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The horses were harnessed in two pairs, the driver being mounted on one of the rear pair. As far as can be seen from the red crayon drawing of the locomotive by J. H. Maronier, a copy of an illustration in *Die Kinderschuhe der neuen Verkehrsmittel* by F. M. Feldhaus, the traces were attached to the railings which surrounded the treadmill.

The locomotive, which had a metal frame, might be described as a 2-2-0. The driving wheels were large—something like 8 ft. in diameter—and the leading wheels smaller. Both axles had leaf-spring suspension.

A second man was carried on a rear platform, and presumably worked the brakes, as the drawing shows an elaborate system of brake blocks and actuating mechanism. In the best traditions, the locomotive was named; the name chosen being *Impulsoria.* A machine of this type, probably *Impulsoria* itself, was shown in Berlin in 1853.

The author has no further particulars of this machine, but the drawing suggests that the locomotive must have been very heavy, and it would seem that a good deal of the effort of the horses must have been expended in moving the machine itself.

Now for the horse which built—or almost built—a railway.

The inhabitants of Easingwold were offered the whole of the winnings, for one year, of a well-known racing mare, "Alice Hawthorn", in the year 1845. The offer was made by John Plummer, of New Parks, owner of the mare, and was subject to the promise of the inhabitants to build a railway from Easingwold to connect with the Great North of England Railway.

It must be almost unknown for a horse, in effect, to have been responsible for the funds to build a railway—but in fact the short line concerned was not built until forty-six years later!

How did the horses behave when steam engines,

Snowden of London, who, in 1824, took out a patent for a manually propelled railway car, later suggesting that the working of such cars would give "ample employment for all industrious labourers throughout the country".

This same Mr. Snowden produced a design for a horse treadmill car on a special track of its own. This enormous contraption was described in the *Register of Arts* for 14 January 1826. It combined a rack with the guide-rail system—from the "unusual" point of view it thus had nearly everything.

A track was to be laid with broad flat surfaces to take the wheels of a large carriage. Between the "rails" would be a trench, boarded over except for a central slot. On each side of the trench would be fixed a vertical rack rail, with the teeth on the inside edges, pointing towards the middle of the trench. Two vertical spindles passing through the slot from the front and rear of the carriage would have horizontal toothed wheels engaging in the rack, one on one side and one on the other, and so drive the carriage along. A reversing mechanism was included in the drive. Snowden proposed that the vertical spindles should be driven either by a steam engine or a horse treadmill. There would be a large circular platform on which two horses would walk round and round. Each horse would push against a yoke which, attached to the end of a bar, would turn a toothed wheel, 12 ft. in diameter, situated underneath the platform. This great wheel would engage two 3-ft. gear wheels, one on each of the vertical spindles driving the horizontal wheels below the track.

The horse platform would have been at least 16 ft. in diameter, so the gauge of this railway would have been very wide. Above the horse platform would have been a fixed circular platform for passengers, reached by a curved staircase at one end of the vehicle. Luggage would be carried in the centre of the horse platform, as the horses would use only a strip round the perimeter. The carriage would have weighed between six and seven tons, and Snowden calculated that it could be moved at about 10 m.p.h.

A remarkable feature was that the whole superstructure was to have been mounted on a cross-axle, and was designed to be tilted backwards and forwards by a screw mechanism to keep the platform level as the carriage went up and down hills. An attendant was to ride on the vehicle for the express purpose of working the screw mechanism. It seems probable that this refinement was due to the need to keep the tread-mill platform level to get the best work from the horses rather than for the comfort of the passengers.

As a tail-piece to the story of the horse on railways —and only a little of it has been told here—it is worth telling how a grey horse defeated a locomotive one August day in 1830, on the Baltimore and Ohio.

The locomotive was an experimental one built by Peter Cooper, a New York ironmaster. It was the first American-built locomotive to be operated on a common-carrier railway in the United States, and was called the *Tom Thumb*. The engine made its first trip, from Baltimore to Ellicott's Mills and back, on 25 August 1830, drawing a car with about 30 passengers on board, including many of the directors of the line. A speed of 15 m.p.h. was kept up without slackening for the sharp curves, and there was no trouble on the gradients. Edward Hungerford relates that "some excited gentlemen of the party when the train was at its highest speed"—18 m.p.h.—"pulled out their memorandum books and wrote some connected sentences just to show, apparently, that such a thing was humanly possible".

The appearance of *Tom Thumb* is well known. It had an upright tubular boiler feeding a single 3½-in. diameter cylinder. There were only four wheels, driven

MORE UNUSUAL RAILWAYS

By the same author:

UNUSUAL RAILWAYS (*with B. G. Wilson*)

RAILWAY SIGNALLING SYSTEMS (*with B. K. Cooper*)

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FAMOUS RAILWAYS OF THE WORLD (*with B. G. Wilson*)

MORE UNUSUAL RAILWAYS

by

obert

JOHN R. DAY

A.M.Inst.T., Assoc.I.R.S.E.

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TO RENEE

FOR HER PATIENCE, HELP

AND INTEREST

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AUTHOR'S NOTE

When I was asked by Mr. J. C. Reynolds, of Frederick Muller Limited, to write a sequel to *Unusual Railways* I had grave doubts as to whether there were enough unusual railways about which information could be obtained. Mr. Wilson and I had dug deeply into the history of such schemes when we were writing the earlier book.

