LEES

MELBOURNE AND METROPOLITAN TRAMWAYS BOARD
ENGINEERING DEPARTMENT
PLANNING BRANCH.

A DISCUSSION ON FUNDAMENTAL ASPECTS OF UNDERGROUND TRAM OPERATIONS THAT ARE OF IMPORTANCE FOR THE PRELIMINARY DESIGN.

July 1966.

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A discussion on fundamental aspects of underground tram operations that are of importance for the preliminary design.

Preparatory to the preliminary design of the routes for underground tramways, a number of provisional technical decisions are necessary. It should be appreciated however that because of the magnitude and cost of these projects exhaustive and in some cases extensive investigations will be necessary before a final decision is made. This report however, is intended only as an early discussion of such technical aspects and the ideas and opinions are not expressed with any intention of finality.

It is considered that great emphasis should be placed on the importance of designing for the maximum ultimate tunnel capacity.

The tram service in Swanston Street on the 13th June, 1965, was 1,001 tram passes in the south bound direction and on the 13th September, 1965, there were 1004 tram passes in the north bound direction which in each case represents an average headway of 61 seconds over a period of 17 hours. The corresponding average peak headways for the busiest 15 minutes in each case were 32 and 30 seconds respectively.

Few if any overseas underground systems on the other hand are being designed for a minimum headway of less than 90 seconds. This of course with a 10 car train would mean a car for each 9 seconds as against a tram every 30 seconds in Swanston Street at present.

The total numbers of passengers carried on trams in Swanston Street according to the Melbourne and Metropolitan Transport Study 1964, were 43,000 northbound and 44,000 southbound for a normal week day.

1. Tunnel Cross-Section.

1.1 Shape of tunnel cross-section.

As the shape adopted will depend largely on the type of construction employed, it is not considered fundamental for the preliminary designs. It would be circular if machined bored, and probably rectangular if open cut construction is employed. Recent advances in machine tunnelling are making it more competitive with open cut methods.

Circular single track tunnels are assumed between "Stations" and rectangular tunnels at "stations".

Where rectangular cross-sections are used, a double track tunnel would generally be more economical, hence design should be such that where possible single track tunnels are kept at the same level and as close as possible to each other so that rectangular double track cross-sections may be substituted.

1.2 Size of Tunnel.

The tunnels should be designed so as to be suitable for single unit tram operation and also for upgrading for multiple unit operation, that is for train operation.

1.2.1 Size required for tram operation.

The tunnels must be suitable for the widest vehicle that is likely to be operated on the street tramways. As the track centre distance of 11'0" on the street is not likely to be exceeded, the width of 9'2" of our largest existing trams is likely to remain the maximum width of future trams.

Following the success of double deck trains in Sydney, the question of double deck trams will no doubt be raised from time to time. However, the possibility of double deck trams being required to operate in the tunnels is considered too remote to justify the additional cost of the greater tunnel height to meet such an eventuality. Diagram no.1 shows the cross-section of one of the Board's earlier double deck buses drawn within an 18 feet internal diameter tunnel as representing the absolute minimum size necessary for double deck vehicles.

As floor heights and headroom are not likely to be increased on single deck trams, it is assumed that the minimum satisfactory operating heights of present day trams will not be exceeded.

Passageways in the tunnels on each side of the trams over the entire underground route is considered most desirable if not essential, so that passengers can readily escape from a disabled tram particularly if it is on fire, and also to offer refuge for maintenance personnel.

A circular tunnel of 16 feet internal diameter meets these requirements with adequate allowance for overhang on curves, and preliminary designs are based on such. The outside diameter is assumed to be not more than 19 feet refer diagram no.2.

1.2.2 Size of tunnel required for Victorian Railway Stocks.

The "Australian Railways Ultimate Maximum Rolling Stock Outline 1963" is shown on diagram no.3 to this must be added the outline of the pantograph in the operating position.

The Railway Construction Board proposes to build the tunnels for the underground railway with an internal diameter of 20'6" to accomodate such rolling stock.

The cross-section area of such a tunnel would be over 50% greater than that proposed for tram operation, and as the possibility of Victorian Railways rolling stock being required to operate in these tunnels is so remote it is considered that the additional cost of this increased size cannot be justified.

1.2.3 Size of tunnel required for railway type operation.

This of course may only take the form of coupled trams or it may eventually have trains that are also required to operate out onto the V.R. system using high level platforms. Here the distinction must be stressed between the case of a tram tunnel that would take any V.R. rolling stock and a tram tunnel that would only take special rolling stock which would also be suitable for operation on the V.R. system. This would probably require a dual voltage system and maybe a dual current collection system such as pantograph on the V.R. system and pantograph, trolley pole or third rail in the tram tunnel - no great technical problem would be imposed in any of these cases.

The Barris trains could be satisfactorily operated inside a 16 ft. internal diameter tunnel, refer diagrams nos. 2 and 4, however, there seems little likelihood of the two systems being converted to a uniform gauge within the immediate future.

1.2.4 Recommended size. Refer diagrams nos. 2, 5 and 6.

The 16'0" internal diameter is recommended for the circular tunnel.

In the case of the double rectangular straight tunnel the following minimum dimensions are recommended:-

Head room	14'6"
Width clear of obstructions	25'0"
Width clear of obstructions from track centre line	7'0"
Track centres	11'0"

Note: The Victoria Line Tunnel in London is 12'8" internal diameter while those for Frankfurt are 16'0" internal diameter for 8'2½" wide rolling stock. Toronto also has a circular tunnel of 16' internal diameter.

1.3 Tunnels at Stations.

Preliminary designs are based on no fixed obstructions on "platforms" within 9'6" of track centre lines - this gives a clearance of 5'0" from the side of a 9'0" wide tram - safety zones are about 8'4½" from track centre lines.

Platform widths will have to be further increased to accomodate stairways or ramps.

2. Passenger Access.

It is assumed that the population of Melbourne will continue to grow indefinitely and that each tramway tunnel will ultimately reach capacity. Factors which may limit tunnel capacity should as far as possible be eliminated from even preliminary designs. In particular, the necessity for pedestrians to cross tram tracks at grade level (or even the temptation to do so) should definitely be excluded.

Pedestrian subways immediately above the trams with access to at least both sides of the street (and maybe all 4 corners at an intersection) and also to platforms for the trams in each direction would therefore be essential. Refer diagram no. 7.

Pedestrian subways would also be of advantage to pedestrians other than tram travellers as well as to street traffic. Continuous left hand turning motor traffic could then be permitted if pedestrians are induced to cross via the subway. Such subways would no doubt incorporate some shops as in the case of the Degrave Street subway.

If pedestrian traffic is to be grade separated from motor traffic, subways would be preferable to overhead bridges from the point of view of underground trams, particularly if the intending passenger is on the wrong side of the street. Subways also offer protection from inclement weather. However, where there is no grade separation of motor and pedestrian traffic it is considered that there will be continuous pressure brought to bear to permit pedestrians to cross the tram tracks in preference to the street at motor traffic grade level.

The advantages of the pedestrian subway of course must be balanced against the increased depth of the passenger platforms. This could be up to 8½ feet provided that the minimum tunnel depth is not already limited by other underground obstructions.

At this stage, it is considered that pedestrian access should be provided connecting to both sides of the street and by subway in preference to overhead bridge or deck.

3. Direction of Operation.

The choice between left hand and right hand underground running is subject to few limitations apart from ease of passenger access and tram access to street levels.

3.1 Passenger access.

As it is assumed that passenger access to trams will remain on the left hand (near) side, "island platforms" will be necessary for right hand running. Access to these platforms would have to be by pedestrian subways crossing above the tunnel - refer diagrams nos. 7 and 8. This would however, permit access from either side of the street to either tram tunnel with a simpler arrangement of stairs or ramps - fixed or moving - than for left hand running as the one arrangement would serve trains operating in either direction.

3.2 <u>Tram Routes.</u>

For right hand running it would be necessary for one tram line to cross over the other.

This would present no difficulty at grade separated junctions near the end of the tunnel refer diagram 17. In streets of at least restricted width it would be an advantage to place "outboard" tram lines to the right - refer diagrams Nos. 9 and 10. The tunnels could then continue underground for either left or right hand running.

3.3 <u>Underground Rapid Transit Work.</u>

The island platform arrangement necessary for right hand running complicates the layout of cross-overs (refer diagrams 19, 21 and 22).

At this stage, it is considered that the question of left or right hand running be left open, and where other factors are equal preference should be for right hand running.

4. <u>Curvature.</u>

Here the aim should be to impose the absolute minimum of restrictions on speed such that the only cause to reduce speed is for the purpose of stopping to set down or pick up passengers. It is assumed that the trams using the subway some years hence will be operated at speeds much in excess of todays average top speeds between stops of 20 to 25 m.p.h.

4.1 <u>Radius of curvature.</u>

The approximate speeds for various curves based on present day practices are as follows:-

Radius Ft.	Equilibrium Speed m.p.h.	Recommended Maximum m.p.h.	Absolute Maximum m.p.h.
100	13	14	17
150	15	18	22
200	18	20	25
300	22	23	30
400	25	28	35
500	28	32	40
600	30	35	43

Refer special report on "Preliminary Investigation of Horizontal Track Curvature and Cant (Super Elevation) for Underground Trains", April 66.

While it is evident that curves of greater than 500 feet radius are unlikely to offer any restriction on operating speeds or tunnel capacity, curves of less than 300 feet radius on the other hand, will definitely be restrictive and should be avoided.

4.2 Horizontal Curves.

Where curves are located in regions of acceleration or retardation such as near stations, consideration should be given to curves of varying radius to suit the increasing or decreasing speed of train. Refer "Preliminary Investigation of Track Curves designed for regions of Acceleration or Retardation", May 1966.

4.3 Transition Curves.

The design of transition curves is complicated by the fact that the tunnel centre line will be required to follow the path of the train body as distinct from the path of the bogies. The matter is further complicated with modern trains fitted with "soft suspension" for the purpose of ensuring passenger comfort, in that the body will not immediately follow the bogie when entering a curve, and if the transition is too rapid, undesirable oscillations may be set up.

In most underground systems the radii of the curves and the lengths of the transitions are large enough to render this problem negligible except for instances where severe speed restrictions are imposed. However, with the smaller radius curves likely to be used on underground trains it is considered that this should be the subject of detailed investigation.

4.3.1 Type of Transition.

Preliminary design of transition curves will be based on the radius varying inversely as the length that is, they will be designed as Euler Spirals.

4.3.2 Length of Transition.

This is generally governed by the distance to establish the cant of the circular curve.

British Railway practice is to limit the rate of increase of cant to 1 in 300 and also to 2½ inches per second which corresponds to 150 feet for a 6 inch cant when the speed does not exceed 36 m.p.h. However, where possible, the length is further increased by 50%.

4.3.3 Relationship between cant and radius of transition curve.

Initially a linear relationship is assumed, i.e. that cant increases proportionally with distance and radius is inversely proportional to distance. However, further refinements may be necessary for particular types of vehicles determined by trial to achieve satisfactory passenger comfort, rail wear, and tunnel clearance, particularly at speeds in excess of the design speeds. Refer "Horizontal Curves - General Arrangement and Selection" May 1966.

4.4 Preliminary design.

Preliminary design will be based on -

1. Transition curves of Euler Spiral form for the tunnel centre line.

2. The minimum length of transition curve to give a cant gradient of $\frac{1}{300}$.

3. A maximum cant of 6 inches - this would require a minimum transition curve of 150 ft.

4. The length of transition to be increased by 50% where this can be achieved without reducing the radius of the circular curve.

5. Turnouts and Cross-overs.

The recommendations are in accordance with "Preliminary Investigation of Turnout and Cross-over Design for Underground Tramways" - May 1966, namely:-

Tunnels be designed for 350 feet radius 1/7 turnouts and that clearances be so adjusted that turnouts down to 150 feet radius and 1/5 frog angles may be substituted. If there is a reverse curve immediately after the turnout, it should be treated in a manner similar to that for a cross-over.

Tunnels be designed for 350 feet radius 1/8 cross-overs (irrespective of track centres) and that clearances be adjusted so that cross-overs down to 200 feet radius and 1/7 frog angles may be substituted.

It should be noted that where the track centres exceed 11 feet, larger frog angles for cross-overs may be substituted without any appreciable reduction in clearances.

5.1 Location of facing turnouts (points or switches).

5.1.1 The factors to be considered are:-

(a) Safety.

(b) Affect on transit time and hence tunnel capacity.

(c) Initial construction cost.

(d) Operational convenience and cost.

(e) Maintenance convenience and cost.

(f) Noise.

5.1.2 Requirements.

1. They should be in locations where speeds are already reduced for other reasons such as passenger stops, immediately after sharp curves or at the top of steep grades. This is desirable from the point of view of safety as well as tunnel capacity.

