SYSTEM IF HE IS SUBJECTED TO A LENGTHY WALK OR THE INCONVENIENCE OF A TIME-CONSUMING "ON-SURFACE" BUS RIDE. ACCEPTANCE OF MASS RAPID TRANSIT IS ONLY POSSIBLE BY EMPLOYING A SYSTEM WITHIN THE HIGH DENSITY AREA OF THE CENTRAL CITY THAT WILL PROVIDE MAXIMUM COVERAGE, FLEXIBILITY AND CONVENIENCE THROUGH SOME FORM OF OFF-STREET CONVEYANCE. CALL IT A BLANKET COVERAGE SYSTEM. ONLY THROUGH A BLANKET COVERAGE SYSTEM IN THE HIGH PRODUCTIVITY AREA CAN MASS RAPID TRANSPORTATION BE MADE ATTRACTIVE TO THOSE TRAVELING TO AND FROM THE CENTRAL CITY. MOST OF THE BENEFITS ACCRUED THROUGH INCREASED EFFICIENCY CAN BE CONSIDERED BEYOND REACH IF SUCH A SYSTEM IS NOT UTILIZED.

THE BLANKET COVERAGE OFF-GRADE SYSTEM WILL BE COSTLY, AND IS ONLY POSSIBLE IN HIGH DENSITY AREAS. THE SYSTEM SHOULD NOT BE DESIGNED IN TERMS OF THE PRESENT CITY DEVELOPMENT, BUT DESIGNED SO THAT IT WILL BE ADEQUATE WHEN THE INTENSIFIED BUILDING PROGRAM OCCURS AS A RESULT OF THE PARTIALLY CONSTRUCTED TRANSIT SYSTEM. A SUBSTANTIAL INCREASE IN DOWNTOWN PROPERTY VALUES WILL BE BROUGHT ABOUT THROUGH THE BLANKET COVERAGE SYSTEM, AND THIS SHOULD NOT BE LOST SIGHT OF IN CONSIDERING THE SYSTEM'S COST.

THE CENTRAL CITY IS THE FOCAL POINT OF THE LOS ANGELES METROPOLITAN AREA AND IS VITAL TO THE ECONOMIC WELL-BEING OF LOS ANGELES. THE ECONOMICS OF THE HEART OF THE CITY AND ITS OUTLYING AREAS ARE INTERRELATED AND INTERDEPENDENT. IF THE CENTRAL CITY FALTERS, THE REMAINDER OF THE CITY WILL NOT ESCAPE THE CONSEQUENCES. FIRE, POLICE, BUILDING AND SAFETY, HEALTH AND WELFARE SERVICES TO BLIGHTED AREAS WITHIN THE CENTRAL CITY WILL BE GREATLY INCREASED, ACCOMPANIED BY A MARKED DECREASE IN REVENUE TO THE CITY FROM SALES AND PROPERTY TAXES. TODAY DOWNTOWN PAYS ABOUT 10% OF ALL CITY TAXES. INVESTORS WILL REJECT THE CENTRAL CITY AND LOOK TO THE SUBURBS OR, IN THE CASE OF DEVELOPMENTS THAT MUST BE LOCATED IN A HIGHLY PRODUCTIVE AREA, INVESTORS WILL LOOK TO DOWNTOWN AREAS IN OTHER MAJOR CITIES.

IN SUMMARY, IN OUR OPINION THE CENTRAL CITY IS THE KEY ELEMENT IN THE FRAMEWORK OF THE METROPOLITAN AREA. A CITY WITHOUT A LIVING AND PRODUCTIVE CENTRAL AREA WILL FAIL. THE INSTALLATION OF MASS RAPID TRANSPORTATION IN THE LOS ANGELES METROPOLITAN AREA WITH BLANKET COVERAGE IN THE CENTRAL CITY IS ONE OF THE MOST IMPORTANT MEASURES THAT CAN BE TAKEN TO INSURE A SUCCESSFUL CENTRAL CITY.

VERY TRULY YOURS,

VICTOR GRUEN ASSOCIATES

BEN H. SOUTHLAND

BHS:LB

VICTOR GRUEN ASSOCIATES

COMMUNITY ACCEPTANCE

OF

A RAPID TRANSIT SYSTEM

LOS ANGELES METROPOLITAN TRANSIT AUTHORITY

JANUARY, 1960

HOW WILL THE COMMUNITY REACT TO A RAPID TRANSIT SYSTEM EMPLOYING CARS TRAVELLING AT A MAXIMUM OF 75 TO 80 MILES PER HOUR, WITH HIGH ACCELERATION AND DECELERATION RATES, WITH 20-SECOND STATION STOPS AND CAPABLE OF ACHIEVING 90-SECOND HEADWAYS?

THIS QUESTION MUST BE ANSWERED FROM TWO POINTS OF VIEW--THE PASSENGER'S AND THE NON-PASSENGER'S--AND THE TWO ARE NOT NECESSARILY COMPATIBLE, EVEN THOUGH THE TWO POINTS OF VIEW WILL, IN MANY CASES, BE SHARED BY THE SAME INDIVIDUAL. A PASSENGER'S CRITERIA FOR JUDGING A RAPID TRANSIT SYSTEM IS QUITE DIFFERENT THAN THAT OF THE NON-PASSENGER, WHO IS A RESIDENT, WORKER, SHOPPER, ETC., IN CLOSE PROXIMITY TO THE SYSTEM BUT TEMPORARILY NOT A USER OF IT.

THE PASSENGER IS INTERESTED IN CONVENIENT STATION LOCATIONS, MINIMUM WAITING PERIODS, MAXIMUM SPEED, A COMFORTABLE RIDE WITHIN A CAR OF PLEASING APPEARANCE, LOW NOISE LEVEL AND CONTROLLED TEMPERATURE. HE DOESN'T WANT TO WALK UP AND DOWN STATION STAIRS, TRANSFER, UNDERGO COMPLICATED FARE PROCEDURES, WALK VERY FAR FROM PARKING TO STATION OR FROM STATION TO DESTINATION. HE IS INTERESTED IN SAFETY AND HE IS CONCERNED WITH COST.

THE MAN WHO AT THE MOMENT IS NOT USING THE SYSTEM AND WHOSE ENVIRONMENT IS INVADED BY THE SYSTEM HAS A RADICALLY DIFFERENT SET OF CONCERNS. IN GENERAL, HE WOULD WISH IT TO BE SOMEPLACE ELSE ALTOGETHER. SINCE THIS IS IMPOSSIBLE IN ALL CASES, HE SETS A DECLINING SERIES OF STANDARDS STARTING WITH A SYSTEM TOTALLY NOISELESS AND INVISIBLE, THROUGH A SYSTEM NOT PLEASANT BUT TOLERABLE, DOWN TO A SYSTEM INTOLERABLE IN ONE OR MORE RESPECTS.

A BARELY TOLERABLE SYSTEM WILL PLACE HUGE SECTIONS OF THE METROPOLITAN AREA IN JEOPARDY BECAUSE A BORDERLINE SET OF STANDARDS WILL REDUCE THE POTENTIAL NUMBER OF PEOPLE DESIRING THAT PARTICULAR LOCATION, NO MATTER WHAT ITS USE MIGHT BE. ONCE THE DESIRE OR POTENTIAL IS LOWERED, VALUES STABILIZE OR, MORE LIKELY, DECREASE. STABILIZATION AND/OR DECREASE TENDS TOWARD BLIGHT. BLIGHT, IN TURN, DECREASES REAL ESTATE VALUES AND THE VICIOUS DOWNWARD CYCLE BEGINS. NO CITY CAN AFFORD THE RESULTANT LAND LOSS, TAX LOSS, AND GENERAL DEFLORATION THAT RESULTS.

AN IDEAL SYSTEM, UNNOTICED AND UNHEARD, ALSO PLACES A BURDEN ON THE COMMUNITY. LOSS OF OTHERWISE USEABLE PROPERTY, HEAVY MAINTENANCE COSTS OR, AT BEST, EXTREMELY HIGH CAPITAL COSTS, ARE THE PRICES THAT MUST BE PAID FOR THE SYSTEM THAT THE (SOMETIMES) NON-USER WOULD CONSIDER PERFECT.