More Unusual Railways has therefore been a research project rather than just a book, but in these days when new transport methods are being advocated in considerable numbers, especially for urban transport, it is perhaps a good thing that it should have been done.

Every endeavour has been made to achieve accuracy, and, where possible, contemporary accounts have been used. Where these accounts differ, as they too often do, I have used my judgement as to which account seems the most probable.

If some of the schemes in this book are a little removed from the general conception of railways, most of them have recognizable railway characteristics—and we are, after all, discussing *unusual* railways.

Enfield JOHN R. DAY

August 1959

1

HORSE AND SAIL ON RAILWAYS

IN 1676, writing on a visit by Lord Guildford, his brother, to Newcastle, Roger North recorded: "When men have pieces of ground between the colliery and the river, they sell *leave* to load coals over the ground, and so dear, that the owner of a rood of ground will expect £20 per annum for this leave. The manner of the carriage is by laying rails of timber from the colliery down to the river exactly straight and parallel, and bulky carts are made with four rowlets fitting these rails, whereby the carriage is so easy, that one horse will draw four or five chaldrons of coals, and is of immense benefit to the coal merchants."

With these two factors, the rail and the horse, the great days of railways began. From the day it was shown that the horse could pull several times as much on rails as it could on the road, the railways never looked back. From that point followed the early "steam-horse", destined to be improved practically beyond recognition and only today being pushed aside by other forms of motive power.

At the Carmarthenshire slate quarries belonging to Lord Penrhyn, where there was considerable traffic, the experiment of flattening the hitherto rounded "edge" rails, and of flattening the hitherto grooved treads of the wheels, seems to have been made in the late 18th century. The effect of this change is recorded as enabling two horses to draw a train weighing 24 tons.

On 21 May 1801, the Surrey Iron Railway was

One particular feature of this monorail system would be the automatic control under which the trains would run. As with the Alweg system, when originally expounded as a complete transport system, the trains would have no driver in the true sense, but only a train attendant located at the front of the train, whose duties would consist mainly of watching the area in front of the train to make sure that there were no collisions with objects of which the control system could have no cognizance, e.g. a crane jib temporarily obstructing the passage of the train.

The automatic train control, based on a well-known coded cab signalling and train control system, would incorporate controls for stopping the train at stations, observing speed restrictions, slowing to a greater or lesser degree as required by the sharpness of curves, and generally applying the brakes or changing to the lower speed range as required.

The train would stop automatically at stations, the control system taking account of the length of the train in selecting the exact stopping place of the front of the train in the platform. Once the train had stopped, the doors would open automatically, closing again after a predetermined interval. As soon as all doors were closed, the train would continue on its journey. There is nothing very startling about the lack of a driver, for at least two conventional "rapid transit" organisations—New York and Leningrad—have something of the sort in mind and are making experiments. The main-line railways of the U.S.S.R. are also experimenting in this direction.

In each car of the trains described by Mr. Anson, there would be a push-button and microphone enabling passengers to communicate with the train attendant, who would be able to hear calls from the microphones through a loudspeaker. This apparatus would take the place of the familiar chains and handles used for alarm purposes on trains, but would not automatically initiate a brake application. As stops would not be more than two miles or so apart, the attendant's normal reaction would be to tell the train controller (or "dispatcher"), by means of the ultra-high-frequency radio link provided, of the situation so that the train could be stopped at the next station and examined.

The dispatcher, by means of a selective code-dialling system, would be able to hold the train at the next station, over-riding the normal automatic controls. The description of the emergency given to the train attendant by the passenger would enable him to tell the dispatcher whether assistance, e.g. an ambulance, would be required.

All this is straightforward enough. When the emergency has been dealt with, the train attendant can release the train manually. Once he has done this, the doors close and the train moves away, coming under automatic control again.

Lay-by sidings and depôts for the cars are basically similar to those for normal railways. The overhead girders, however, are lowered so that the cars run just over the ground and can be entered and cleaned from ground level. The points leading to the depôts, and within them, are similar to those designed for most monorail systems, consisting of a traversable section of track. Similar points are found on some rack railways. such as that climbing Mount Pilatus in Switzerland. A section of girder supporting both the main line and the turn-out is moved sideways by hydraulic power to bring the appropriate section of track into use. The movement will be made in only 3 seconds, and it will be possible for the whole cycle to be repeated in 90 seconds—which is in fact none too rapid when the small headways of modern rapid transit lines are considered. No doubt the action will be speeded up in due course. The points can be worked by remote control, and will presumably be fitted with some type of detector to make certain that they are fully in the required position.

The question of speed would depend on distance between stations, length of station stops, etc.

The line discussed by Mr. Anson would have stations 2·47 miles apart. For this situation the cars would have an overall average speed, including stop time at intermediate stations and reduced speed operation on severe curves, of 45 m.p.h. The rates of acceleration and braking deceleration, on which the scheduled speed also depends, would be the maximum consistent with available adhesion and the comfort of passengers.