2. They should be in locations where the tram would normally be accelerating rather than braking. This is desirable from a safety point of view so that the driver has available a greater reaction time.

3. They should be located near access points such as "stations", for the ease of maintenance and safety of maintenance personnel.

4. As the tunnel will need to be of special cross-section, it may be desirable to have them adjacent to "stations".

5. They should be suitable for single driver operation such as by the Selling point shifter maybe with the refinement of an electric lock and release and perhaps indicator lights.

6. They should be located after a "station" so that one platform can serve vehicles for each route.

5.1.3 Location.

The most suitable location from all aspects except perhaps noise is immediately after but as close as possible to a "station". Refer diagram 11.

5.2 Location of trailing turnouts.

These constitute a serious hazard in tramway tunnels due to trams converging under conditions of limited visibility. The selection of their location should be determined chiefly by this consideration. Signal systems will reduce the hazard provided that they are obeyed, but it is essential that they will not restrict the tunnel capacity.

5.2.1 Requirements.

The requirements would be as for facing turnouts with the following exceptions:-

1. Selling point shifters would not be used but some form of blade operation may be desirable. Signal lights to indicate "right of way" for trams converging from each direction at about the same time would of course be necessary.

2. Preference should be given to location immediately after a "station" because of safety despite the fact that separate platforms would be necessary. This is not likely to be serious from a passenger point of view as converging routes would generally be at the approach to the central business area where more passengers are likely to be alighting.

3. An exception could be at the top of a steep ascent and immediately before a "station" where speeds would be reduced. This however, should be avoided if possible.

5.2.2 Location.

The most suitable location from all aspects except perhaps the necessity to have two platforms is immediately after but as close as possible to a "station". Refer diagram 12.

5.3 Grade Crossings at Junctions.

It is considered to be most important that all such crossings are grade separated. The chief reasons being as follows:-

(a) They are a most serious hazard. Referring to diagram numbers 13 and 14, it is evident that a tram on track 2 risks first a head on collision with a tram on track 3 and then a side-on collision with a tram on track 4.

(b) They will slow down the service due to the necessity to have a positive signalling system and trams will have to wait their turn. A failure of the signalling system could be most embarrassing.

(c) Inadequate cant will slow down the trams crossing on the curve as cant cannot be provided on the crossing.

(d) It may not be convenient to arrange for the UP and DOWN tracks to be at the same level, which is of course essential for a grade crossing. In slowing down the service they will restrict the ultimate capacity of the tunnels. Their elimination at a later date would be most costly.

Grade separated crossings are considered essential, despite the fact that one line would be lowered by at least 12 feet at the crossing.

Use of arrangement A is illustrated in diagrams 15 and 16.

9.4 Location and Arrangement of Cross-overs.

Problems associated with cross-over location and arrangement in tram tunnels are much more serious than on street tramways. The latter can be readily relocated to suit changing traffic conditions whereas the former once installed may be very costly to relocate and could restrict the ultimate tunnel capacity. Cross-overs in tunnels however need not generally be restricted to two tracks with 11 feet centres as on city streets, and are free from restrictions due to other traffic.

9.4.1 Requirements.

1. The requirements for turnouts also apply to crossovers. As the curved track of the turnout is not used for mainline running it may be designed for a lower speed limit, nevertheless it must be suitable for pushing or pulling disabled trams.

2. It should not be necessary to stop the tram on the mainline to change direction. This would impose a restriction on the ultimate tunnel capacity and would also be undesirable from a safety point of view. An exception would be the case where the tram is reversed at a stop which is necessary for passenger requirements.

9.4.2 Arrangements.

9.4.2.1 Direct type cross-overs refer diagrams 17 and 18, location A.

While the reversing tram is using the platform, following "through" trams will have to wait on the mainline in a region where trams are normally braking. This would restrict tunnel capacity and would also be a dangerous practice.

Location B. The two major objections would be the increased length of platform necessary (approx. 100 feet) and traffic delays that may result, as a number of trams will have to stop twice due to the platform being occupied by "through" trams. Tunnel capacity would therefore be restricted. In the right hand running case, two island platforms would be necessary. Refer diagram No. 19.

Location C. This arrangement would be dangerous as trams being reversed will converge with mainline trams approaching the stop.

Location C. Modified.

The arrangement as shown in diagrams 20 and 21 are modifications of location C to obtain the advantages of either location B or location A by offsetting the platforms. A disadvantage of the arrangement illustrated in diagram 20 is that the reversed tram will not be able to pick up passengers at the platform, whereas, the arrangement of diagram 21 permits a stop at both platforms. The major objection is reversing on the mainline while the arrangement of diagram 21 could cause some inconvenience due to converging at the platform.

Tracks at different levels.

The crossover must run for some distance as a third track (or siding) to change grade - refer diagrams 22 and 23. In the case of the R.H. running it is dangerous in that following trams must stop before the station and the reversed tram converges onto the opposite mainline where trams are braking from running speed.

5.4.2.2 Reversing from sidings, left hand running.

To ensure that the mainline is as free as possible for through running, it is most desirable if not essential that reversing trams run off the mainline through facing points onto reversing sidings.

The simplest arrangement that meets this requirement is that of diagrams 24 and 25. The length of sidings should be such as to accommodate the longest train of trams.

Diagrams 26 and 27 illustrate arrangements whereby two trams can enter the siding in such a manner as to enable either to be first to depart.

Diagram 28 illustrates an arrangement whereby either tram on the siding may be the first to depart.

Diagram 29 is a combination of 27 and 28.

Diagrams 24 to 29 are for reversing trams entering the station from one direction only.

Diagram 30 is an arrangement whereby trams may be run off onto a reversing spur from either the Up or Down lines, it is actually a combination of diagram 29 with its reverse image.

5.4.2.3 Reversing from siding, right hand running.

This method of operation does not lend itself so readily to convenient crossing over arrangements because of the central platform.

Diagram 31 is an arrangement for reversing trains of trams entering from one direction only while diagram 32 is for trams from either direction and is diagram 31 superimposed on its reverse image; both of which meet the requirements for minimum turnouts.

The complexity and corresponding cost of these arrangements is likely to offset their advantages over the street type crossover illustrated on diagram 19 unless the length of sidings could be justified for temporary storage purposes.

5.4.3 Comments.

The important consideration at this stage is to ensure that the tunnel is so designed as to permit suitable "crossing over" arrangements to be installed and conveniently added to from time to time as traffic requirements dictate - arrangements that can be so located that they do not become a safety hazard, a cause of delay or a restriction on the ultimate tunnel capacity.

6. Track gradients.

Gradients on underground tramway are not subject to the same restrictions as street tramways which have to follow very closely the street level. Generally the levels of the stations will be fixed by the requirement that they be as shallow as it is possible to make them, but the gradients between can be varied to give the optimum arrangement from the point of view of capital cost, operating costs and maintenance.

Thorough design could result in a considerable saving in power and at the same time achieve the maximum tunnel capacity.

6.1 Existing tramway gradients steeper than 1 in 14.

Route	Location	Gradient	Length Ft
Northcote	Dundas St. east of Railway Bridge.	1 in 13.37	25
Wattle Park	Riversdale Rd. at Brinsley Rd.		
	(3300' to 3500'	1 in 13.59	200
	(3500' to 3600'	1 in 13.69	100
	at Spencer Rd.	1 in 12.88	25
	at Middlesex Rd.	1 in 12.41	200
	at Verdun St.		
	(10750' to 10900'	1 in 13.52	150
	(10900' to 11230'	1 in 13.38	330
	(11230' to 11350'	1 in 13.98	120
Camberwell	Malvern Rd. - at Irving Rd.	1 in 12.81	80
	Burke Rd. at King St.		
	(8000' to 8050'	1 in 13.08	50
	(8050' to 8150'	1 in 13.02	100
	(8150' to 8200'	1 in 12.38	50
	(8200' to 8237'	1 in 12.66	37

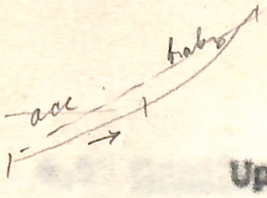
Route	Location	Gradient	Length Ft.
Camberwell	at Wills St.	1 in 11.17	35
	At Middle Rd.		
	(11900' to 12000'	1 in 13.64	100
	(12000' to 12025'	1 in 12.02	25
	(12025' to 12100'	1 in 11.89	75
	(12100' to 12200'	1 in 12.13	100
	(12200' to 12300'	1 in 13.72	100
Glen Iris	High St. - at Northbrook Ave.	1 in 13.43	62
Cotham Rd.	Glenferrie Rd. at Toorak Rd.		
	(5450' to 5500'	1 in 13.75	50
	(5500' to 5800'	1 in 13.90	300
	(5800' to 5950'	1 in 13.89	150
	(5950' to 6150'	1 in 13.79	200
	at Callantina St.	1 in 13.89	175
	At Fitzwilliam St.	1 in 13.23	100
West Maribyrnong.	West Rd.	1 in 13	302
Ascot Vale	Edgar St.	1 in 13.69	100
William St.	at Flinders Lane	1 in 13.72	85

6.2 Gradients for acceleration zones.

Downhill gradients are most desirable here for the purpose of power economy and elimination of wheel spinning. The limiting factor being the ability to brake in the event of an emergency.

The ability to traverse these grades in the uphill direction would also be essential.

It is assumed at this stage that all axles on all vehicles would be motorized, as it is doubtful if a suitable scheme could be designed for underground tramways limited to the gradients necessary for trailer operation due to wheel spinning of the motorized axles. The Victoria Railways, because of this, limit their gradients to 1 in 40.



Uphill gradients are of course restrictive. Where they are unavoidable they should be reduced below the average between the "stops".

Gradients between 1 in 15 downhill and 1 in 30 uphill are not likely to create any appreciable acceleration problems.

6.3 <u>Gradients for coasting zone.</u>

The ideal would be a gradient on which velocity remains constant without the expenditure of power. The actual gradient would depend largely on type of vehicle as well as speed. The coasting distance will however be relatively short.

6.4 <u>Gradient for deceleration zone.</u>

The ideal is if course to convert the kinetic energy of the vehicle to potential energy by running uphill. However to achieve driver control the gradient should not be steep enough to render friction or electric braking unnecessary, particularly as the vehicle nears the stopping point.

An uphill gradient of 1 in 15 would result in a retardation of over 2 ft. per sec.^{2} which would be the order of the desired maximum gradient.

Braking on downhill gradients is undesirable for a number of reasons the chief being the following

(a) The braking reserve for emergency use is reduced.

(b) Unnecessary energy is expended as heat, that is energy which must be purchased as electrical energy, and removed by the ventilation system.

(c) Scheduled speeds must be reduced to permit slower deceleration rates, and hence tunnel capacity.

(d) Grades must be suitable for pushing disabled vehicles.

Gradients between 1 in 15 uphill and 1 in 50 downhill are not likely to create any appreciable braking problems.

6.5 Gradients at Stops.

This may not be as critical as the case for acceleration or braking however it is essential that gradients be as near level as possible for the following reasons:

(a) The driver should have full control of his vehicle when approaching a stop without the necessity to apply power or excessive braking.

(b) The minimum of braking should be necessary to hold the vehicle stationary - preferably no braking at all.

(c) "Roll-Back" on starting should be negligible.

(d) The grade should be suitable for "coupling-up" of vehicles.

Gradients flatter than 1 in 50 should create no appreciable problems.

7. Storage sidings.

Tracks in tunnels could provide a storage for vehicles that is weather proof, vandal proof, and warm enough to keep the temperature of the vehicle above quite a high dew point. Adequate fire precautions would however be essential.

Storage tracks should in general be incorporated in crossing arrangements by extending sidings.

The storage could be used for "block cars" and also to ensure a smooth peak service.

8. Freight services.

The use of tram tunnels for freight is not likely to be seriously considered. The P.M.G.'s Department has however considered the use of their underground tunnels for the carriage of mail.

Freight would necessitate special loading and unloading sidings and it may also create dust and unpleasant odours.

It is not intended to consider this matter further at this stage.