AN INTOLERABLE SYSTEM GUARANTEES ALL OF THE EVILS THAT ANY COMMUNITY WOULD HOPE TO AVOID. AN INTOLERABLE SYSTEM WILL FORCE BLIGHT, SLUMS, AN IRRESPONSIBLE LAND USE PATTERN INCONSISTENT WITH PRESENT USAGE, AND DEPRECIATIONS IN VALUE THAT COULD BE CONFISCATORY.

THE PROBLEM, THEN, IS TO EVOLVE A RAPID TRANSIT TECHNIQUE THAT WILL:

A. SERVE THE RIDERS' NEEDS,

B. PRESERVE OR ENHANCE (BUT NEVER DETERIORATE) THE AREA SERVED, AND

C. DO SO WITH A CAPITAL EXPENDITURE COMMENSURATE WITH OR BETTER THAN OTHER TRAVEL MODES.

THE CRITERIA IMPORTANT FROM THE RIDER'S STANDPOINT ARE <u>INTERNAL</u> AND MOST CLOSELY ASSOCIATED WITH THE ENGINEERING ASPECTS OF A TRANSIT SYSTEM.

THE CRITERIA IMPORTANT, FROM THE STANDPOINT OF THOSE WHO FIND THEMSELVES NEAR THE SYSTEM AT SOME TIME DURING THEIR DAY OR NIGHT, ARE EXTERNAL AND CLOSEST ASSOCIATED WITH PLANNING. THESE ARE OUR PRIMARY CONCERN HERE.

- - - - - - - - - -

IMAGINE, FOR A MOMENT, A HIGH-SPEED VEHICLE, TRAVELLING 75 TO 80 MILES PER HOUR, ACCELERATING OR BRAKING, STOPPED AT A STATION FOR 20 SECONDS OR LESS AND THEN STARTING THE CYCLE OF GAINING SPEED, MAINTAINING THE MAXIMUM AND THEN BRAKING FOR THE NEXT STATION STOP. THE VEHICLE WILL NOT BE SMALL. ALTHOUGH IT COULD, THEORETICALLY, RANGE IN SIZE FROM THE BULK OF A PRIVATE AUTO TO THE BULK OF A SUBURBAN DUO-RAIL TRAIN, ASSUME FOR A MOMENT THREE TRANSCONTINENTAL BUSES COUPLED TOGETHER, ACCELERATING RAPIDLY TO REACH 75 MPH SPEEDS, MAINTAINING THIS SPEED FOR A BRIEF PERIOD AND THEN DECELERATING TO A DEAD STOP EVERY TWO OR THREE MILES.

A CONVEYANCE TRAVELLING IN THIS MANNER CREATES THESE SITUATIONS:

1. NOISE

THE NOISE CREATED HAS THREE SOURCES: FROM THE ENGINE, MOTOR, AND/OR OTHER MOVING PARTS WITHIN THE VEHICLE; FROM THE POINT OF CONTACT BETWEEN VEHICLE AND ITS STATIONARY SUPPORT; AND FROM THE TURBULENCE CREATED BY THE VEHICLE'S PASSAGE THROUGH THE AIR. ALL THREE OF THESE SOURCES ARE SUBJECT TO SOPHISTICATION IN DESIGN SO THAT MINIMUMS CAN BE OBTAINED. BUT NO MATTER HOW SOPHISTICATED THE DESIGN MIGHT BE, THE TOTAL ELIMINATION OF NOISE IS NOT YET POSSIBLE. WE ASSUME NOISE AS A MAJOR FACTOR, WHETHER IT BE THE

THE HIGH WHINE OF A SLIP STREAM OR THE LOW RUMBLE OF A HEAVY CAR ON A SOLID SUPPORT.

2. <u>PHYSIOLOGICAL DISTURBANCE</u>

ALTHOUGH NOISE REALLY FALLS INTO THIS CATEGORY, WE HERE PLACE EMPHASIS ON THE VISUAL AND EMOTIONAL IMPACT OF A MASS TRAVELLING AT HIGH SPEED IN AN INCONGRUOUS SETTING. TO TAKE TWO EXTREMES, THERE IS LITTLE PHYSIOLOGICAL DISTURBANCE WHEN A CAR TRAVELLING 75 MPH RUNS PARALLEL WITH A RAILROAD TRACK CONTAINING A TRAIN RUNNING 75 MPH IN THE SAME DIRECTION. TO BE SURE, THE LATENT OR NOT SO LATENT TENDENCY TO RACE IS THERE BUT THE RELATIVE SPEED IS ZERO; LITTLE RECOGNITION IS GIVEN TO SOUND AND AIR TURBULENCE IS LEFT BEHIND.

BUT LET THIS SAME TRAIN CURVE OFF AND ENTER AN OTHERWISE QUIET RESIDENTIAL AREA. THE RESIDENTS THERE EXPERIENCE AN ENTIRELY DIFFERENT SITUATION THAN THE HIGHWAY DRIVER. REACTIONS WITHIN THE RESIDENTIAL AREA WILL VARY FROM A CURSORY TIME CHECK TO OUTRAGE WITH REDFACED INDIGNATION AS THE NORM.

THE PHYSIOLOGICAL DISTURBANCES ARE FOUR IN NUMBER, EXCLUDING NOISE WHICH HAS BEEN GIVEN A SEPARATE CATEGORY.

A. VISUAL DISTURBANCE AND DISTRACTION. NO HIGH-SPEED VISUAL OBJECT CAN MOVE THROUGH A CONE OF VISION WITHOUT REPERCUSSIONS. THE CLOSER ONE IS, THE MORE VIOLENT THE REPERCUSSIONS. THE PEDESTRIAN, THE WORKER, THE HOUSEWIFE, THE DRIVER OR THOSE AT PLAY ARE ALL AFFECTED AND, MOST, NOT BENEFICIALLY.

B. AIR TURBULENCE IS AS PHYSICAL AS IT IS PHYSIOLOGICAL. PROXIMITY TO A HIGH-SPEED OBJECT SUBJECTS PEOPLE TO A TUGGING AND PULLING ON CLOTHING, SKIN AND HAIR THAT IS, AT BEST, UNPLEASANT, AND THE TAIL END VACUUM IS CAPABLE OF PULLING AN AUTOMOBILE OUT OF ITS DICTATED PATH. THE MAN ON FOOT, IF HE HAS GONE THROUGH A "CLOSE-IN" RELATIONSHIP, STANDS WELL BACK AND BRACES SOLIDLY.

C. VIBRATION, THOUGH USUALLY ACCOMPANIED BY NOISE, IS SOMETIMES TOO SUBTLE TO "HEAR" EVEN THOUGH IT CAN BE "FELT." THE DEEP, INAUDIBLE RUMBLE THAT MIGHT RESULT FROM A TRANSIT CAR'S MOVEMENTS IS LIKELY TO BE OFTEN MISINTERPRETED IN THIS EARTHQUAKE-CONSCIOUS AREA. EVEN IF THE SOURCE WERE UNDERSTOOD, THE OBJECTION TO GENTLE DISH RATTLING, IF NOT FLOOR SHAKING, REMAINS.

D. EMOTIONAL RATHER THAN PHYSIOLOGICAL, TO BE SURE, BUT THE NAGGING FEAR THAT A CHILD OR SOMEONE INCAPACITATED MIGHT INADVERTENTLY WANDER INTO TROUBLE, NO MATTER WHAT SAFETY PRECAUTIONS EXIST, WOULD BE ALWAYS PRESENT. ALTHOUGH MORE SAFETY COULD BE BUILT INTO ANY TRANSIT SYSTEM THAN EVEN OUR NEIGHBORHOOD STREETS NOW OFFER, THE SPEED, THE SIZE, AND THE AGGRESSIVELY MECHANICAL NATURE OF A RAPID TRANSIT SYSTEM WOULD BE A CONSTANT SOURCE OF WORRY TO MANY.

3. PHYSICAL INTERFERENCES are factors that must be reckoned with. Even though these interferences can be minimized or solved, the cost in so doing is great and, again, as with sound, visual distraction, vibration, air turbulence and the worry caused by the presence of real or imagined danger, compromises must be sought.

A. Traffic

In order to achieve the mandatory speeds, no grade crossings can be tolerated. This means that either a grade separation must be constructed or that the surface street system be interrupted wherever a conflict exists. Grade separations are costly and street or sidewalk interruptions can emasculate or revitalize an area depending on the location of the interruption.