The balancing speed of the train would be 75 m.p.h. A higher speed would be of little value, for, with the short distance between stations, the trains would hardly have time to reach it before starting to slow down again for the next stop.

Although this account has been of a split-rail system, Mr. Anson and his company have also studied pure monorail systems, i.e. with a single rail. There is probably not a great deal to choose between the two, except that the enclosed rails of the split-rail type should allow of quieter operation, and there is no danger of slipping wheels caused by wet rails. Also, the double rail enables the sway of trains to be controlled to a much greater extent than is possible with a single rail—though it may also entail super-elevation on curves, i.e. banking.

A study carried out a few years ago in connection with applying "single-rail" monorail to part of Los Angeles, showed that a two-direction rapid transit system about 45 miles long could be built for something like $138,000,000. In this case some two miles of underground line were included in the route, putting up costs considerably. Even so, the cost was not much more than an average of $3,000,000 a mile, including everything necessary for operating the system, and 131 motored monorail cars. If the underground section could have

anchor bolts to concrete foundations resting on piles. The contractors used 266 hollow concrete piles and 245 wooden piles. Because of the need for exact alignment, the pillars were erected temporarily and fixed by the anchor bolts. After adjustment, the running beams were winched up to their final positions. The permanent fastenings were then made good, including the use of ferro-concrete round the foundations. The running beam is faced with lightweight concrete to give a bearing surface, the concrete being laid in a trough formed in the upper surface of the beam. Asphalt was used as a contact surface between concrete and steel. The height of the track varies from 16 to 37 ft. according to the irregularities in the terrain crossed by the line. The maximum gradient is 1 in 25.

Extensive loading tests have been carried out on the track and its various installations to detect strain and distortion. The results obtained were checked against the theoretical calculations, and confirmed the innate safety of the line. More than 400 gauges, as well as oscillographs and other instruments, were used in these tests.

The train has two coaches, each 30 ft. 6 in. long and with seats for 31 passengers. They weigh six tons each and are of monocoque construction. Extensive use is made of plastics and lightweight materials, the outer sheathing being of aluminium plate.

The coaches are unlined, largely to save weight, but the floors are covered with vinyl sheeting. Apart from fixed seats at the ends, all the seats are reversible, so that the passengers can face the direction of travel. The seats are arranged in rows of three, two on one side of the gangway and one on the other, except that there is one seat only opposite the door, in order to give passengers more room to enter and leave the coach.

The windows, of heat-resisting safety glass, run along both sides of the coach and round the driving end—there is no separate cab for the driver—and this gives passengers a very good view of their surroundings. Externally, the coaches are of smooth streamline finish, with the outer ends rounded into an attractive curve. Beneath each coach is an emergency chute, normally folded into the under surface of the coach and unseen by passengers. Should the train be stopped in an emergency between stations, the chute can be lowered so that passengers can slide down to the ground below in perfect safety. The chutes are of substantial metal construction, and are hinged to the main body of the coaches at the driving ends. The provision of this safety device meets one of the objections frequently levelled at suspended railways—that there is no way for passengers to escape in case of fire, etc.

Each coach is carried on two bogies. Curved "C"-shaped arms, attached to the centre of the bogies by four bolts with springs and rubber elements, support the coach below. The supports (or "hangers") are so arranged that the coach would continue to be supported even if all the bolts attaching the curved arms to the bogies failed.

The bogies each consist of two large pneumatic-tyred wheels in tandem, mounted in a frame supporting the electric motor. Both bogies of the coach are motored with 30-kW. motors, taking current at 600 V., d.c. Short spring arms at each corner of the bogie frame carry horizontal guide wheels, also pneumatic-tyred, which run on the side surfaces of the box girder and keep the tandem running wheels on the track. The bogie wheelbase is 4 ft. 2 in., and the distance between bogie centres is 14 ft. 8 in. Small rubber-tyred wheels are mounted fore and aft of the main running wheels, and would appear to be designed to come into use should a main tyre be punctured, so enabling the train to continue at reduced speed.

All apparatus is carried on the roof of the coaches, so that there is nothing to obstruct the floor space; and the whole length of the coach, except for the driver's position, can be used for passengers. The train is equipped with public address apparatus for making announcements to passengers, full lighting and ventilation equipment, and a telephone enabling the driver to speak with the controller. The telephone wires for this purpose are carried on the pillars supporting the track at a height convenient for the driver. There is indirect automatic emergency braking, as well as driver-controlled air brakes and an emergency braking device at the bogie centre.

Traction current is picked up by an unusual design of pantograph, mounted on the roof of the coach, from double light tramway rails mounted on insulators, upside-down on the under surface of the running beam.

There are two stations, Hon-en in the Main Zoo and Bun-en in the Aquatic Zoo. The Hon-en station is of one storey only, the cars coming down almost to ground level at this point. The structure is of lightweight steel, and extensive use is made of plastics in the outer walls. This station has been equipped with a hoist, and serves also as a car depôt.

The other station, Bun-en, is a two-storey building of reinforced concrete construction. The track is about 15 ft. above ground level here, and passengers entrain and detrain at first floor level. The ground floor contains a booking office, rest room, toilets, etc., as well as a waiting room. The outer walls are of concrete-block construction.