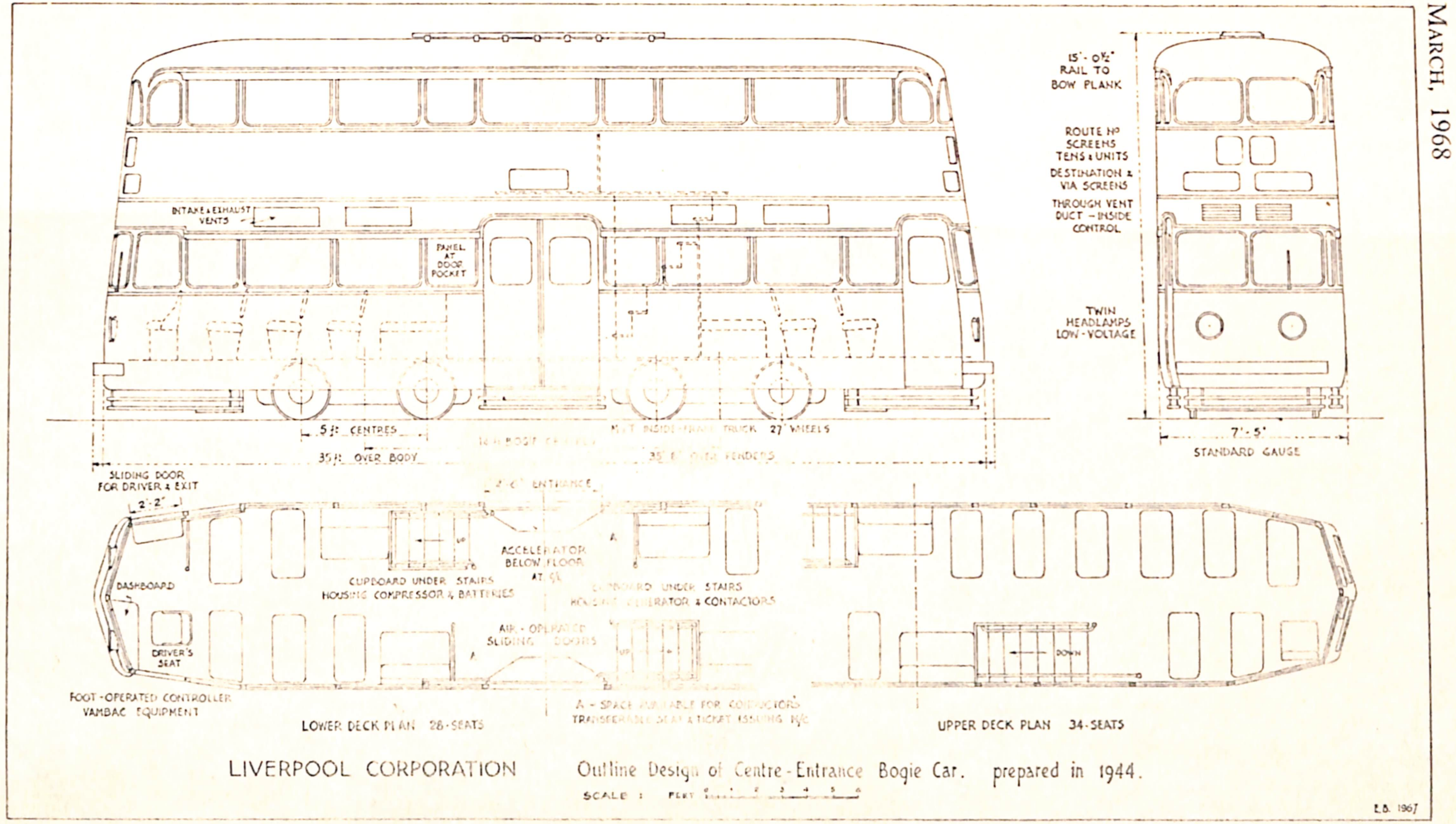
9. **Ventilation.**

Adequate ventilation - whether natural or forced - is essential for the maintenance of comfortable atmospheric conditions, in particular the removal of heat. The design must incorporate provision for increasing of the necessary ventilation as tunnel usage, with the corresponding heat release, increases and tunnel temperatures rise. This matter is at present the subject of further investigation.

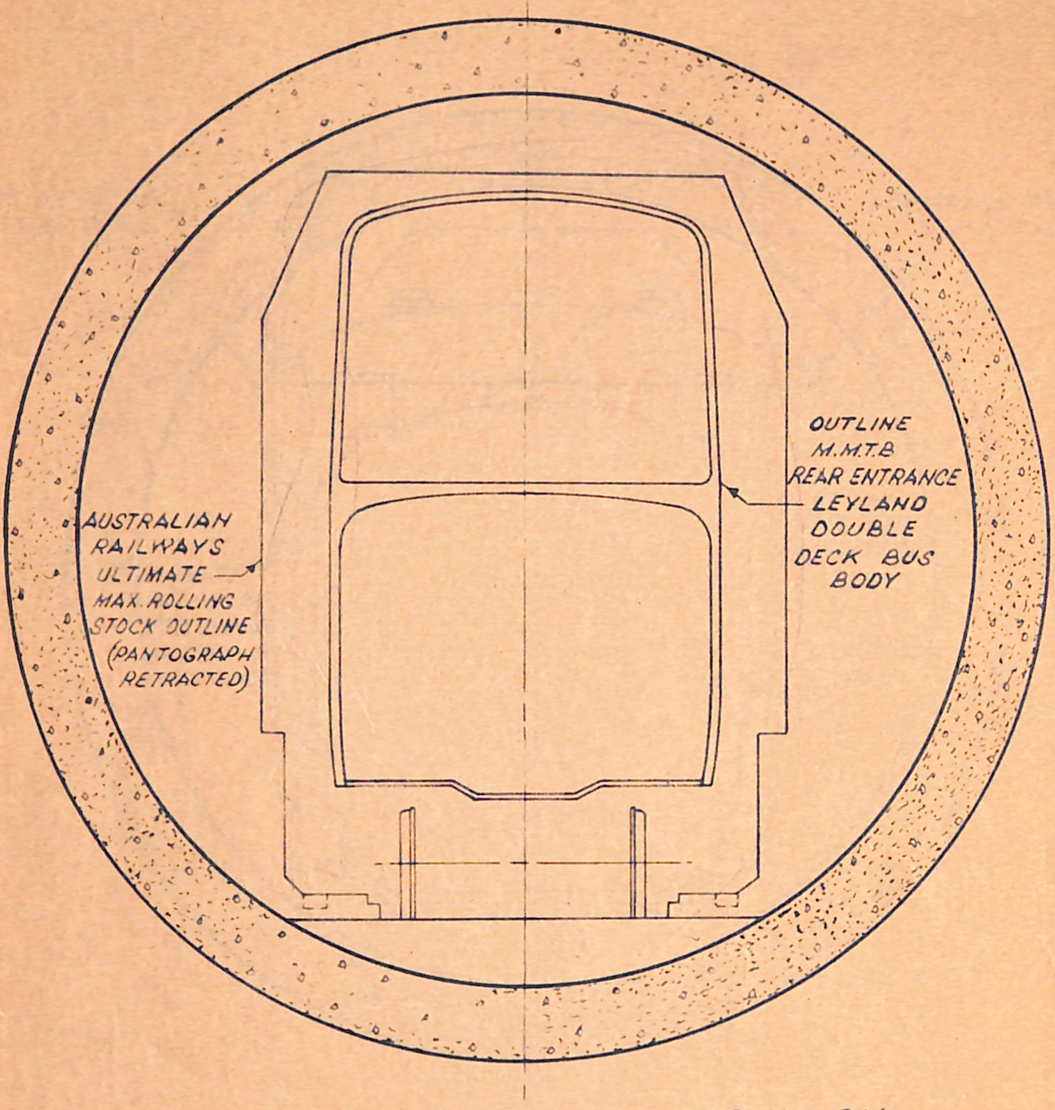
10. **Emergency uses.**

In the event of a major emergency people will crowd into the underground tunnels. Though further investigations are considered necessary preliminary design will however be based on tunnels to be used for normal passenger transport only.

No. 1

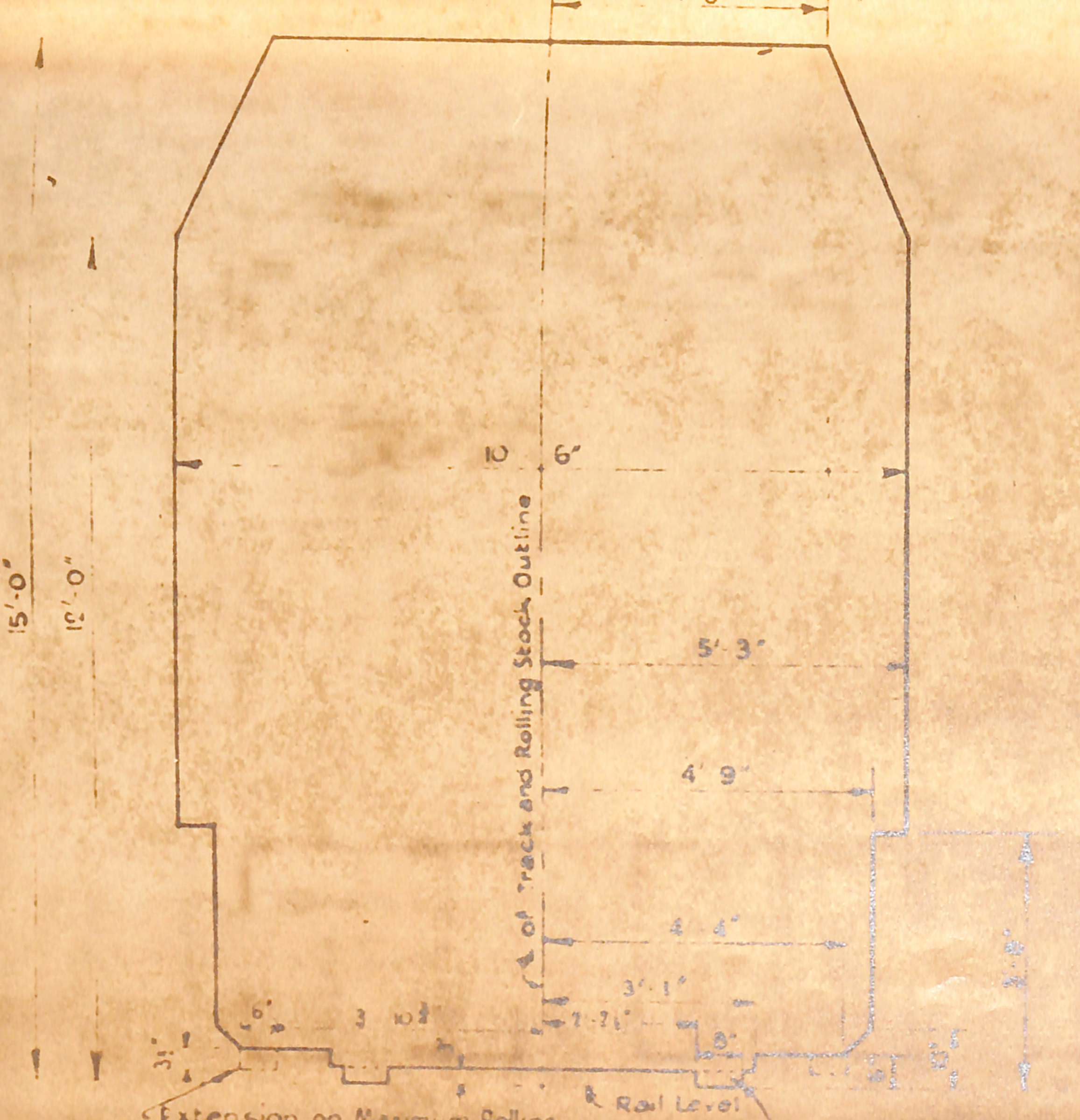


Outline drawing of a centre-entrance bogie car using PCC-type trucks and equipment, prepared by R. J. Heathman for the Liverpool Corporation Transport Committee in 1944 in conjunction with the proposals in the Marks Report.
(Courtesy A. Williams



CIRCULAR TUNNEL 18 FT. INTERNAL DIA.
M.M.T.B. REAR ENTRANCE DOUBLE DECK MOTOR BUS
BODY CROSS SECTION
SHOWN

SCALE $\frac{1}{4}$" TO 1'



Extension on Maximum Rolling Stock Outline for Trip Valve Arm only (Dimensions constant for straight or curved track)

This area (R̄ₓ) shall be occupied by wheels only and no other portion of the car shall

Any vehicles built to the ultimate maximum rolling stock outline, as shown in Appendix C, to be restricted to use on lines conforming to the ultimate minimum structure gauge, as shown in Appendix E.