The most careful attention must be given to general and internal traffic flow if large areas are not to be stagnated by lack of access and egress and if solid neighborhoodsor integral developments are not be be mangled and deprived of their strength that comes mainly from identification and self-sufficiency.

B. Utilities

This metropolitan area's utilities are sub-surface (water, gas, oil, sewer, storm drain), surface (drainage), and overhead (electricity and telephone). The elevated, depressed or surface installation of rapid transit lines would interfere, to some degree, no matter where located, with the incredibly complex service systems of the city. Assuming some interference as obligatory, it is the extent

OF THIS INTERFERENCE THAT BECOMES A FACTOR. VERTICAL FLEXIBILITY--THE ABILITY OF A TRANSIT SYSTEM TO GO BELOW GRADE, ON SURFACE, OR OVERHEAD--WOULD BE A TREMENDOUS ASSET IN THIS REGARD; JUST AS THIS SAME FLEXIBILITY WOULD GREATLY ASSIST THE TRAFFIC SOLUTIONS.

4. ESTHETIC CONSIDERATIONS SHOULD BE RELATED TO THE APPEARANCE OF THE STRUCTURE, PARK STRIP, CUT OR OTHER TREATMENT OF THE LINE, THE EXTERNAL APPEARANCE OF THE CONVEYANCES PROPER AND THE STATION STRUCTURE AND GROUNDS. THE HIGH LEVEL OF INDUSTRIAL DESIGN ALREADY ACHIEVED IN THIS COUNTRY SHOULD MINIMIZE ANYONE'S CONCERN WITH THE EXTERNAL APPEARANCE OF THE CONVEYANCES. THE STATIONS ARE AN ARCHITECTURAL PROBLEM NOT ESPECIALLY UNIQUE AND, THOUGH THEY WILL REQUIRE IMAGINATIVE AND SENSITIVE HANDLING, THERE IS NO MAJOR CONCERN FROM A PLANNING STANDPOINT. IT IS THE TREATMENT OF THE LINE ITSELF THAT WILL HAVE THE GREATEST IMPACT ON THE COMMUNITY.

THE MOST UNOBTRUSIVE LOCATION FOR A LINE IS UNDERGROUND AND IF IT IS SO LOCATED, NO EXTERNAL PROBLEMS EXIST. THE MAXIMUM VISUAL PROBLEM WILL EXIST IF THE LINE IS OVERHEAD. THE SURFACE LINE WOULD PRESENT THE PROBLEM OF NEXT MAGNITUDE AND THE OPEN CUT OR COMBINATION SECTION OF CUT AND EARTH-FILL BERM WOULD BEGIN TO APPROACH THE SUBWAY MINIMUM.

IN THIS LOW DENSITY CITY OF OURS, THE OVERHEAD OR ELEVATED LINE, WHETHER CARS RIDE ATOP IT OR ARE SLUNG BELOW IT, RAISES A VERY SERIOUS DESIGN PROBLEM. WE MUST BE REALISTIC ABOUT THE SIZE OF THE SUPPORTING STRUCTURE. IT IS NOT GOING TO BE A DELICATE WEB STRETCHED LACE-LIKE THROUGH THE CORRIDOR. IT IS GOING TO BE A STRUCTURE DESIGNED TO CARRY

HIGH-SPEED CARS ACCELERATING AND DECELERATING ON HORIZONTAL AND VERTICAL CURVES WITH A BUILT-IN STRUCTURAL SAFETY FACTOR. LONG SPANS ARE GOING TO BE REQUIRED IN MANY PLACES AND BECAUSE ONLY THE MINIMUM DEFLECTION CAN BE TOLERATED, BEAM DEPTHS WILL BE GREAT. SIDE SWAY WOULD BE DANGEROUS AS WELL AS UNPLEASANT, SO HORIZONTAL STABILITY MUST BE INSURED. NO MATTER HOW INGENIOUS THE STRUCTURAL DESIGN, ANY OVERHEAD STRUCTURE WILL VISUALLY DOMINATE MOST OF THE CITY-SCAPE THAT IT PASSES THROUGH.

THE OPEN CUT OR SEMI-CUT AND EARTH BERM PRESENT SOME ESTHETIC PROBLEMS BUT THESE ARE LIMITED TO LOW SCREENING TECHNIQUES AND EMBANKMENT TREATMENTS. BECAUSE THE LINE IS BELOW GROUND EYE LEVEL, SUPER DOMINANCE OF THE CITY-SCAPE WILL NOT OCCUR, GENERALLY, BUT WILL OCCUR TO A LIMITED DEGREE IN THE SINGLE-FAMILY, SMALL-SCALE ENVIRONMENTS.

A SURFACE LINE WILL DEMAND THAT ESTHETIC CONSIDERATION BE GIVEN TO ITS PROTECTIVE FENCING BUT OTHERWISE, <u>AS A LINE</u>, WOULD BE UNOBTRUSIVE. HOWEVER, WHENEVER A CONVEYANCE USES THE LINE (AND THEY MIGHT, DURING RUSH HOURS, BE PASSING EVERY 90 SECONDS EACH WAY), THE SITUATION WORSENS APPRECIABLY. THIS FACTOR WAS DISCUSSED UNDER "VISUAL DISTURBANCE" BUT IF ANY CORRECTIVE MEASURES ARE TAKEN TO LESSEN "VISUAL DISTURBANCE," THEN THE ESTHETIC PROBLEM GAINS IN MAGNITUDE RANGING FROM A LANDSCAPED SCREEN TO A VERITABLE CHINESE WALL.

ONLY THE SUBWAY CAN ELIMINATE THE ESTHETIC CONSIDERATIONS OF THE LINE PROPER.

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IN SUMMARY, WE BELIEVE THESE TO BE THE FACTORS HAVING GREATEST INFLUENCE ON THE RAPID TRANSIT SYSTEM'S ACCEPTANCE BY THE COMMUNITY--FROM AN EXTERNAL STANDPOINT:

NOISE

VISUAL DISTURBANCE

AIR TURBULENCE

VIBRATION

DANGER

TRAFFIC INTERFERENCE

NEIGHBORHOOD DISRUPTION

UTILITY INTERFERENCE

ESTHETICS

THERE ARE 3 VERTICAL LOCATIONS FOR A RAPID TRANSIT LINE:

SURFACE (OWN RIGHT-OF-WAY WITH GRADE SEPARATIONS)

OVERHEAD (SUSPENDED OR SUPPORTED)

BELOW GRADE (SUBWAY OR OPEN CUT)

FROM A STRICT PLANNING STANDPOINT IT IS NOT TOO SIGNIFICANT WHAT TYPE OF CONVEYANCE IS EMPLOYED - ONE RAIL, TWO RAILS, SUPPORTED, SUSPENDED, SELF-PROPELLED BUSES OR "TRAINS" OF BUSES. MORE IMPORTANT FROM AN EXTERNAL POINT OF VIEW IS THE LOCATION OF THE SYSTEM VERTICALLY OR HORIZONTALLY, I.E., ABOVE, BELOW, OR ON SURFACE AND THROUGH OR BESIDE A GIVEN LAND USE AREA.

ALTHOUGH EACH LAND USE AREA HAS DIFFERENT TOLERANCE LEVELS UPON WHICH AN ACCEPTANCE OF A SYSTEM CAN BE BASED, THESE USES MAY BE BROADLY CLASSIFIED INTO SIX TYPES:

TYPE 1 - OPEN LAND - PRIVATE AND PUBLIC.

SUCH AS WATERSHED OR FLOOD CONTROL AREAS, PARKS, PRESERVES, AGRICULTURAL, MILITARY, RECREATIONAL AREAS, EXCESSIVE SLOPE LANDS, ETC.

TYPE 2 - RIGHTS-OF-WAY, EASEMENTS, AND TRANSPORTATION LANDS.

SUCH AS FREEWAYS, RAILROADS, UTILITY EASEMENTS, STREETS AND BOULEVARDS, AIRPORTS AND AIR APPROACH ZONES, ETC.

TYPE 3 - RESIDENTIAL LANDS.

SEMI-OPEN OR POTENTIAL RESIDENTIAL; LOW, MEDIUM AND HIGH DENSITY AND TRANSIENT RESIDENTIAL (HOTELS, MOTELS, TRAILER PARKS, ETC.)

Type 4 - Commercial lands.

Retail, offices, services, commercial recreation, eating and drinking; with sub categories for each into high and low productivity.

Type 5 - Institutional lands.