The track installations were manufactured by the Yawata Iron and Steel Co. Ltd., erection on site being by Ishikawajima Heavy Industries Limited. The electrical equipment for the train is by Tokyo Shibaura Electric Co. Ltd., and the coach builders were Nippon Sharyo Co. Ltd. All contractors engaged worked to the directions of the Tokyo Metropolitan Government.

In its first year of operation this line carried 1,100,000 people, and the single two-car train ran 600 miles. A careful inspection was carried out at the end of the first year, as a result of which some modifications have been or are being made.

These alterations include improvements to the ventilating system, and the changing of the resistance covers on the coach roof to make them more easily removable for inspection purposes. Asphalt, which was tried at first as a running surface, has been replaced by concrete to eliminate changes due to temperature fluctuation. Various points in connection with the "C"-shaped hangers have been improved in detail, and side supports have been provided to the hangers to reduce shocks. These cover more of the bogies, and therefore also do something to reduce noise. Some modification to the driving bevel gear ratio is also under consideration.

The monorail line, at Ueno, was intended primarily as a trial system to see whether monorail could solve the rapidly growing problem of traffic congestion in Tokyo, and it should perhaps be stressed that it is an experimental line on a somewhat reduced scale. In addition to giving experimental information, however, it is obviously popular with the public—probably mainly because it is a novelty. The 600 miles run in a year sounds very little—less than a trip from London to Edinburgh and back—but it has been done on a very short track, with a great deal of acceleration and braking and loading and unloading of passengers. The latter has obviously subjected the train to a great deal of wear and tear—probably more than would be met with in ordinary service. Nevertheless, it is of interest to note that the Tokyo Transportation Bureau, responsible for Tokyo's public transport system and for the monorail, states that in any future monorail construction, careful consideration should be given to reducing maintenance costs. The total cost of the line, including rolling stock and stations, was Y211,000,000.

3

SUSPENDED MONORAILS (2)

Among the several proposals for monorails and other rapid transit systems put forward in connection with the Century 21 Exposition at Seattle was a workmanlike suspended monorail system designed by the St. Louis Car Company. The St. Louis Car Company's proposals are particularly interesting in that they are based on over seventy years' experience of supplying material for rapid transit systems, and should therefore be a sound engineering proposition.

As put forward for Seattle, the line would have run about one mile along Fifth Avenue to the exhibition site. It would have handled up to 15,000 passengers an hour each way, with six double-car trains in service. In putting his company's scheme forward, Edwin B. Meissner, Jr., the president, said: "This type of equipment incorporates the latest components in the mass transportation field, as well as principles which have been tested and established in service. It would be the first monorail installation in America with real mass transportation capabilities."

In this system the lightweight, streamlined aluminium cars would be powered by four 100-h.p. high-performance electric traction motors of the latest type, capable of high operating speeds and smooth, rapid starts and stops. The cars would be suspended from a single overhead rail, and take on and discharge passengers from raised platforms. Inside, the cars would be provided with many features for passenger comfort, including ample head and leg room, fluorescent lighting,

(*Above*) Gibbs & Hill Inc. proposal for a split-rail suspended monorail system. (*Drawing: Gibbs & Hill Inc.*)

(*Below*) The experimental suspended monorail at Ueno, Tokyo. (*Photo: "Passenger Transport"*)

with the apex of the triangle pointing downwards. The small vertical plate is retained as a guide-rail, and is positioned along the centre line of the running surface.

The tubular supports, the curved upper parts of which are formed of short straight sections welded, now have reinforcing members welded to the inside of the curves. No points were used on either of these lines, so that it remains to be seen how this problem would be solved.

As far as can be seen from photographs, the coach used at the State Fair is the same as that used at Houston. The line is comparatively short, and no great speed is attained in the 1,000-ft. or so runs. A trial on a really adequate length of track would be most interesting, as the automobile-type engines used would then have a chance of developing their full power.

This type of monorail was proposed in 1958 for a 16-mile line linking New Orleans with Moisant Airport. The scheme, which would have cost something like $16,500,000, was put forward by Monorail of Louisiana Inc. operating under a 75-year franchise from Monorail Inc. of Houston, Texas.

Trains of two cars would have been used, running at speeds up to 100 m.p.h., and would have made the trip in 14½ minutes. Four trains would have been needed to work the service, and they were of very handsome design, finished inside in pastel shades of plastic and with gold anodized aluminium exteriors. The trains would have been diesel powered. Two of them would have worked the express airport runs and two, designed for suburban traffic, would have operated stopping services. There would have been seven stations along the route.

There were complementary proposals for two types of service—high-density and low-density. For the high-density service the cars would have seated 64, with room for another 50 people to stand. Three-coach trains would have been preferred for this service; each would have cost about $50,000 if driven by petrol or diesel engines, or $57,500 if electrically powered. The supporting columns for the track would have been 100–125 ft. apart. The low-density system would have had coaches seating 26 with 15 standing. They would have cost $25,000 each, or $28,750 if electrically powered. Columns for this type of service would have been 70–80 ft. apart.