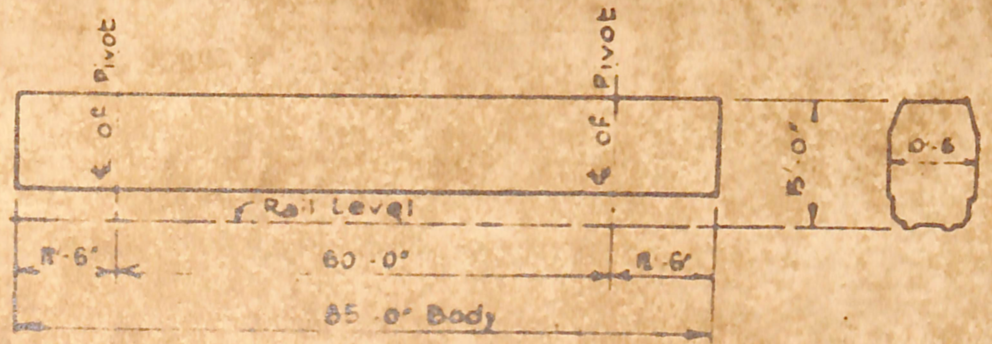


DIAGRAM of 85'-0' CONVENTIONAL CAR

No projections whatever are permissible outside this outline

Pantograph in retracted position is to be included in this outline

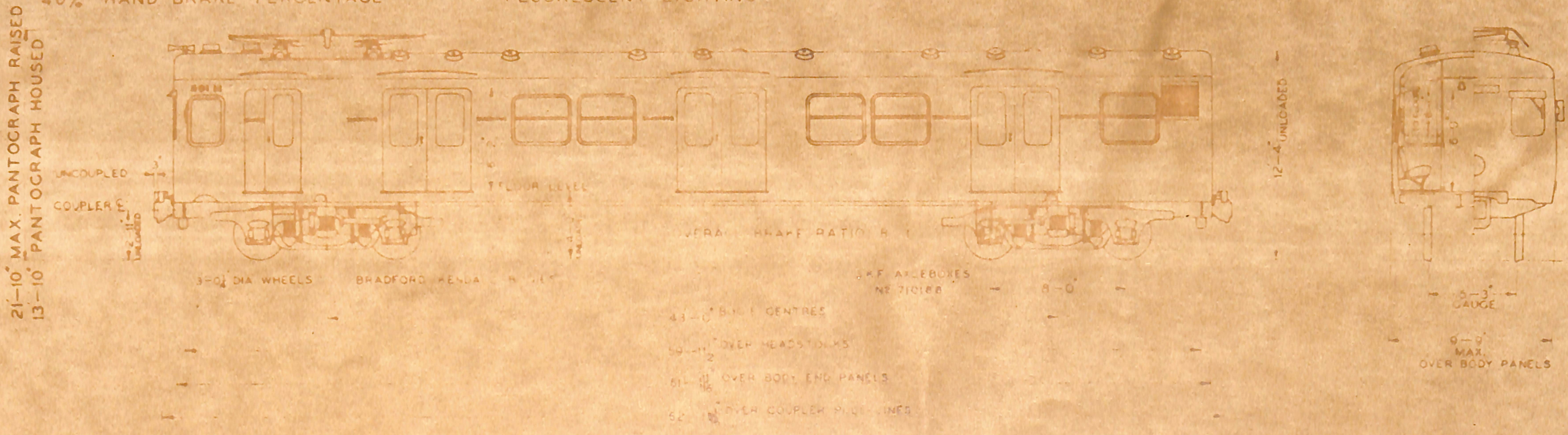
The distances between bogie pivots and from bogie pivot to end of car are not to be increased above those shown unless adequate allowance is made by reduction of width to compensate for the increased central overhang and end swing on a curve of five chains radius.

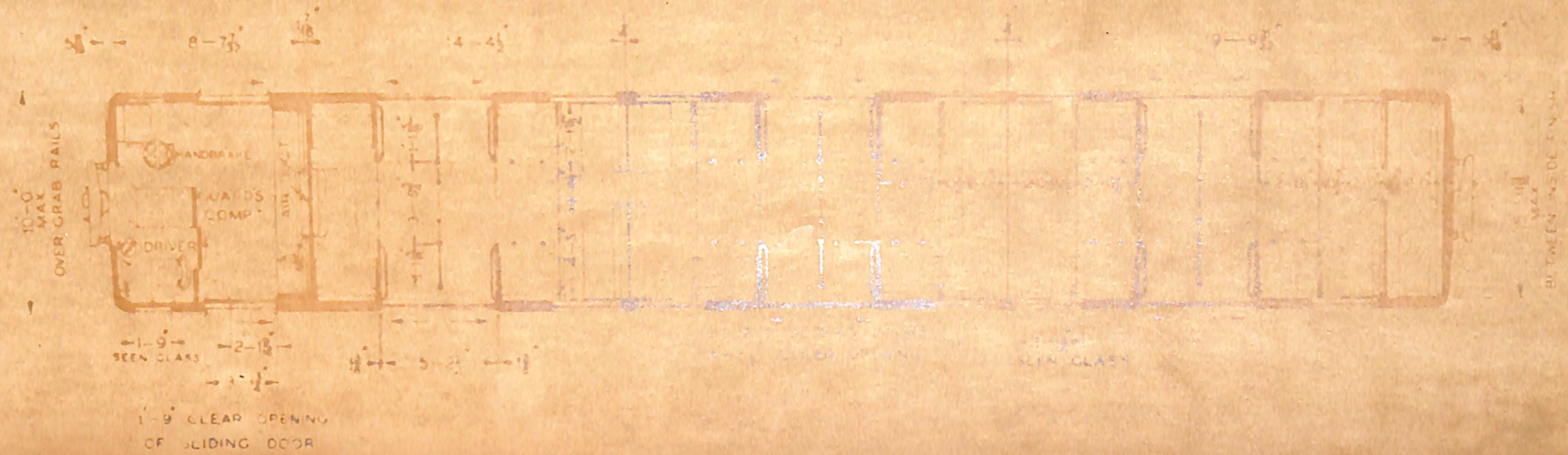
The bottom of side hung doors which swing outwards shall have a minimum height above rail of 3'-8" under all conditions.

DIAGRAM

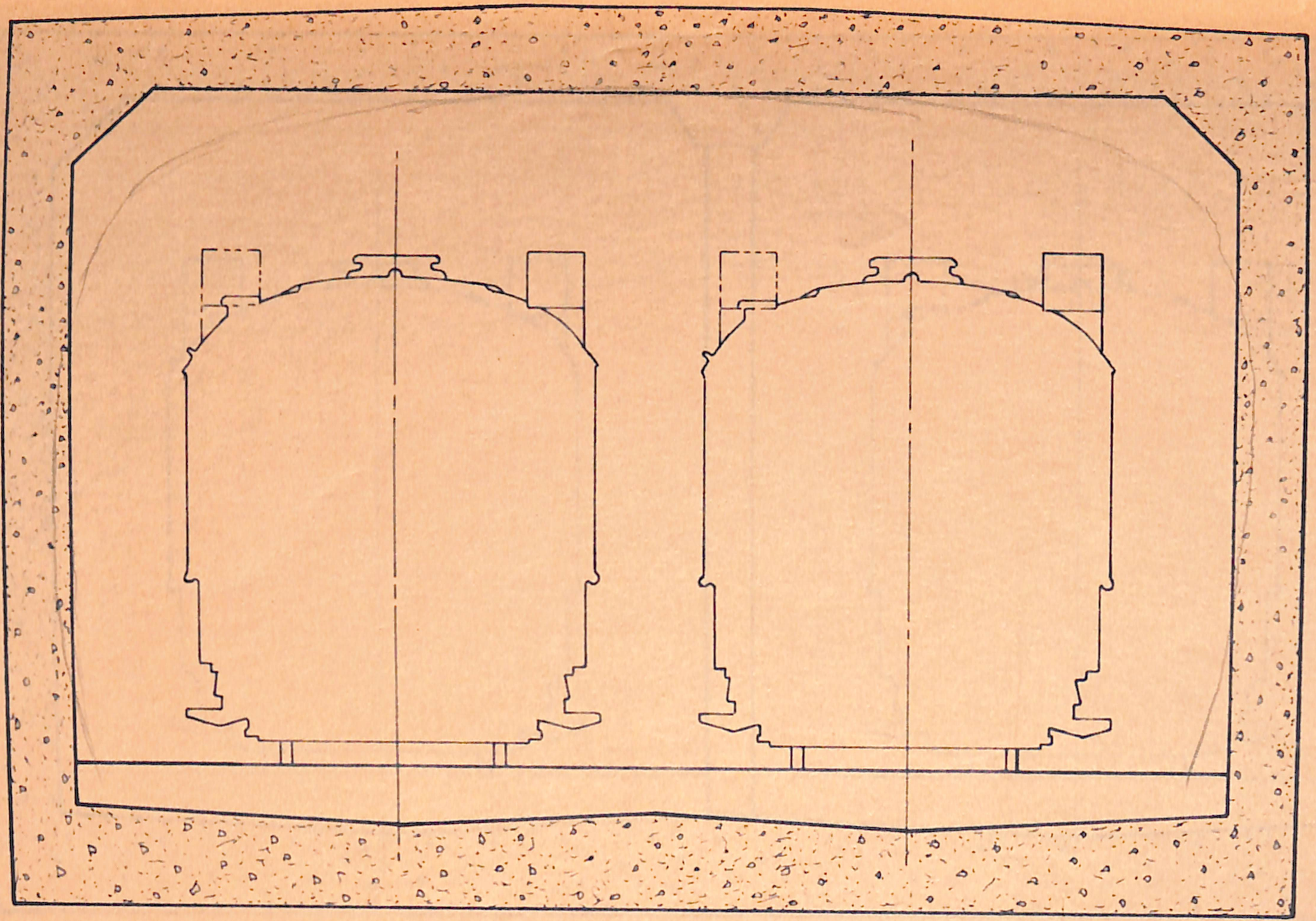
BRAKE EQUIPMENT
18" DIA BRAKE CYLINDER
104% AIR BRAKE PERCENTAGE
40% HAND BRAKE PERCENTAGE

GEAR RATIO 63/17
MOTOR GROUPS 1 4 IN SERIES
2 2 PARALLEL GROUPS OF 2 IN SERIES
FLUORESCENT LIGHTING





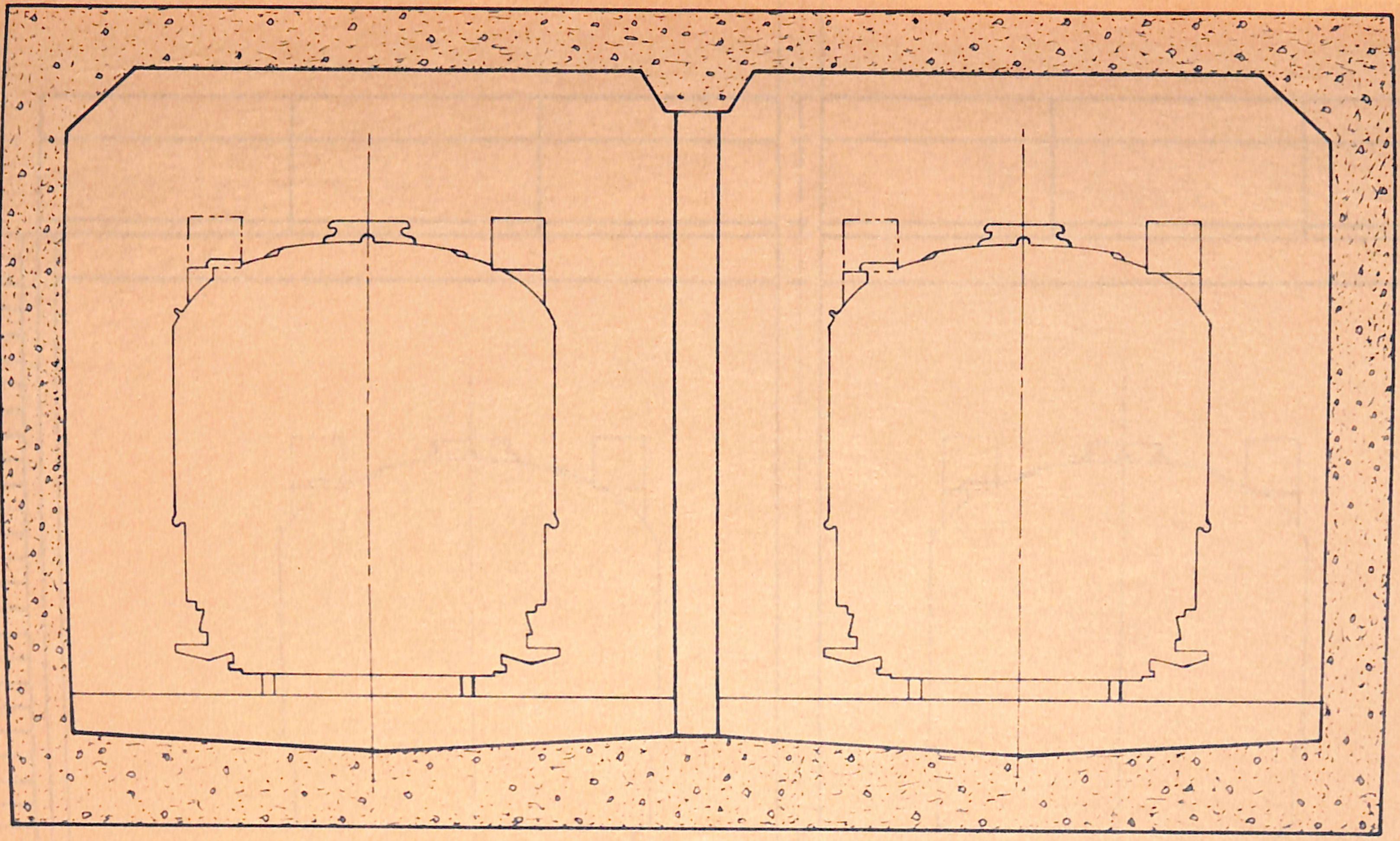
VICTORIAN RAILWAYS
CAR CLASS M
THREE DOOR
STEEL SUBURBAN



RECTANGULAR DOUBLE TUNNEL
MINIMUM STRUCTURAL CLEARANCE WIDTH 25 FT.
TRACK CENTRES 11 FT.
(IF ADDITIONAL SERVICES ARE TO BE ATTACHED
TO WALLS TUNNEL WIDTH WILL INCREASE ACCORDINGLY.)
(CLASS W4 TRAM PROFILE SHOWN.)