Such as hospitals, schools and universities, churches, clubs, cemeteries, clinics, etc.

Type 6 - Industrial lands.

Heavy and light industry, research and development, wholesale and warehousing; each with a sub category of high and low density of employment.

Each of these six categories must be considered as permanent or transitional in character and when applying transit acceptance criteria to them, the next most potential use must be the guide. Sometimes the transitional character can be determined by actual happenings within an area; other locations may be primed for a change by neighboring conditions: or a long-range master plan not yet implemented may be the deciding factor. In any event, and no matter what the reason, the transit criteria must anticipate - not lag behind.

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The vertical location of a system has a strong bearing on the factors affecting community acceptance. Considering each in turn:

A SURFACE SYSTEM. If we assume grade separations as a mandatory requirement, traffic interference is eliminated as a consideration, but noise,

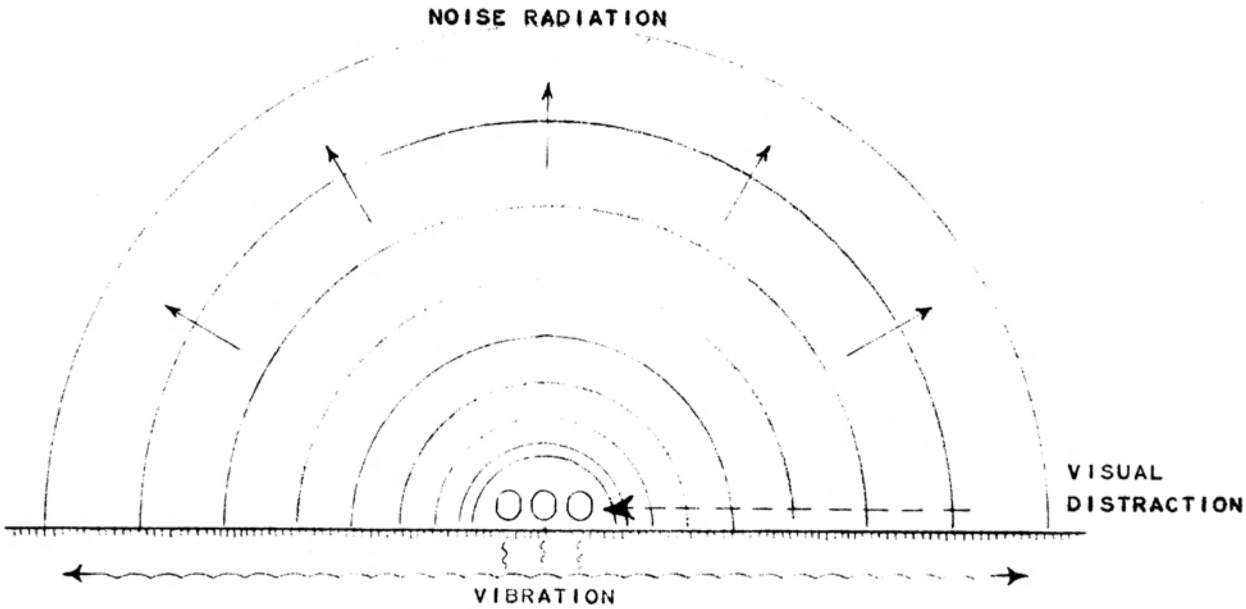
VISUAL DISTRACTION, TURBULENCE, VIBRATION, DANGER, UTILITIES INTERFERENCE AND ESTHETICS REMAIN. WHEREVER OR WHENEVER PEOPLE ARE PLACED IN PROXIMITY TO A SURFACE SYSTEM, PROTECTIVE AND BUFFERING DEVICES ARE MANDATORY. THE EXTENT OF THESE DEVICES MAY RANGE FROM SIMPLE PROTECTIVE FENCING THROUGH ELABORATE LANDSCAPED BUFFERS. WHEN CAREFULLY DESIGNED, THESE DEVICES CAN PARTIALLY OR WHOLLY OVERCOME ALL OF THE FACTORS RELATING TO COMMUNITY ACCEPTANCE BUT THE RIGHT-OF-WAY REQUIRED PLUS THE CAPITAL AND MAINTENANCE COSTS OF THE BUFFERS WILL, IN MOST CASES, OFFSET THE SAVINGS IN LINE INSTALLATION COSTS. SINCE A SURFACE SYSTEM CAN BE MADE ACCEPTABLE, THE DECISION REGARDING ITS USE CAN BE BASED MAINLY ON ECONOMICS.

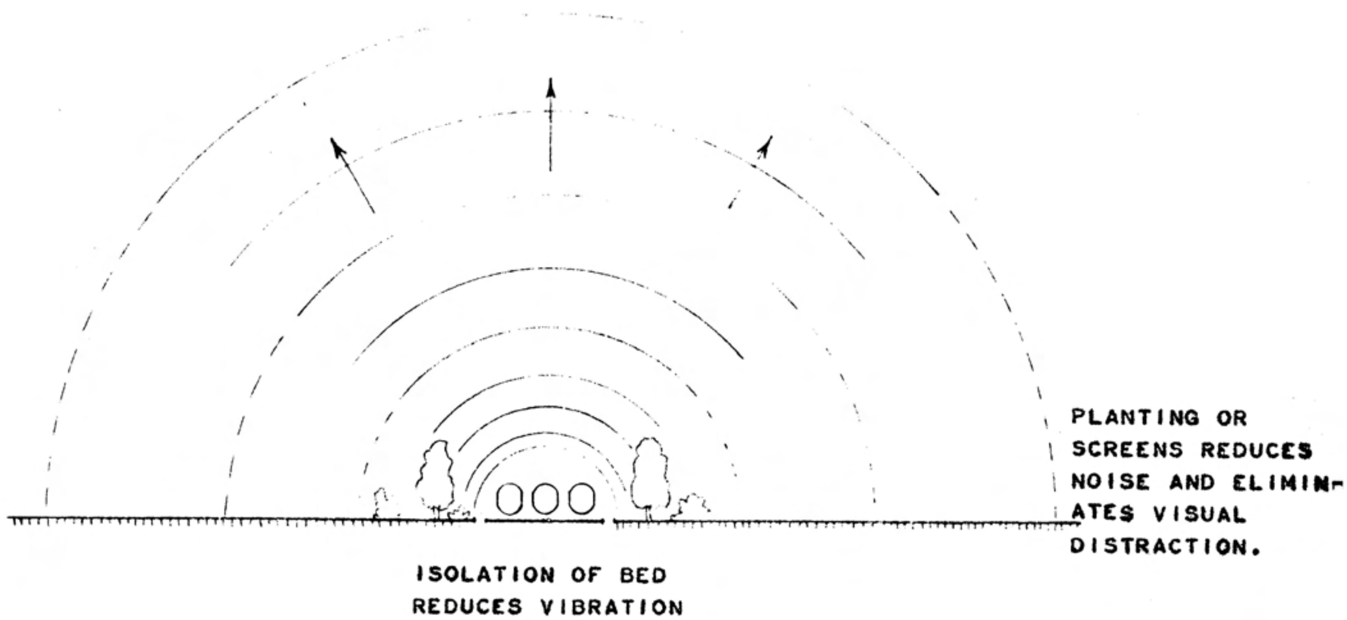
IN OPEN AREAS (TYPE 1, SEE P. 10), THE DISTURBANCES RESULTING FROM A SURFACE INSTALLATION ARE OF A LOW ORDER AND RELATIVELY CHEAP TO OVERCOME. PROTECTIVE FENCING AND LANDSCAPED BUFFERS AT CRITICAL POINTS WITH GRADE SEPARATIONS AT NECESSARY INTERSECTIONS WILL SUFFICE. RIGHTS-OF-WAY CAN BE HELD TO A MINIMUM. UTILITIES INTERFERENCE IS PRACTICALLY NON-EXISTENT.

AS THE TRANSIT SYSTEM LEAVES AN OPEN LAND AREA AND ENTERS AN AREA MORE DENSELY POPULATED, CONDITIONS CHANGE GREATLY EVEN IF THE AREA IS OCCUPIED MAINLY BY A TEMPORARY OR TRANSIENT POPULATION. SUCH IS THE CASE WITH RIGHTS-OF-WAY, EASEMENTS AND TRANSPORTATION LANDS (SEE TYPE 2, P. 10).