Little has been published about an intermediate system tried by Monorail Inc. in November 1957, probably because it was soon dropped as unsuitable and never demonstrated to the general public. The company, however, has been kind enough to send photographs of this design, known as the "A" system. It was a saddle-type monorail, with the car above the rail and guide wheels running on the side of the "I"-shape track beam. The beam itself seems from the photographs to have been of steel. A trial coach was built, looking something like the fuselage of an aircraft, the resemblance being increased by a large plastic nose incorporating a round window, very much like the nose of certain bomber aircraft. The upper part of the body was largely of plastic, and the doors slid on runners along the outside of the main body. The doors were curved to follow the shape of the coach—vertical sides to the waist rail and a semicircular roof section. The guide wheels were shrouded by streamline "spats".

The most important reason for abandoning this system (very similar basically to the Alweg) was that a heavier and therefore more expensive rail was needed. The type of column, in the event of a double track being required, would have been more expensive than those used for the original "Skyway" system. A secondary point, but important, was that the rail was only about 15 ft. above ground, whereas with the "Skyway" the tubular or triangular track beam is at least 27 ft. up. This greater height is held to be of æsthetic advantage when city operation is envisaged. No performance details of this over-rail coach are available.

Another proposal put forward for the Seattle Exhibition line is that of the Northrop Corporation. This well-known aircraft and missile manufacturing company calls its system the "Gyro-Glide Transit System", and it is in some respects a combination of well-proven ideas rather than new ones. The whole thing, however, adds up to an attractive proposition.

The main track structure in this proposal is a massive split box girder—4 ft. × 5 ft.—built, apparently, of concrete, and supported by pre-cast concrete arches springing from both sides of a street to meet above the girder in the centre. These arches would have been 75 ft. apart in Seattle, with a span of about 54 ft., and high enough to give a clearance of at least 16 ft. between the road surface and the bottom of the train. Near the terminals, pylons of inverted "L" shape would have been used as supports instead of the arches, and would have been spaced at 60-ft. centres. These pylons were designed to be of pre-cast post-tensioned concrete.

In the Northrop system, the box girder would be split along its lower surface to allow supports for the cars to pass through, and would have two rails of standard type, 2 ft. 6 in. apart, on the upper side of the lower surface of the beam, so that one rail runs on each side of the centre slot. On these rails run bogies very similar to tramcar bogies (but of much narrower gauge) and using wheels resembling those of P.C.C. cars in having a rubber insert. The 26-in. flanged wheels would be of aluminium, with steel tyres and, of course, the rubber insert. The wheelbase is 6 ft. The track has been designed by J. H. Pomeroy & Company in co-operation with the Northrop Corporation.

Four-coach articulated trains are envisaged, with two sliding doors on one side of each of the cars as far as the Seattle project is concerned—but this would not necessarily be the case in another application, where doors on both sides might be an advantage. Each car seats 64 passengers, and has a safety chute incorporated in the fairings underneath, much as in the Tokyo monorail design.

Every axle in the train, except for those of one bogie, is driven by a direct current electric motor of 85 h.p. continuous rating. These would give an operating speed of 50 m.p.h. over the Seattle route. Acceleration at the rate of 3·4 m.p.h. per second is considered possible, or may prove to be even bettered in practice.

At each end of the train is a power pod and driver's cabin, so that the train can run forwards or backwards with equal facility, obviating the turning loops required for unidirectional monorail systems.

These power pods are among the more unusual features of this system. Each pod contains a flywheel-motor-generator unit basically similar to those of the Oerlikon locomotives and gyrobuses (see *Unusual Railways*).

The flywheel (or gyroscope) weighs 1,000 lb., and is directly coupled to a 125-kW. generator, capable of supplying current to two of the motors driving the train. The generator acts as a motor to bring the flywheel up to speed. This process is said to take only 15 seconds, but as the flywheel speed is given as 1,800–4,400 r.p.m. it seems probable that it is only the lower figure which is reached in this 15-second period. A protection device prevents the flywheel reaching too high a speed.

Power is supplied to the train at stations to speed up the flywheel, and is also fed to the train during the acceleration period—the period of maximum current drain (for about 600 ft. from a station). The motor driving the flywheel is then switched to its rôle of generator, and drives the train motors until the next station is reached. On a reasonably large transit system, it is calculated that four out of every five miles would be covered with the train out of contact with any external power source. Even if the train should have to stop between stations, there is enough energy stored in the flywheel to enable the train to restart and reach the next station—albeit at low speed.

The "inertial drive unit" (flywheel and generator-motor) is suspended directly from a power bogie, none of the weight being taken by the structure of the pod itself. The skin of the pod is in upper and lower halves, and the drive unit can be exposed for servicing by taking off the lower half of the pod structure. The whole pod can, in fact, be detached easily when required for extensive servicing or repairs, and a spare can be put into its place.

The flywheels serve a second purpose, which is why they were referred to as "gyroscopes" a little earlier. They are enclosed in lightweight cases which are supported by two trunnions acting as gimbals for the gyroscopic action. The axis of the gimbals is across the train, and so allows the drive unit to swing in a longitudinal plane. Any rolling motion of the train will make the drive unit attempt to rotate fore and aft about the gimbal axis. This attempted movement will be dampened by hydraulic cylinders arranged between the flywheel housing and the floor of the power pod.

The final effect, therefore, will be that the flywheels will steady the motion of the train—already steadier than a true monorail because it uses the "split-rail" system.