SCALE $\frac{1}{4}$" TO 1'

DIAGRAM Nº 5



RECTANGULAR DOUBLE TUNNEL
WITH CENTRAL SUPPORT
MINIMUM STRUCTURAL CLEARANCE WIDTH 14 FT.
SCALE ¼" TO 1'

DIAGRAM Nº 6

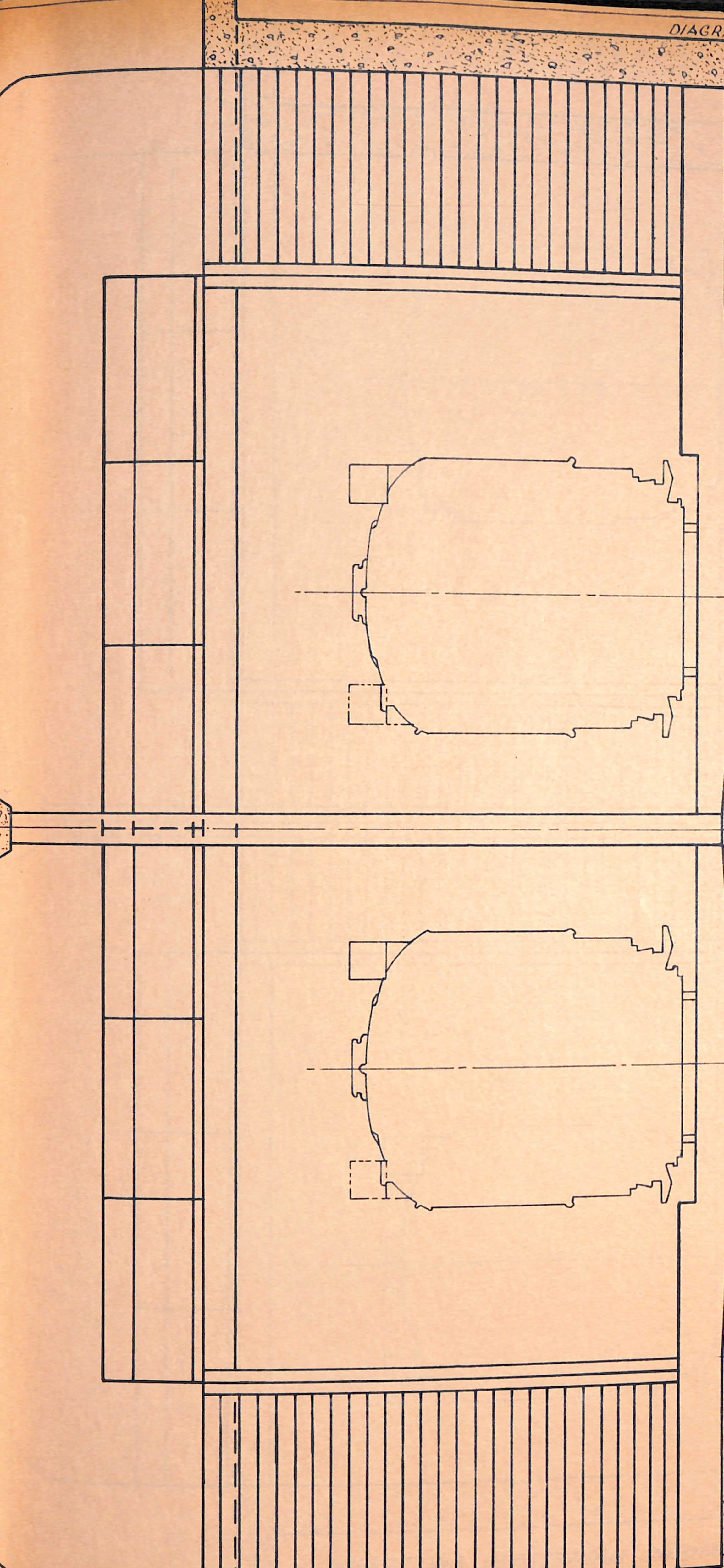
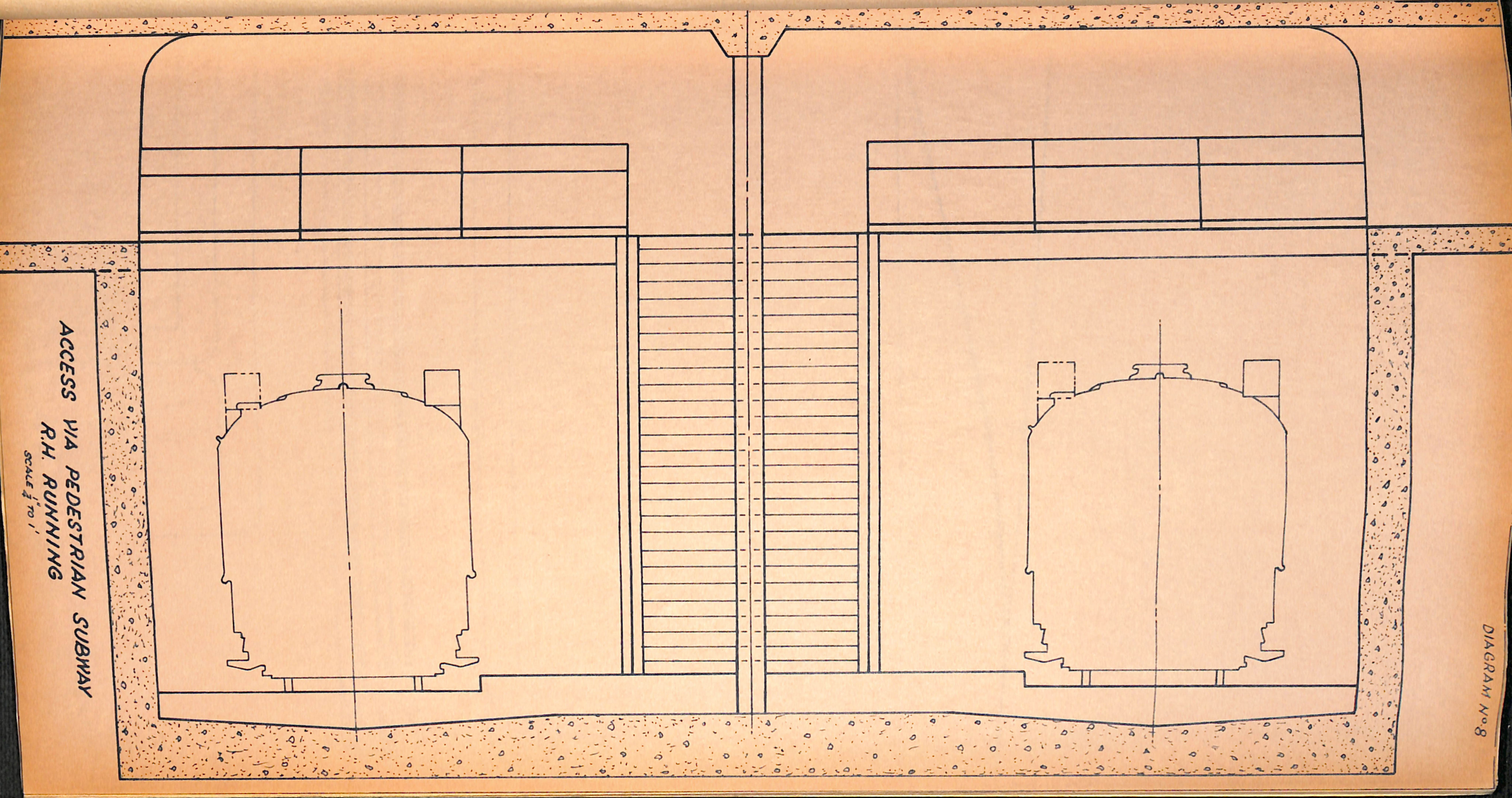