IN THIS TYPE OF LAND, THE TRANSIT SYSTEM FACES TWO CRITICAL PROBLEMS - THE FREQUENCY OF REQUIRED GRADE SEPARATIONS AND THE VISUAL DISTRACTIONS CAUSED BY THE HIGH SPEED OF THE TRANSIT CONVEYANCES. A SURFACE INSTALLATION CANNOT, ECONOMICALLY, SOLVE THESE TWO PROBLEMS. HOWEVER,

SURFACE SYSTEM





WHEN A SECTION OF LINE IS FREED OF THE NECESSITY FOR TRAFFIC SEPARATIONS AND IS NOT IN CLOSE PROXIMITY TO PEOPLE, A SURFACE SYSTEM IS THE IDEAL. THIS MIGHT WELL BE THE CASE WITH LINES ADJACENT TO FLOOD CONTROL CHANNELS, WITHIN WIDE UTILITY EASEMENTS AND LINES BORDERING AIRPORTS. BUT IT IS DOUBTFUL THAT FREEWAYS - BECAUSE OF TRAFFIC INTERFERENCE AND TO SOME EXTENT, VISUAL DISTRACTION - COULD EMPLOY A SURFACE INSTALLATION.

UTILITY EASEMENTS AND RAILROAD LINES QUITE OFTEN EXTEND THROUGH POPULATED AREAS. WHENEVER THIS IS THE CASE, ALL OF THE ADDITIONAL FACTORS - NOISE, VIBRATION, TURBULENCE, ETC. - COME INTO PLAY AND WILL BE SO DIFFICULT TO OVERCOME THAT IT IS DOUBTFUL A SURFACE LINE WILL BE PRACTICABLE.

A SURFACE LINE THROUGH RESIDENTIAL AREAS WOULD ACCENTUATE ALL OF THE DISRUPTIVE ELEMENTS OF THE LINE. EVEN WITH EXTENSIVE BUFFER STRIPS, NOISE WILL REMAIN AS A MAJOR PROBLEM INADEQUATELY SOLVED BY PLANTING.

IN COMMERCIAL LANDS, TRAFFIC INTERFERENCE WILL BE THE DOMINANT PROBLEM AND ONE SO DIFFICULT TO SOLVE AS TO RULE OUT A SURFACE LINE.

A SURFACE SYSTEM IN INSTITUTIONAL LANDS FACES ALL OF THE FACTORS INVOLVED IN RESIDENTIAL LANDS AND IS THEREFORE NOT FEASIBLE IN THIS LOCATION.

IN INDUSTRIAL LANDS, HOWEVER, A SURFACE LINE WOULD BE ACCEPTABLE IN HEAVY INDUSTRIAL ZONES AND WITH SOME LIMITATIONS, IN LIGHT INDUSTRIAL ZONES. IN RESEARCH AND DEVELOPMENT AREAS, NOISE AND VIBRATION ARE

PERTINENT FACTORS AND A SURFACE INSTALLATION WOULD NOT BE PRACTICABLE IN VIEW OF THE MASSIVE BUFFERING THAT WOULD BE REQUIRED.

GENERALLY SPEAKING, THE SURFACE LINE, EVEN THOUGH IT ENJOYS CERTAIN ADVANTAGES RELATED TO ECONOMY, AIR TURBULENCE, VIBRATION ESTHETICS, AND UTILITY INTERFERENCE, AND EVEN THOUGH ITS VISUAL DISTRACTION CAN BE SIMPLY SCREENED, IS LIMITED IN ITS APPLICATION TO OPEN, RELATIVELY UNINHABITED AREAS OR INDUSTRIAL AREAS WHERE TRAFFIC INTERFERENCES AND NOISE ARE NOT MAJOR CONSIDERATIONS.

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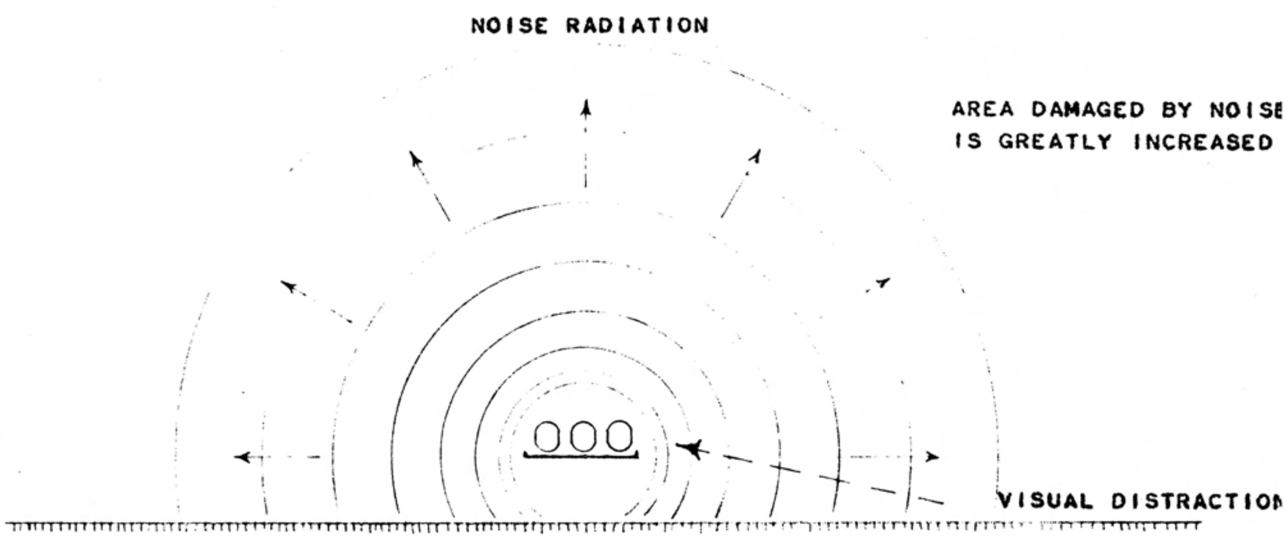
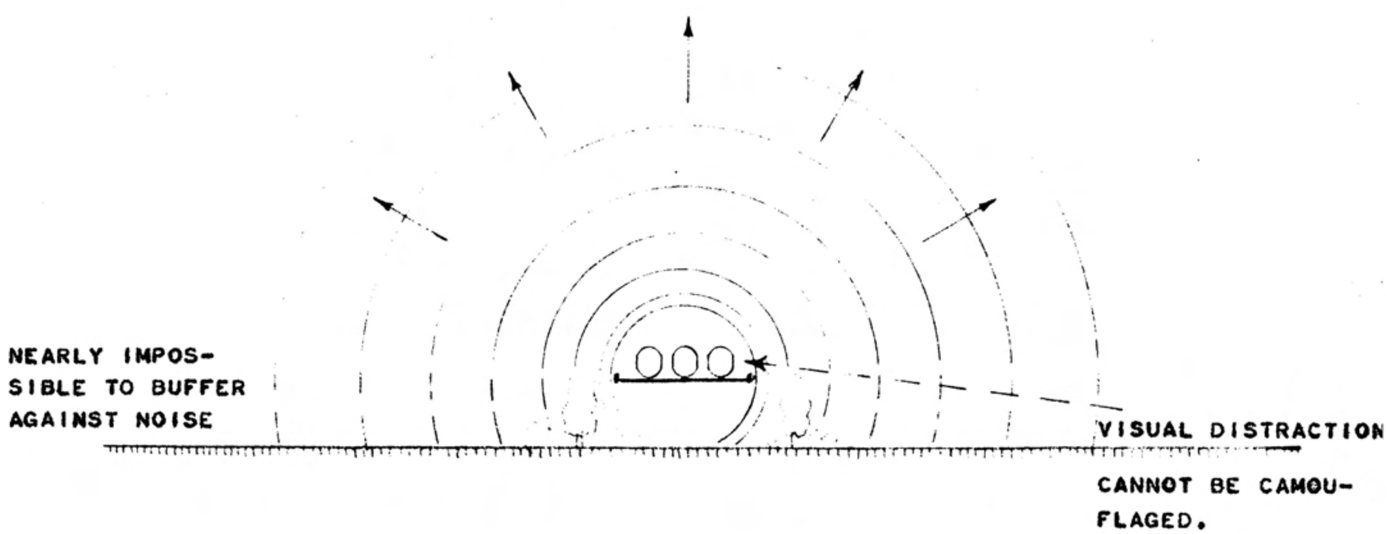
AN ELEVATED SYSTEM. A RAPID TRANSIT LINE CONSTRUCTED WITHIN AN OVERHEAD PLANE HAS TWO GREAT ADVANTAGES: IT MINIMIZES TRAFFIC INTERFERENCE AND THE INTERFERENCE WITH UTILITIES IS LIMITED TO OVERHEAD POWER AND TELEPHONE LINES PLUS, PERHAPS, AN OCCASIONAL CONFLICT AT THE FOUNDATION LEVEL. HOWEVER, ALL OTHER FACTORS PERTINENT TO COMMUNITY ACCEPTANCE ARE ADVERSELY AFFECTED AND IN THE EXTREME.