In the Seattle application, two trains of four cars each would have been used, each 230 ft. in length and weighing, fully loaded, 51 tons (the empty weight is about 33½ tons). This would give a seating capacity of 2,560 passengers an hour one way, assuming a three-minute headway for the four-car trains. There would have been two tracks at the terminals, and trains would have used each platform alternately, one train unloading and loading while the other made the trip, taking about 90 seconds on the run.

The terminus at the Exposition end would have had a circular platform-level waiting room at one end of the main platform, connected by two covered curving ramps to the main passenger building at ground level. Points just before the station would lead off to a special maintenance building for the trains, which would have included facilities for power-pod changing.

As this book was being written, Northrop were studying the possibilities of aluminium instead of concrete trackwork.

It is evident that Northrop intend their system to be a serious contender for rapid transit schemes, and not just an exhibition stunt. In April 1959, their system was explained to a special meeting of the Board of Supervisors of Los Angeles County. Nothing more seems to have been forthcoming about the track and trains than has been stated in the last few pages, but an estimate of £35,000 as the cost of a car has been mentioned.

The Northrop system seems to have made an impression, for, according to reports from Los Angeles, the Chairman of the Board declared that a test line ought to be built immediately.

It is understood that at the meeting in Los Angeles, an artist's impression of a saddle-type monorail put forward by Northrop as a later idea also was shown.

A suspended monorail has been proposed by Alan Hawes of El Segundo, California. This uses a single suspended track beam, at the base of which wheelways are supported on projecting brackets on each side of the beam. The cars have bogies with double rubber-tyred wheels, one wheel running on each of the wheelways. The effect is thus of a very narrow gauge railway turned upside-down. Stabilizing wheels, running on the sides of the beam, are provided.

The author has been able to gather very little information about the Rice monorail proposals in the U.S.A. The proposed Rice track seems to have been an overhead lightweight structure in which guy wires were to be used to reduce the strength requirements of the vertical supports. The cars to be used on this track would have been very small, seating probably not more than 20.

The Piasecki Company, in the U.S.A., well known as manufacturers of helicopters, has proposed a suspended type of monorail using airscrew propulsion.

A few miles from Barcelona is Mount Tibidabo, the amusement ground of the city, with magnificent views from its terraces and buildings. Mount Tibidabo is reached by a single-track funicular railway 3,750 ft. in length and with a gradient of 1 in 4. Near the summit is a monorail line which swings out on high double steel supports over the mountainside, and then dives into a tunnel in which are various illuminated objects and scenes of interest.

The author has no information on this monorail except that provided by a photograph. There is a car holding perhaps a dozen seated passengers, with a driver standing at the rear. The car is open-sided, but appears to have a roof canopy. It is suspended from two small bogies, electrically driven, the wheels of which run on the bottom flanges of an "I" beam, in much the same way as in factory overhead monorail systems for transporting goods; certain warehouse cranes run on similar tracks. The Mount Tibidabo monorail is probably more closely related to a fairground scenic railway than anything else, but it *is* a passenger-carrying monorail line which appears to work perfectly successfully in its limited rôle. The speed is not known, but the design suggests that it is probably not much more than a smart walking pace.

In the 1920s, there was a project for a Central Paris–St. Denis monorail, designed by Francis Laur. Two types of car were envisaged; one with one propeller and the other with two. They would have been driven by aero engines and built of duralumin. The line would have been about 4½ miles long, and speeds of over 150 m.p.h. were discussed. In the event, the Préfecture de la Seine refused to grant the necessary concession, and the project fell through.

One curiosity in France was the suspended atmospheric monorail proposed by Andraud in 1846. It was never built on a full scale, but was a strange combination of new ideas which really reflects great credit on the inventor. There was a single girder-like rail supported on pillars of length varying according to the nature of the terrain. At the sides of the girder rail were long rubber tubes, lying between the side of the girder and vertical rollers on the front car of the train. When compressed air was pumped into the rubber tubes, they expanded; and being held flat between roller and rail, they exerted pressure to push the cars along the track. The faster the air was pumped in, the faster the train went.

Trials with a reduced scale train and track were conducted in Paris, in the Champs d'Elysées, in 1856.

A contemporary drawing shows a train with double-bodied coaches, half of the coach hanging on each side of the track. They were carried by two wheels in line running on top of the girder-rail. From the side, the coaches looked, as did many early conventional railway coaches, like two road passenger coaches put together end-to-end. If the drawing is reasonably accurate, there were two compartments on each side of the rail, each compartment seating four. Apart from these inside seats, there were seats on the roof, mounted above the rail—two, one behind the other, to each coach. The driver sat in a similar seat over the rail at the front of the leading car, and is shown with his hand on a lever—presumably the brake.

(*Above*) Artist's impression of the monorail train proposed by the St. Louis Car Company. (*By courtesy of the St. Louis Car Company*)

(*Below*) Artist's impression of the Northrop "Gyro-Glide" monorail as proposed for the Seattle Exposition. (*By courtesy of "City & Suburban Travel"*)

(*Above*) The Davino Suspended Rapid Transit System, showing a transcontinental flyer in open country. (*By courtesy of Al Davino*)

(*Below*) Artist's impression of Andraud's suspended atmospheric monorail in France (1846).