DIAGR

DIAGRAM No 8

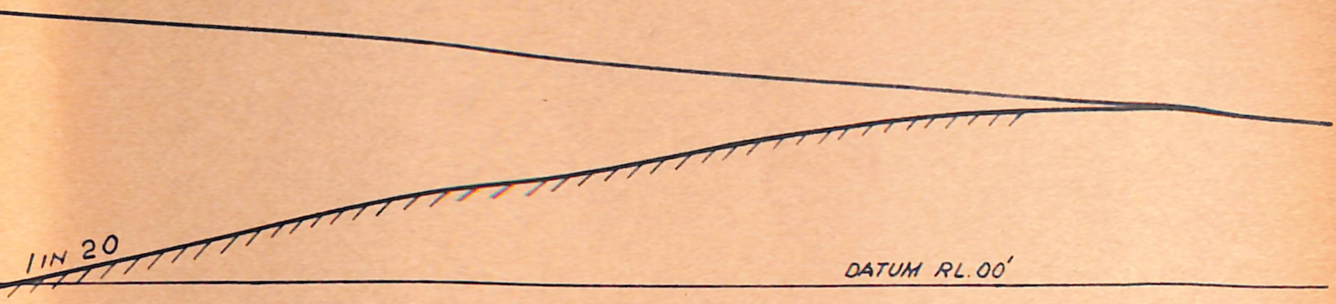


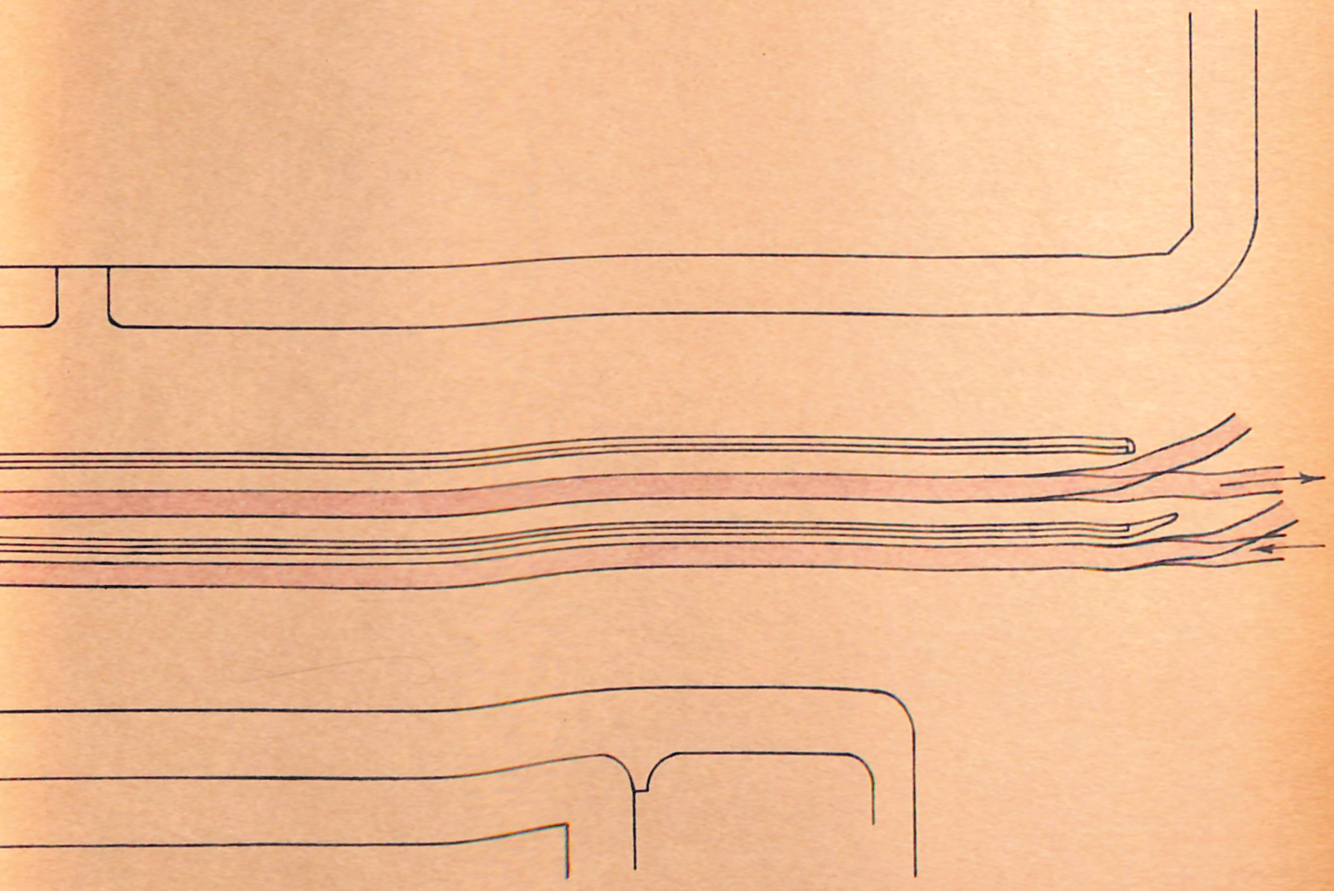
ACCESS VIA PEDESTRIAN SUBWAY

R.H. RUNNING

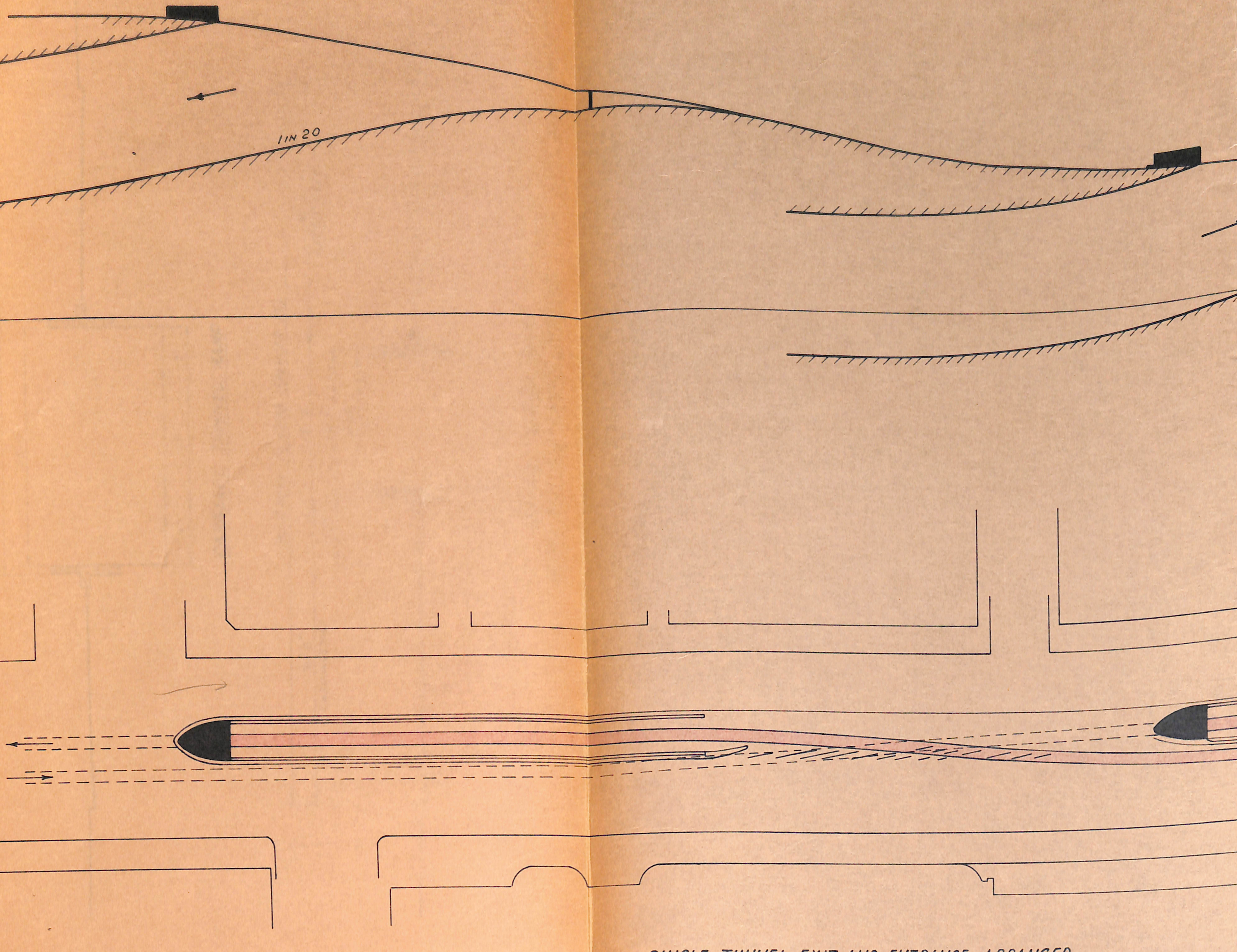
SCALE ¼" TO 1'

No.9

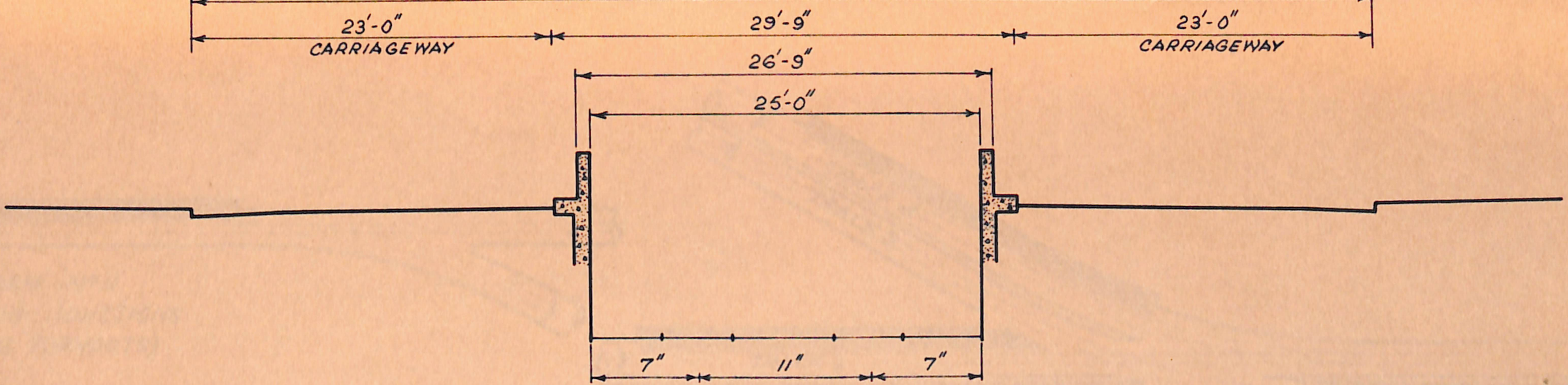




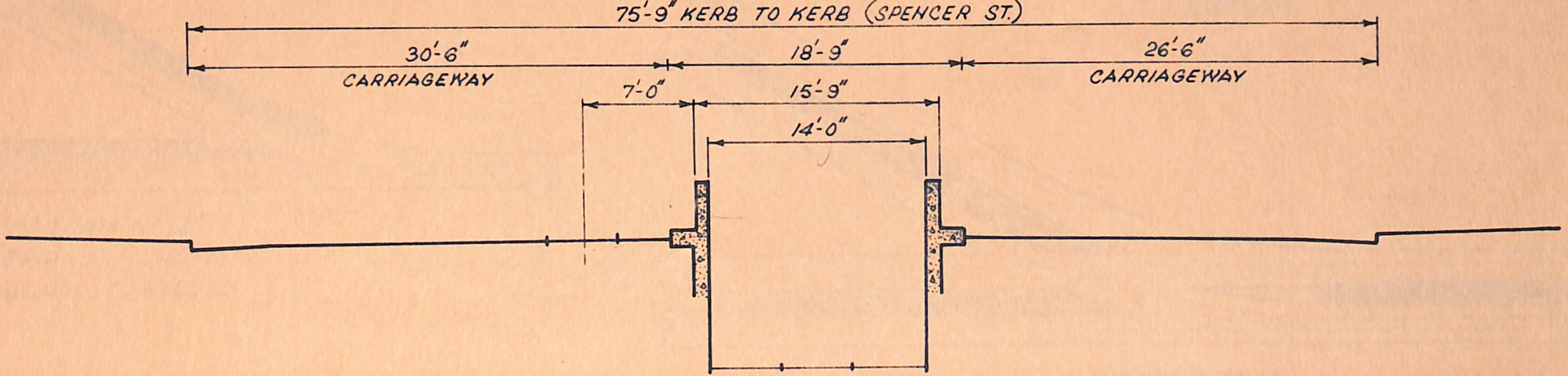
SCALE: 40' = 1"



SINGLE TUNNEL EXIT AND ENTRANCE ARRANGED
TO OCCUPY MINIMUM STREET WIDTH AND ALSO
TO PERMIT LEFT HAND RIGHT HAND RUNNING
CHANGEOVER



PARALLEL TUNNEL RAMP



SINGLE TUNNEL RAMP

OFFSET EXIT & ENTRANCE TUNNELS

SCALE: 10 FT. TO 1 INCH.

DIAGRAM No. 10

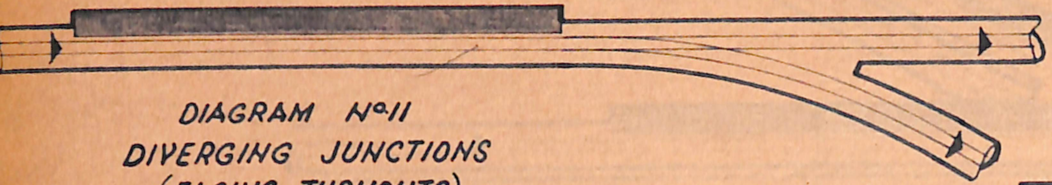


DIAGRAM Nº 11
DIVERGING JUNCTIONS
(FACING TURNOUTS)

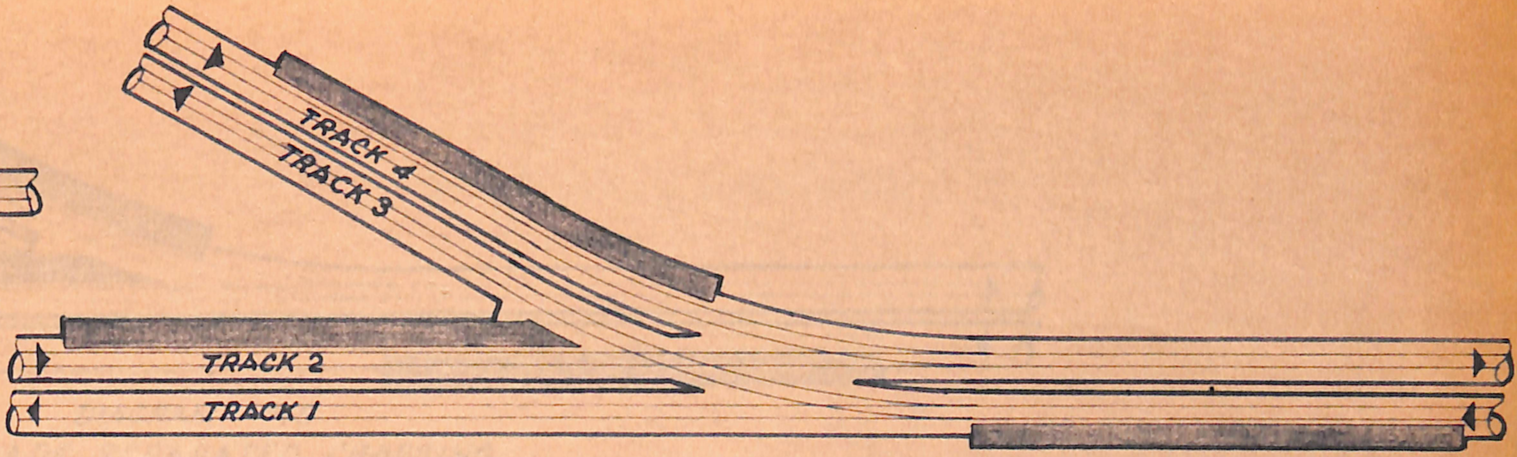


DIAGRAM Nº 13
GRADE CROSSING AT A JUNCTION
L.H RUNNING

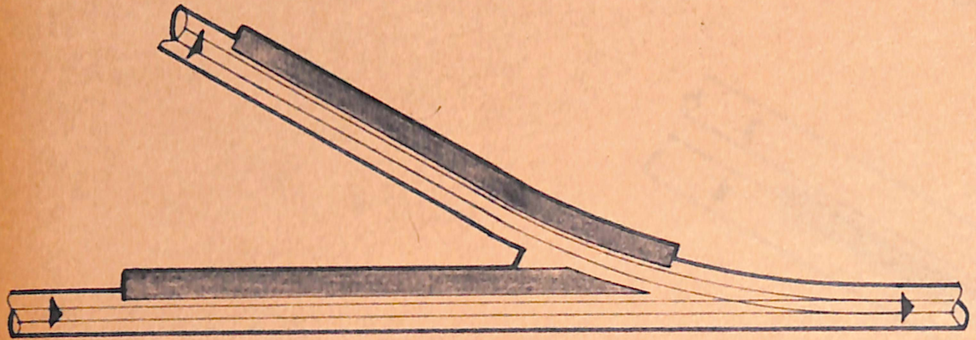


DIAGRAM Nº 12
CONVERGING JUNCTIONS
(TRAILING TURNOUTS)