THE AREA DAMAGED BY NOISE IS GREATLY EXPANDED AND BECAUSE THIS NOISE HAS ITS SOURCE HIGH ABOVE GROUND, IT IS NEARLY IMPOSSIBLE TO BUFFER AGAINST. THE VISUAL DISTRACTION CAUSED BY A SPEEDING ELEVATED VEHICLE IS IMMENSE AND UNLESS HIGHLY EXPENSIVE SCREENING DEVICES ARE CONSTRUCTED, CANNOT BE CAMOUFLAGED. AIR TURBULENCE NEAR TO AND ESPECIALLY BENEATH THE MOVING CARS WILL BE INTENSE. VIBRATION WILL BE A MAJOR PROBLEM, AND, ESTHETICALLY, SUCH A MAJOR AERIAL INSTALLATION WILL SURELY DOMINATE MOST OF THE AREA IT PASSES THROUGH.

ELEVATED SYSTEM





BECAUSE OF THESE BASIC PROBLEMS, AN ELEVATED SYSTEM IS NEARLY AS LIMITED AS A SURFACE ROUTING. IT CAN BE USED IN OPEN AREAS, IN RIGHTS-OF-WAY (IN UNPOPULATED AREAS), IN ALL HEAVY AND SOME LIGHT INDUSTRIAL ZONES, AND COULD POSSIBLY BE USED ON COMMERCIAL AREAS IF SCREENED FOR VISUAL DISTURBANCE AND IF TRAIN SPEEDS WERE RADICALLY REDUCED TO LESSEN NOISE, TURBULENCE AND VIBRATION.

AN ELEVATED SYSTEM IS NOT APPLICABLE, GENERALLY, IN RESIDENTIAL, INSTITUTIONAL OR HIGH-PRODUCTIVITY COMMERCIAL AREAS.

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A BELOW-GRADE SYSTEM. A RAPID TRANSIT SYSTEM OPERATING ON A BELOW-GRADE LEVEL CAN ADOPT THREE BASIC SECTIONS:

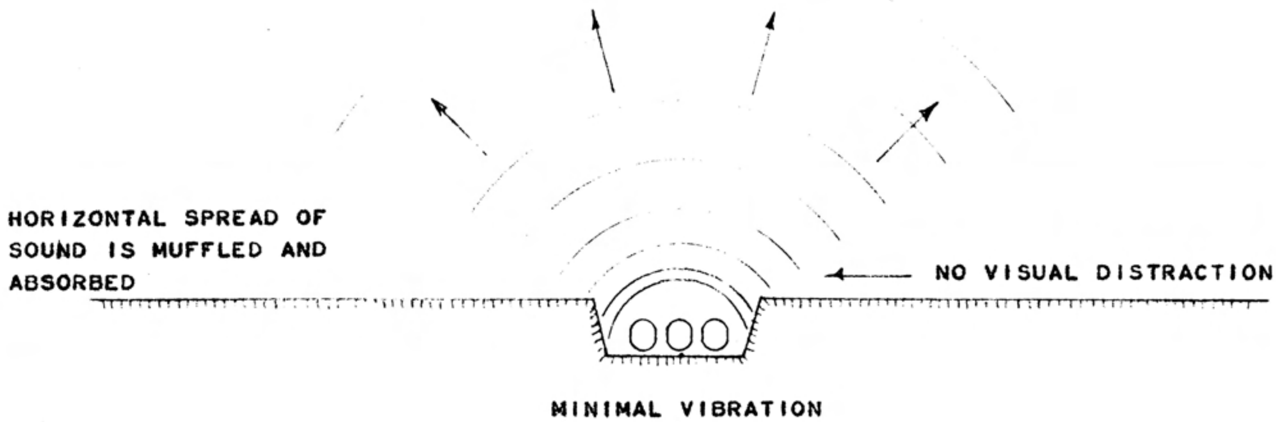
1. AN OPEN CUT WITH VERTICAL OR SLOPED BANKS,
2. A COMBINATION OF OPEN CUT WITH EARTH BERN FILLS AS SHOULDERS,
3. A SUBWAY.

THE OPEN CUT SECTIONS REQUIRE OVERPASSES FOR TRAFFIC SEPARATION AND UNDERGROUND UTILITIES INTERFERENCE WILL BE CONSIDERABLE. BUT A SYSTEM SO INSTALLED MINIMIZES OR ELIMINATES ALL OTHER PROBLEMS RELATED TO LAND USE AND COMMUNITY ACCEPTANCE. THE SUBWAY, THOUGH VERY COSTLY, TOTALLY ELIMINATES ALL FACTORS RELATING TO EXTERNAL ACCEPTANCE BUT UTILITY INTERFERENCE AND FOUNDATION PROBLEMS WILL BE CRITICAL.

THE OPEN CUT OR COMBINATION CUT AND FILL SECTION CAN BE USED IN ALL LAND AREAS WHERE:

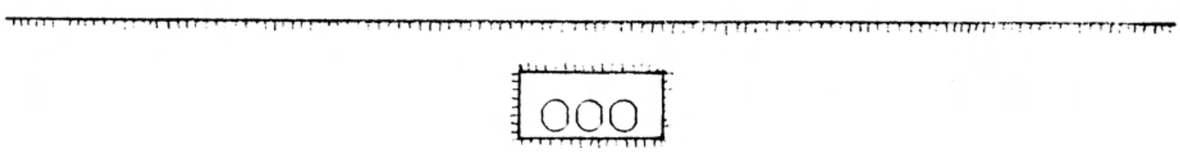
1. THE VERTICAL SPREAD OF NOISE CAN BE TOLERATED (WHERE NO NEARBY HIGH-RISE BUILDINGS EXIST),
2. ADEQUATE RIGHTS-OF-WAY CAN BE ACQUIRED WITHOUT NEIGHBORHOOD

OPEN CUT



SUBWAY

NOISE, VISUAL DISTRACTION AND VIBRATION ELIMINATED



OR COMMUNITY DISRUPTION (WHERE LINES CAN BE PLACED OUTSIDE OF INTEGRATED COMPLEXES OF URBAN OR SUBURBAN ACTIVITY),

3. UTILITY INTERFERENCES ARE NOT INSURMOUNTABLE.

THE OPEN CUT MUFFLES AND ABSORBS THE HORIZONTAL SPREAD OF SOUND. VISUAL DISTRACTION IS MINIMIZED TO A POINT BELOW OBJECTION. AIR TURBULENCE IS CONFINED TO THE CUT ITSELF. VIBRATION, IF PRESENT AT ALL, IS MINIMAL. SIMPLE, INEXPENSIVE PROTECTIVE FENCING AND SCREENING WILL ADEQUATELY SOLVE THE PROBLEMS OF SAFETY AND ESTHETICS.

WHEREVER THE LINE MUST PASS CLOSE TO HIGH-RISE BUILDINGS OR WHEREVER THE LINE MUST RASS THROUGH ACTIVITY COMPLEXES THAT WOULD BE CRIPPLED BY SEVERANCE, THEN THE FULL SUBWAY IS THE ONLY SECTION CAPABLE OF ATTAINING COMMUNITY ACCEPTANCE.

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BECAUSE OF THE VARYING LIMITATIONS IMPOSED BY DIFFERENT LAND USES, THE IDEAL RAPID TRANSIT SYSTEM FROM AN EXTERNAL STANDPOINT WOULD BE ONE FLEXIBLE ENOUGH TO RUN ON SURFACE WHERE ECONOMIC GAINS COULD BE MADE WITHOUT HARM TO THE COMMUNITY; RUN IN AN OPEN CUT THROUGH LOW DENSITY AREAS CONTAINING A PROPER ALIGNMENT; RUN ELEVATED OVER LOW AREAS OR OVER CRITICAL UTILITY LOCATIONS; AND RUN UNDERGROUND IN HIGH DENSITY AREAS OR AREAS THAT CANNOT BE BISECTED. THIS REQUIREMENT FOR FLEXIBILITY SHOULD BE ONE OF THE MAJOR CRITERIA USED IN THE SELECTION OF A SYSTEM.