4

SUPPORTED MONORAILS (1)

ALTHOUGH, as far as the author has been able to ascertain, the first monorail line was built in 1824 by Palmer in London, it is sometimes claimed that the first working monorail was built in France. This claim is based on the building of such a line in 1872 in Lyons.

This short line ran from the Pont Morand to the park of the Tête d'Or, and was built, as many novel forms of transport have been since, for an exhibition—in this case the Exposition de Lyon of 1872. The line was about two-thirds of a mile long, and was to the designs of its inventor, M. Duchamp. The car was of saddle type, divided into two parts, one on each side of a central rail level with the roof. Traction was by cable.

The monorail systems of Lartigue and Behr were described in *Unusual Railways*, but since that book was written the author has found a reference to an electrically-operated Lartigue line built in 1884, ten years before that at the Ria mines in the Pyrenees. The 1884 line was built for an Agricultural Exhibition in Paris. It was an experimental passenger line, with pannier-type cars fitted with seats. The train of five cars was hauled by a 6-h.p. Siemens electric locomotive, also of pannier type, with the motor geared to driving wheels 12 in. in diameter. The whole train, including the locomotive, weighed only five tons.

In the same year, Lartigue experimented with his monorail on a larger scale in Normandy. He was assisted by his chief engineer, Fritz Bernhard Behr.

The Feurs–Panissières line came rather later than this, and a few years after the Listowel and Ballybunion line, which it very closely resembled. The line was about 10½ miles long, the track resembling that of the Ballybunion line. The actual running rail was a minimum height of 5 ft. above the ground. The line ran for three miles or so across flat country, and then wound into hillier country for the remainder of the route. A special double-boilered locomotive like those of the Ballybunion line was built by the Bietrix works in St. Étienne. There being two fireboxes, one on each side of the rail, a miniature staircase was provided on the footplate, and the fireman had constantly to be scrambling over this to feed one or other of the fireboxes. Trials held in 1894 were perfectly successful, and the opening day was duly fixed.

On that day the official party climbed on board with the usual pomp and circumstance surrounding such occasions, and the train puffed merrily away to the cheers of the local populace. Three and three-quarter miles out the track sank down under the weight of the locomotive, and the train came to a precipitate and inglorious halt. No one was injured physically, but the dignity of the official party was severely hurt, and smarted even more as its members tramped back on foot to the starting point.

An inquiry was ordered, and it seems possible that not a few of the outraged official party were closely connected with it. At any rate, the commission of inquiry ordered that this "engine of death" should be demolished. To run it at all, said the commission, entailed grave risks to passengers.

Thus ended the Feurs-Panissières line, which, with a little more luck, might have become as famous as the Listowel and Ballybunion.

In May 1873, a Captain J. V. Meigs of Lowell, Massachusetts, filed an application for a patent for his elevated railway system. Meigs had been at work on this system for some six years by then, and it was a triumph for him when, secure with his patent rights—granted in May, 1875—he saw a line on his system actually under construction in Cambridge, Massachusetts, in 1886.

Only two years before, the Massachusetts Legislature had resolved that the Railroad Commissioners should examine and report on the abolition of grade crossings in "cities and the populous parts of towns", and perhaps the elevated Meigs system seemed the answer to this still-vexed problem.

The basic idea behind the Meigs system seems to have been to produce an elevated railway capable of being carried on a single line of supports—an object which monorail designers are still seeking to achieve today. The solution found by Captain Meigs was to have his track turned from the horizontal to the vertical, so that instead of the rails lying side by side they were arranged one above the other. In this way, all loads were brought automatically above the centre line of the supports. In practice, it was expected to use a single lattice iron girder or truss, 4 ft. deep, and resting on iron posts 44·4 ft. apart, as the bearer of the rails, but the designer was prepared to consider a wooden supporting structure.

The posts or pillars, he proposed, would be of wood for the wooden track system, and it would make little difference whether the wooden pillars were roughly squared, sawn square, or left in a rough state. For the iron track, he proposed pillars of two 10-in. channel bars and two plates, all riveted together to make a hollow rectangular section. Each post would rest on a plate of rather larger area than the post, and possibly provided with a boss fitting into the open end of the post itself. This would be set in a concrete and stone foundation about 6 ft. deep and 3 ft. in diameter. In soft ground, piles could be driven round the base of the posts to give added support.

A special wooden or metal lining to the post holes was proposed for sites with loose ground above but firm foundation below. Such a lining would increase the effective area, and help to resist lateral forces acting on the post. Special collars would be bolted round the post at ground level.

Posts of this nature, set in foundations such as those described, would be ample, Meigs considered, to carry a girder on which trains could safely run, the bottom of the girder being 14 ft. from the ground. It was calculated that the safe load would be 39 tons, whereas the Meigs type of train would never, at any point, impose a load of more than 35 tons.

The actual girder, 4 ft. deep, consisted of upper and lower track beams with suitable trussing between them. Rails were attached to each side of both of the track beams, so that it may be said that there were four rails instead of the one expected with a monorail track. This multiplicity of rails in a nominal "monorail" system is by no means unusual, the Lartigue and Behr monorail systems having in fact three and five rails respectively. The modern concrete beam systems, if the number of bearing points on the beam are considered, are really the equivalent of multirail systems.