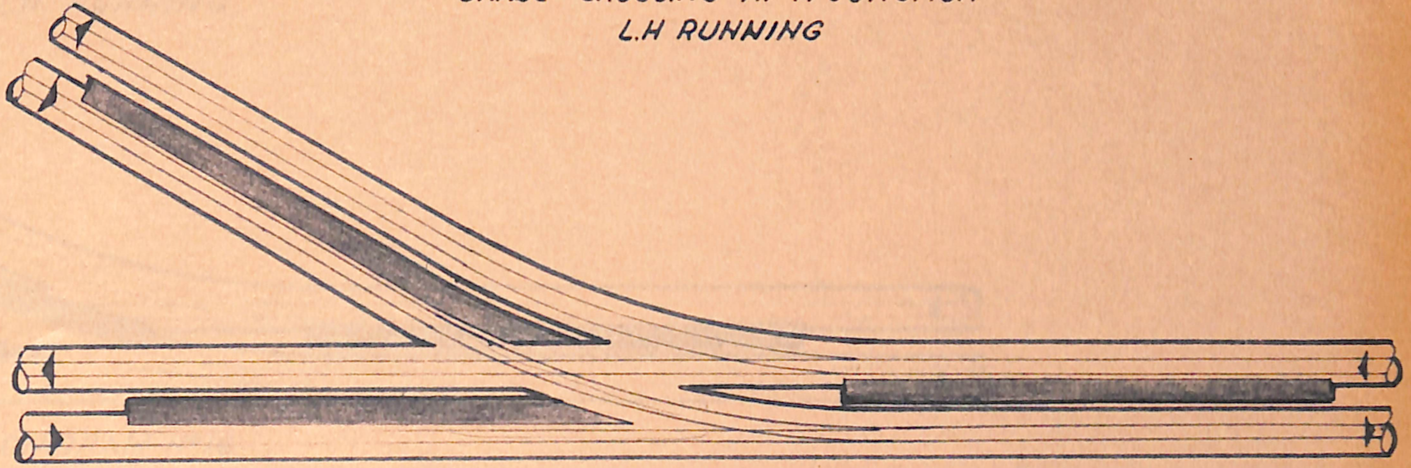


DIAGRAM Nº 14
GRADE CROSSING AT A JUNCTION
R.H. RUNNING

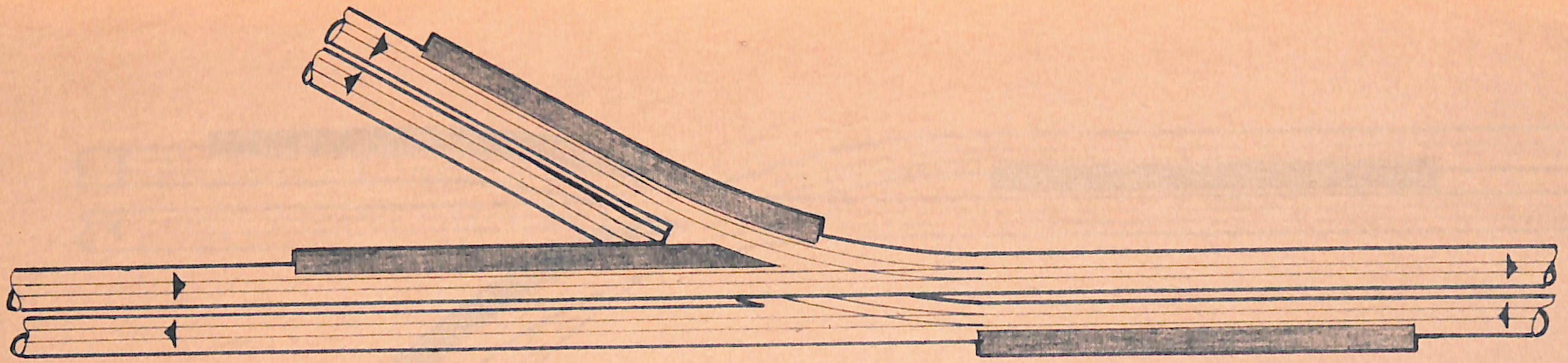


DIAGRAM Nº15
GRADE SEPARATED CROSSING
AT A JUNCTION
LH. RUNNING

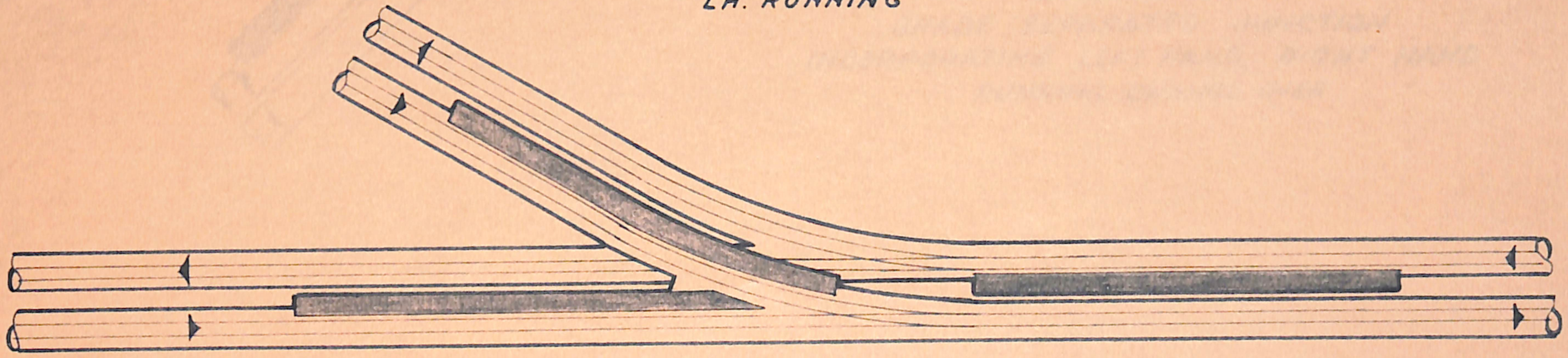


DIAGRAM Nº16
GRADE SEPARATED CROSSING
AT A JUNCTION
R.H RUNNING

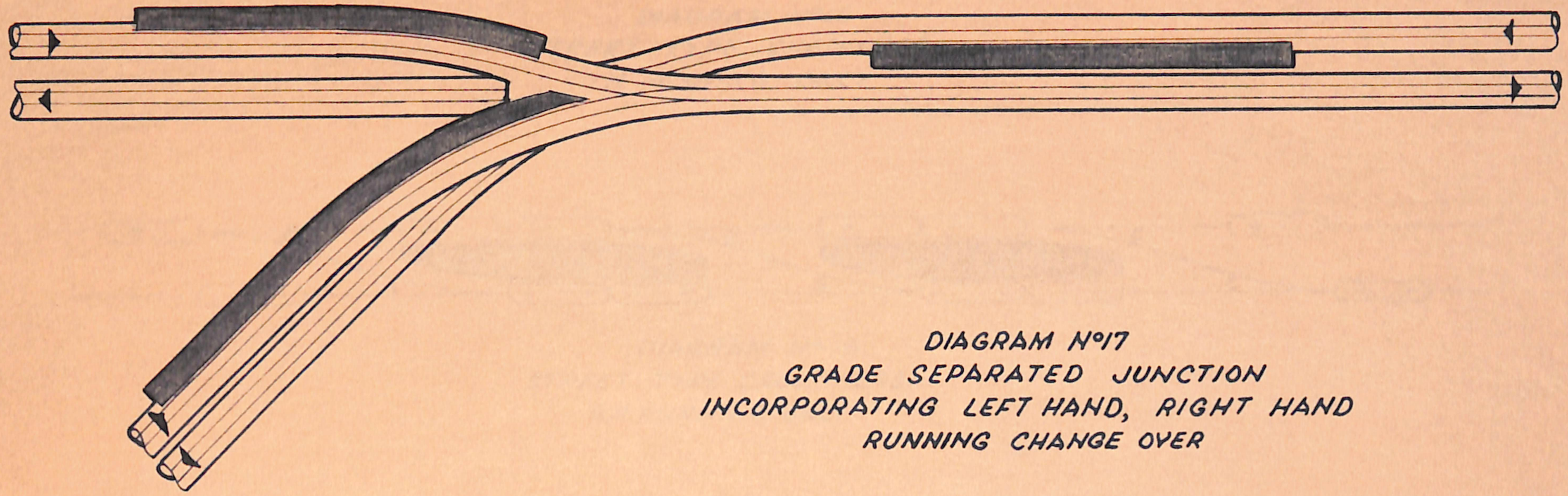


DIAGRAM Nº17
GRADE SEPARATED JUNCTION
INCORPORATING LEFT HAND, RIGHT HAND
RUNNING CHANGE OVER

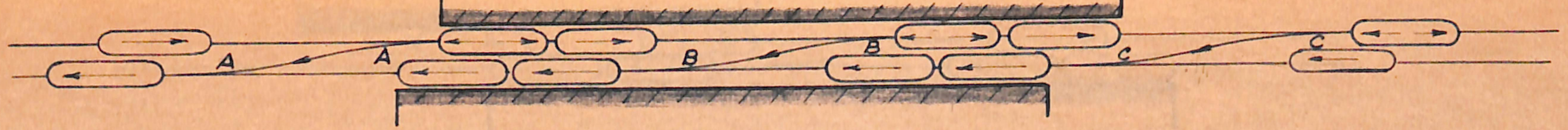


DIAGRAM Nº 18
STREET TYPE CROSSOVERS
L.H. RUNNING ONLY

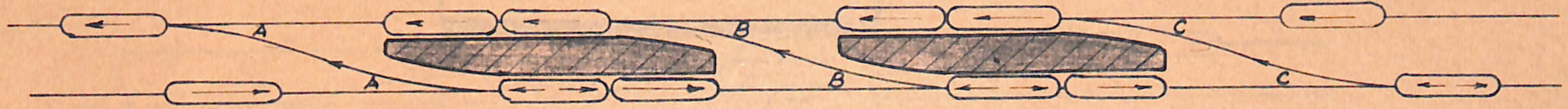


DIAGRAM Nº 19
STREET TYPE CROSSOVERS
R.H. RUNNING ONLY

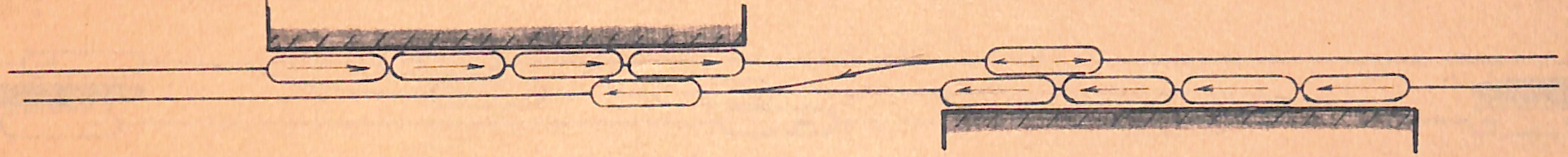


DIAGRAM Nº 20
STREET TYPE CROSSOVER
PLATFORMS COMPLETELY OFFSET
L.H. RUNNING ONLY

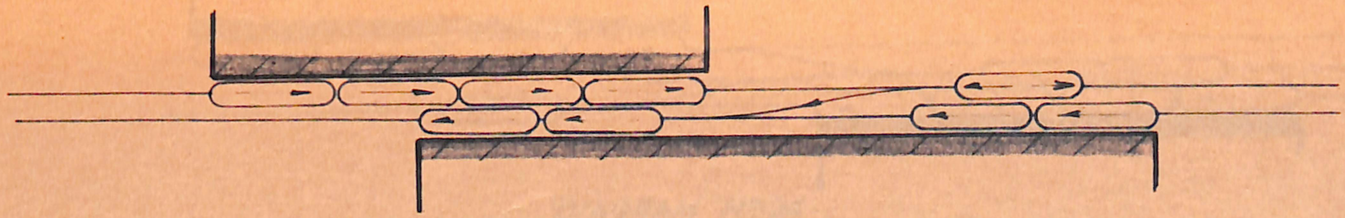


DIAGRAM Nº 21
STREET TYPE CROSSOVER
PLATFORMS PARTLY OFFSET
L.H. RUNNING ONLY

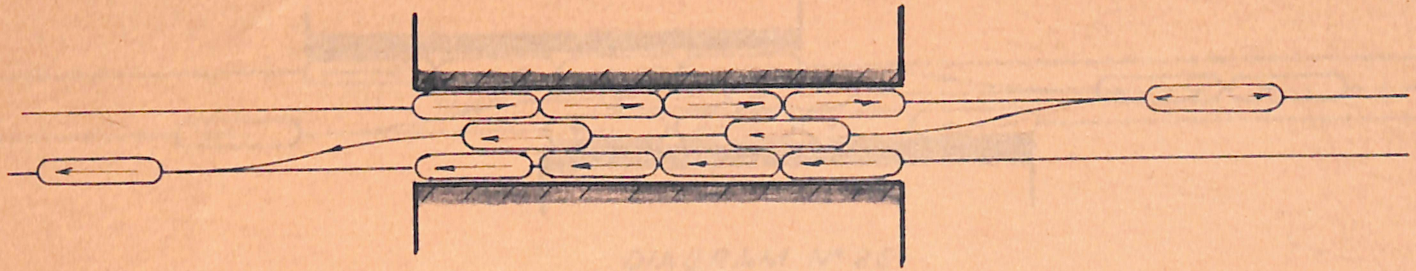


DIAGRAM Nº 22
STREET TYPE CROSSOVERS
TRACKS AT DIFFERENT LEVELS
L.H. RUNNING ONLY

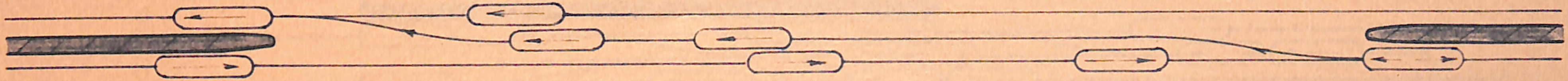


DIAGRAM Nº 23
STREET TYPE CROSSOVERS
TRACKS AT DIFFERENT LEVELS
R.H. RUNNING ONLY

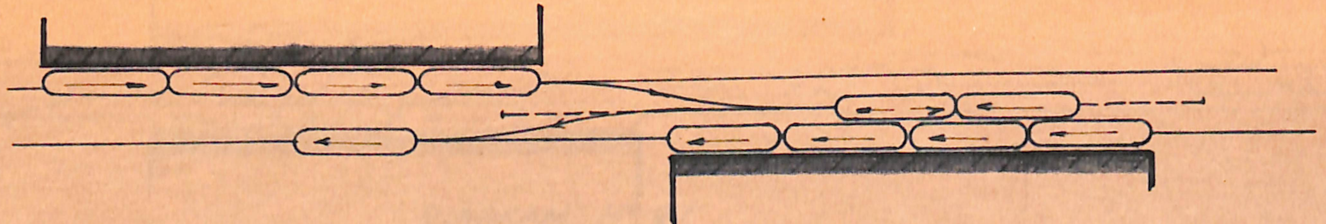


DIAGRAM No. 24
CROSSOVER WITH REVERSING SIDING