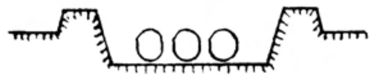
THE FOLLOWING CHART SUMMARIZES LAND USE REQUIREMENTS FOR COMMUNITY ACCEPTANCE:

OPEN AREAS. ANY VERTICAL SECTION (SURFACE, ELEVATED, OPEN CUT OR SUBWAY) GENERALLY ACCEPTABLE BUT SURFACE HAS LIMITATIONS, ELEVATED MAXIMIZES NOISE AND VISUAL DISTRACTION, SUBWAY UNNECESSARILY COSTLY.

IDEAL: OPEN CUT

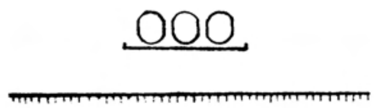
OR

CUT AND BERM



WHERE UTILITY INTERFERENCES ARE CRITICAL:
SURFACE WITH PLANTED BUFFERS

RESTRICTED TO LIMITED SPECIAL SITUATIONS SUCH AS GRADE CROSSINGS, BRIDGING, ETC.:
ELEVATED



RIGHTS OF WAY : EASEMENTS : TRANSPORTATION AREAS

IDEAL: ALONG FREEWAY SHOULDERS WITH SCREEN TO OVERCOME VISUAL DISTRACTION:

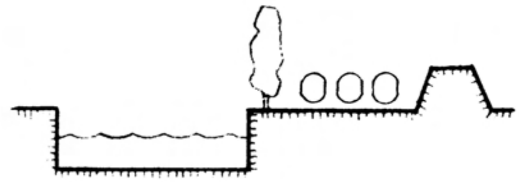
DEPRESSED FREEWAY

OR

ELEVATED FREEWAY

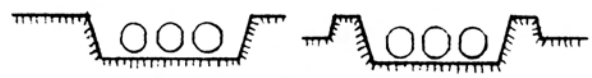
SAME SYSTEM CAN BE EMPLOYED BORDERING FLOOD CONTROL CHANNELS

USE EARTH BERM, BANK, SCREENS OR PLANTED BUFFERS WHERE REQUIRED



FOR UTILITY EASEMENTS WITH GREAT WIDTH:
SURFACE WITH LANDSCAPE BARRIER

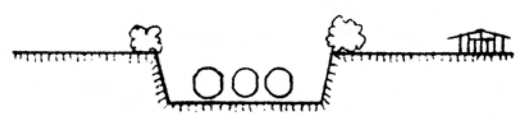
FOR LIMITED WIDTHS:
OPEN CUTS



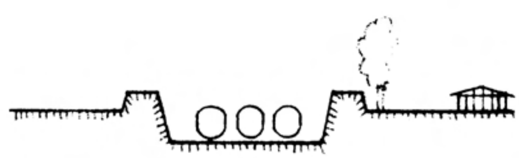
ELEVATED SYSTEMS EXTREMELY DIFFICULT TO SCREEN FOR VISUAL DISTRACTION, SUBWAYS HAVE UNNECESSARILY HIGH COSTS.

RESIDENTIAL AND INSTITUTIONAL AREAS

IDEAL: FOR LOW DENSITY RESIDENTIAL

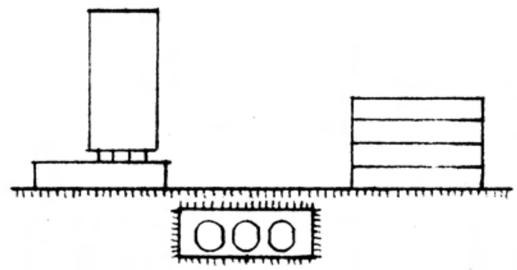


OPEN CUTS WITH LIMITED LANDSCAPE



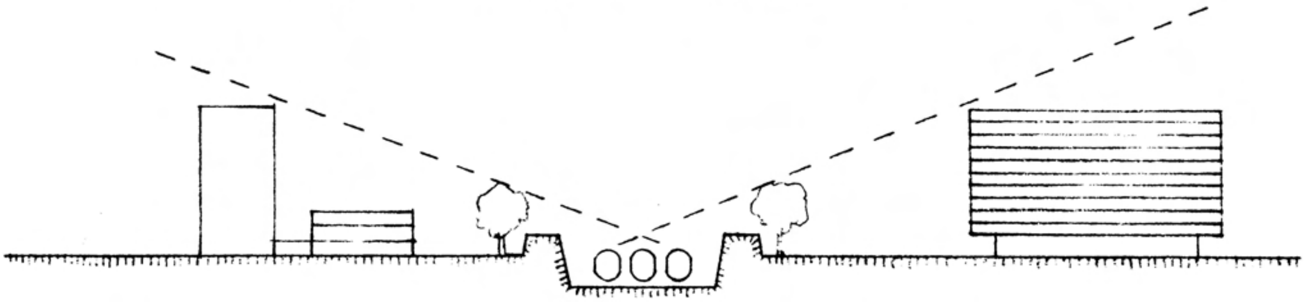
FOR HIGH DENSITY RESIDENTIAL:

SUBWAYS, WHEN BUILDINGS ARE IN CLOSE PROXIMITY



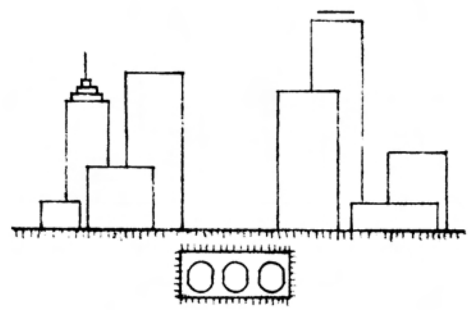
OR

OPEN, LANDSCAPED CUTS WHERE SETBACKS SUFFICIENT AND NEIGHBORHOOD INTEGRITY NOT DESTROYED.



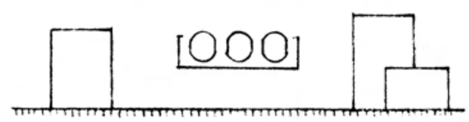
COMMERCIAL AREAS

IDEAL: SUBWAYS



FOR LIMITED APPLICATION WHEN TRANSIT SPEEDS ARE LOW, AREA IS NOT BISECTED AND SCREENING PROVIDED:

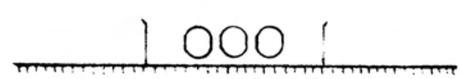
ELEVATED



INDUSTRIAL LANDS

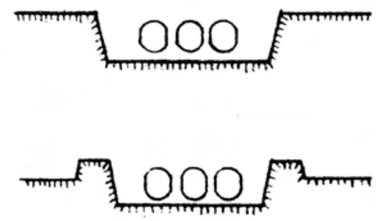
IDEAL: PROBABLY MOST ECONOMICAL AND ACCEPTABLE IN HEAVY INDUSTRIAL AREAS:

SURFACE



FOR LIGHT INDUSTRY, RESEARCH AND DEVELOPMENT:

OPEN CUTS



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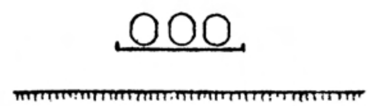
ELEVATED



APPENDIX E

GIBBS & HILL, INC.
CONSULTING ENGINEERS
DESIGNERS · CONSTRUCTORS
LOS ANGELES NEW YORK TAMPA

PENNSYLVANIA STATION
NEW YORK 1, N.Y.

January 28, 1960

Daniel, Mann, Johnson, & Mendenhall
3325 Wilshire Boulevard
Los Angeles 5, California

Gentlemen:

The recommendations, in regard to the forms of rapid transit justifying further detailed examination of their suitability for use in Los Angeles, resulting from your initial examination, have been discussed with Mr. Miller and other members of your staff. We are happy to state we are in full accord with the recommendations: namely, to further examine:

a. The conventional, two rail system;
b. A split-rail type of suspended monorail;
c. A supported form of monorail, frequently referred to as the saddlebag type.

Technically any of the above systems can be designed for acceptable operation. Excluded are several systems of technically doubtful desirability.

The final selection obviously involves questions of economic, as well as technical feasibility. Therefore, additional and more extensive examination than possible during the necessarily curtailed initial phase, is required to formulate the final recommendation for selection.

In order to save time, the discussions prepared by your staff of the following features have been reviewed in their draft form.

a. Electric power applications to rapid transit trains;

b. Automatic train operation and signals.

Again we are in substantial agreement. Some relatively minor questions, and points of degree of emphasis have subsequently been discussed with members of your staff and mutual concurrence reached.

We are happy to have been of assistance to you, and feel a forward step toward realization of rapid transit for Los Angeles has been accomplished.

Very truly yours,

GIBBS & HILL, Inc.

R. L. Kimball

R. L. Kimball
Consulting Electrical Engineer

RLK:kt

LOS ANGELES METROPOLITAN TRANSIT AUTHORITY

RAPID TRANSIT PROGRAM

APPENDIX E

CRITERIA FOR RAPID TRANSIT
SIGNALLING AND AUTOMATIC OPERATION SYSTEM

PREPARED FOR

DANIEL, MANN, JOHNSON, & MENDENHALL

JANUARY 14, 1960

BY

GIBBS & HILL, INC.

CONSULTING ENGINEERS

A. Introduction

Railroad signalling systems have been developed to provide a high degree of safety. The function to provide visual information to the train motorman, enabling him manually to operate the train safely. Certain automatic features have been added to override the manual control and slow or stop the train under certain unsafe conditions. Centralized traffic control, operating in conjunction with the signal system, has been developed which enables a central dispatcher to provide the train motorman with additional information in order to expedite traffic movements.

When automatic train operation is considered, the first requirement is a definition of what is to be accomplished. The system should automatically start the train, accelerate it to the proper speed, maintain the proper speeds over the various parts of the run, decelerate and stop the train at the desired point. All these things should be accomplished to the proper degree and at the proper time; and should be coordinated safely with the activities of other trains. Auxiliary functions such as door opening and closing may also be performed automatically.

In short, automatic train operation is the control of the location of a train with respect to time. In the final analysis, a desired or actual schedule is simply a statement of the location of a given train at various times of day. Thus the parameters of the problem are location, identity and time.

In mathematical language, the location of train "a" is a function of time, where the function is unique to train "a", or $L_a = f_a(t)$.

The speed of train "a" is the first derivative of L with respect to time, or the rate of change of its location with respect to time. Acceleration, or deceleration, is the first derivative of speed with respect to time or the rate of change of speed with respect to time.

In order to fulfil the requirements stated above for automatic train operation, that is, starting, acceleration, speed control, deceleration and stopping at a particular point, all the information required is a continuous, or practically continuous, indication of the location of the train and an expression of the desired schedule, speed restrictions and stopping points. A system should, and can, be designed to control the train accurately and smoothly in accordance with the desired performance. Such a system is known as a closed-loop control system, because it detects actual performance, compares the actual to the intended performance, evaluates the error or deviation and takes corrective action.

Such a system can be designed to handle many trains, safely coordinated, and can be made "fail-safe," economic and practical. It cannot, however, utilize, to its own best advantage, the relatively inaccurate location data derived from track circuit blocks, such as are used in conventional railroad signalling systems. Any system using block location data would require auxiliary equipment to measure speed and acceleration during shorter intervals than required to traverse a block.

It would, moreover, require greater practical headway margins, to compensate for the relative location inaccuracy of the block system. Operation by such a system would be inherently less flexible and relatively too intermittent for satisfactory control action.

B. Design Criteria

1. General

A properly designed signalling and automatic train operating system should provide the safety functions of a conventional signalling system, including the latter's "fail-safe" character. It should also provide automatic operation in a manner to facilitate optimum use of fixed facilities and rolling equipment, together with information for the motorman's guidance in case of emergency manual operation.

The first cost of such a system should be as low as possible in view of present day capital charges and taxes. Its maintenance cost should be kept low, by minimizing the amount of complex equipment installed along the wayside.

The system should obviously be "fail-safe," but should be so designed and constructed as to minimize failures. The use of modern, solid-state devices should be required in order to achieve fewer failures and to facilitate fast, easy replacement.

2. Specific

a. <u>Control for Automatic Train Operation</u>

The system should perform the functions of starting, running and stopping a train by utilizing the basic principles of closed-loop, negative feedback control. A minimum of apparatus should be used aboard the train and along the wayside. The apparatus aboard the train should be portable, insofar as possible, in order to minimize duplication in each car and to allow a high degree of bench maintenance in the shops.

In order to coordinate traffic flow automatically, and to minimize car-borne and wayside apparatus, data should be gathered from the trains, delivered to a central point where automatic control instructions should be developed by high speed, self-checking data handling and logic apparatus, and delivered to the trains over a facility similar to, if not identical with, the data gathering medium. For a large system, several data centers might be required, all to be supervised from a single coordinating central location.

The automatic control should provide for starting, any degree of acceleration and speed regulation available from the car equipment, and braking decelerations of any desired degree attainable.

The precision of the control should be sufficient to operate trains on 90 seconds headway, or less if desirable. The system should be able to determine safe braking distances as a function of the speed of the train in question, the speed and location of the rear end of the train ahead, route conditions and any other conditions desired, such as absolute minimum headways dictated by other than operating considerations.

The data gathered from each train should include the train's identity, and the location of each end of the train within an error of accuracy no greater than 10 feet. The control instructions delivered to the train should provide all necessary information to cause the on-board signal and control apparatus as provided, to respond in the desired manner. The transmissions to and from the train should take place often enough to insure smooth, safe operation. A typical installation would require one two-way transmission approximately every three seconds. All data should be transmitted by self-checking binary digital codes. Any failure of the system for a given train should cause that train to come to a smooth, controlled deceleration stop.

The central office logic system should space the trains, arrange siding passes and meets, and perform other safety functions to at least the same degree as is possible with a conventional signalling system. The transmissions to each train should include, in addition to automatic control instructions, data to operate a cab signal, the latter for guidance of a man in case manual operation becomes necessary.

Presently developed, modern car equipment should require only minor modification of its control apparatus in order to execute the automatic operation instructions successfully. Such a criterion is entirely feasible.

b. Manual Train Operation

The system should operate a cab signal to provide information for the motorman to override the automatic operation and operate the train in the conventional manual manner. Voice communication, between the motorman and the dispatcher and other points if justified, should be provided.

Failure of the of the train-borne automatic control, but not the cab signal, should sound an alarm indicating to the motorman that he should assume manual control of the train. If he fails to do so within a certain time, the train should automatically stop. If the cab signal alone fails, an alarm should indicate the failure to the motorman. If both the cab signal and the automatic control fail, the train should stop automatically.

c. Central Office Facilities

The entire signalling and automatic operation system should be supervised from a single central office. All data handling and logic, or decision making, apparatus should be located at the central office, except for very large systems where several data handling and logic apparatus subcenters might be required. The subcenters, however, would then be under the supervision and control of a central office.

All data handling and logic apparatus should be high speed, self-checking, solid-state computer facilities provided with adequate standby and arranged for "fail-safe" operation.

A dispatcher's display board should be provided showing the identity and current location of all trains. Further information displays should be provided, as required, such as switch positions, speed of any selected train or trains, concentrations of passengers at a station, etc. Provision should be made to record data, as required, on magnetic tape or by automatic print-out for current or later use.

Provisions for computer analysis of operations should be made to facilitate the preparation of new schedules or schedule revisions and refinements. The dispatcher should have manual override control of the central office apparatus and should be able to add or remove trains when necessary, and to rely on the apparatus to adjust traffic automatically to accommodate the change.

d. Auxiliary Automatic Features

Additional automatic features should be provided as required. A partial list is as follows:

(1) Control and position indication of track switches, including interlockings.

(2) Train spotting in stations.

(3) Door opening and closing.

(4) Train annunciators at stations using either visual or voice or both.

C. Conclusions

It is entirely feasible to provide a signalling and automatic train operation system, using available advanced techniques and components, that will provide for the smooth, flexible, safe and efficient performance of a truly modern rapid transit installation.

It is believed that further study will show that such a system would provide better performance, and be more economical to install and operate, than one based on conventional railroad signalling techniques.