SIMPLEST ARRANGEMENT
L.H. RUNNING ONLY

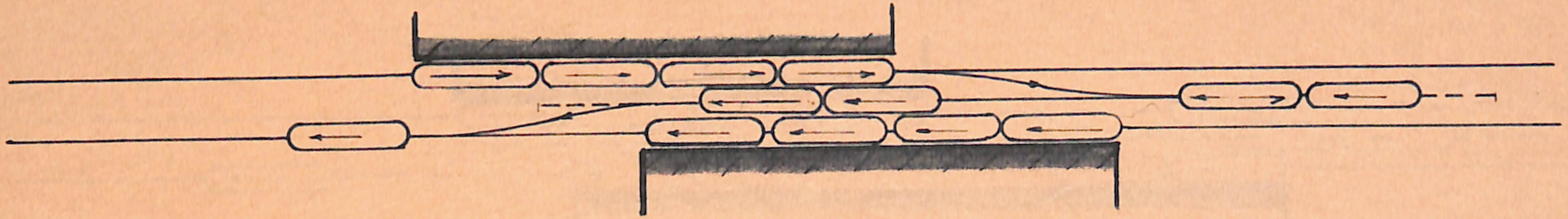


DIAGRAM No. 25
CROSSOVER WITH REVERSING SIDING
SIMPLEST ARRANGEMENT WITH TRACKS AT DIFFERENT LEVELS
L.H. RUNNING ONLY

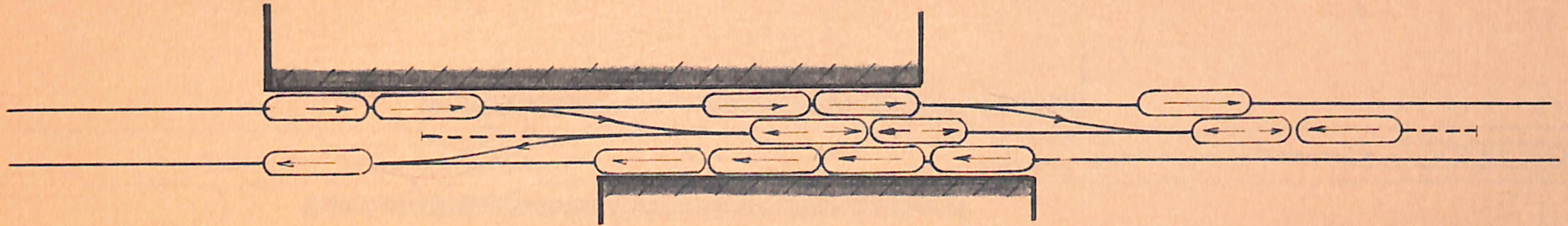


DIAGRAM No. 26
CROSSOVERS WITH REVERSING SIDING
METHOD OF ENTRY DETERMINES ORDER OF DEPARTURE
L.H. RUNNING

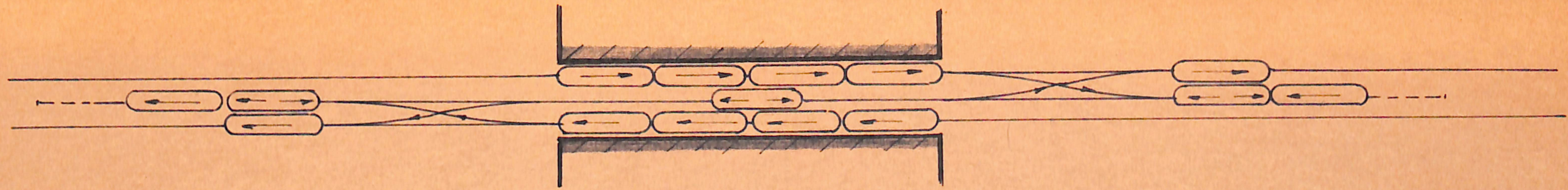


DIAGRAM Nº 30
CROSSOVERS WITH REVERSING SIDINGS
SUITABLE FOR REVERSING FROM EITHER DIRECTION
L.H. RUNNING ONLY

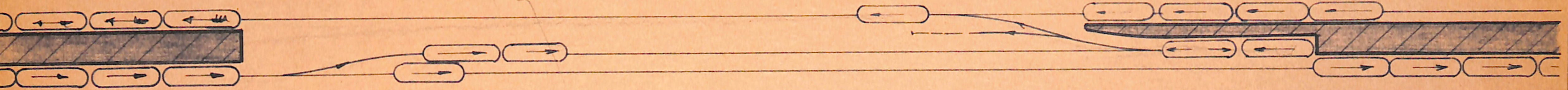


DIAGRAM Nº 31
CROSSOVER WITH REVERSING SIDING
R.H. RUNNING ONLY

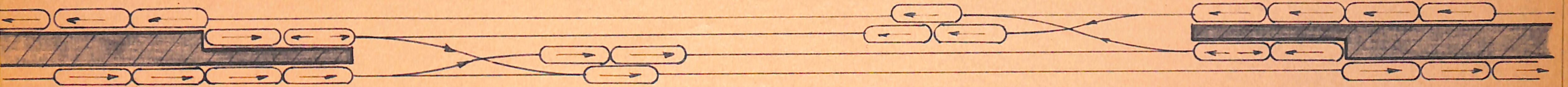


DIAGRAM Nº 32
CROSSOVERS WITH REVERSING SIDINGS
SUITABLE FOR REVERSING FROM EITHER DIRECTION
R.H. RUNNING ONLY

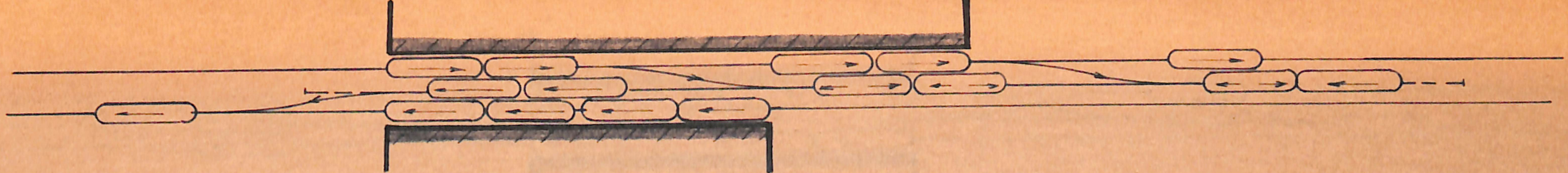


DIAGRAM Nº 27
CROSSOVERS WITH REVERSING SIDING
METHOD OF ENTRY DETERMINES ORDER OF DEPARTURE
TRACKS AT DIFFERENT LEVELS
L.H. RUNNING ONLY

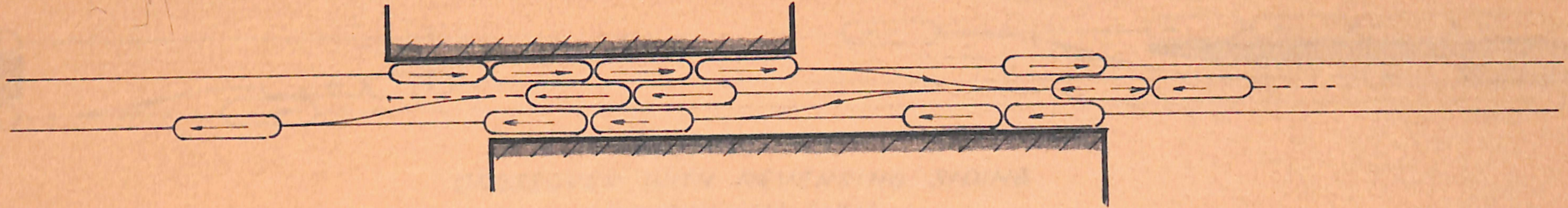


DIAGRAM Nº 28
CROSSOVERS WITH REVERSING SIDING
ORDER OF DEPARTURE DISCRETIONARY
L.H. RUNNING ONLY

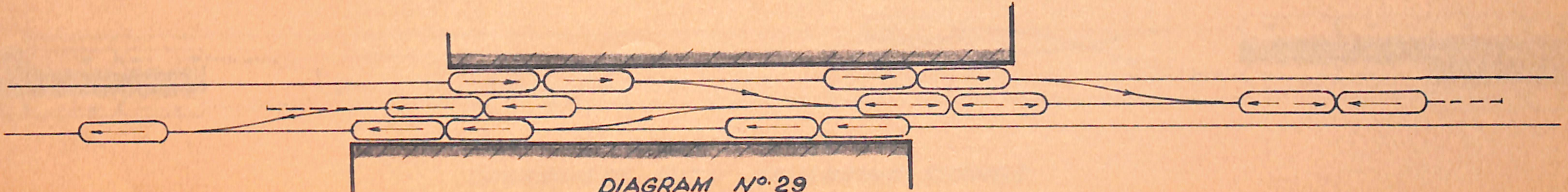


DIAGRAM Nº 29
CROSSOVERS WITH REVERSING SIDING
COMBINATION OF DIAGRAMS Nº 26 & Nº 28
L.H. RUNNING ONLY