The lower beam of the Meigs track girder rested on bracket angle irons riveted to both sides of each post. The upper track beam rested on top of the posts.

The lower track beam was actually a box section built up in a similar manner to the posts, i.e. with two channel bars and two flat plates riveted up with the recesses of the channel bars to the sides. In each of the recesses so formed were wooden beams, forming stringers for two of the four rails mentioned previously.

The whole beam was stiffened by riveting angle irons in the angle between the top of the beam and the posts.

The upper beam was of very similar construction, and also carried wooden stringers in the channels of the channel bars. Between each section of the track beam was an expansion joint. This was arranged by having the bolts fastening the end of the upper track beam, and the brace joining the upper beam at the end to the bracket at each post, pass through slots in the side plates of the bracket. The slots were of sufficient length to allow movement through any likely range. The brackets were regarded only as guides, as the weight was taken by terminal plates on the top of the post, on which the beam actually rested.

The comparative freedom of wood from expansion due to heat was one of the reasons for using wood stringers to support the rails, as it was held that they would help to preserve the alignment of the track. It was also, of course, a convenient material in which to place the rail fastenings and gave a measure of elasticity which the metal lacked.

The two rails carrying the real load of the train were in fact angle irons fitted on the outer and upper edges of the stringers on the lower track beam. They were fastened not only to the stringers, but also to each other and to the track beam itself by through bolts. Two vertical face rails were fixed to the stringers of the upper beam, one on each side. These were for the horizontal balancing wheels of the train. A small recess beneath the upper stringers left a space for the flanges of the horizontal wheels, which thus locked the train to the track.

The "gauge" of the bearing rails, in this case the distance from outer edge to outer edge of the angle irons attached to the lower beam, was 22½ in., and that between the vertical faces of the upper rails was 17½ in. Meigs considered that if his system were to be widely accepted it would be possible to use ordinary rails instead of the angle irons, the upper corners of the stringers being chamfered off to allow the rails to be set at an angle of 45 degrees (this is because the bearing wheels had wide flanges which bore both horizontally and vertically on the lower rails, as will presently be made clear).

Many ideas advanced by monorail promotors today were aired in connection with this monorail of well over 70 years ago. The length of the posts, for example—6 ft. below the ground, 14 ft. for clearance and 4 ft. in the height of the girder—could be varied, Meigs said, to follow the grades and contours of the ground. At "freight houses", the rail could be brought down and even sunk below surface level to bring the trains down for easy loading. These are advantages often claimed by overhead monorail advocates today—and are among the fundamental advantages of any overhead system.

The cost of such a track, carried out in iron and with high supporting pillars, was estimated at $70,000-$75,000 a mile. With low pillars, the estimate was reduced by $20,000 a mile. The very lowest cost, assuming hewn track stringers and hardwood rails, was put by H. Haupt, a civil engineer, at $4,500 a mile. This assumed that the track was being laid the cheapest possible way, with wooden construction throughout and in a well-wooded country, i.e. with timber more or less on the spot.

As might be expected, the points designed for this track were cumbersome and massive—as are many of the newer monorail points. In essence, they consisted of a section of track which could be swung on a special, very strong, hinge attached to one of the posts.

The moving section was supported towards the free end by rollers moving over a section of rail. The distance of travel was about 5 ft., this being sufficient for the train to clear the second track served by the points. The points were moved by handwheels and chains. A locking service was employed to hold the "tongue" of the points in position, the lock being removed automatically as the handwheel started to turn.

It was said that the effect of the inclined wheels of the train was such that they would shut points accidentally left open even if they were open as much as 15 in. The riding over the points must have been rough, for there seems to have been a definite angle at the hinge of the point tongue. Up to 5 degrees was apparently possible.

A much cheaper form of wooden permanent way, based on a Howe truss set on any type of post, was also advocated. The actual running rails were in the same relative position as with the iron track.

In a paper to the American Society of Mechanical Engineers in 1886, Francis E. Galloupe gave a detailed description of the type of bogie used on the Meigs railway. "It consists," he stated, "of a horizontal rectangular wrought-iron frame stiffened by cast-iron pieces and provided with stiff cast pedestals bolted to its under side, in which are fixed short axles for the wheels." These "pedestals", in fact, came down on each side of the track girder. The four axles projected outwards and downwards at an angle of 45 degrees. Each had a wheel with a right-angled groove in its circumference, made to fit the angle-iron rail on the upper corners of the lower track stringers.

Between these supporting wheels—the bogie wheelbase was 4 ft.—were two horizontal wheels, one on each side of the track beam. These ran with their tyres on the vertical rails on the upper track beam and their flanges below the edge of the rail plates. They thus made it impossible for the vehicle to leave the track, since these flanges locked the car down to the beam. To give some measure of elasticity, the vertical axles of these two horizontal wheels were allowed some movement in sliding boxes, and were kept in contact with the rails by powerful springs outside the boxes.

The main (inclined) bogie wheels were 42 in. in diameter. The groove in the circumference was deep enough to allow a tread of 3½ in. to bear on each bearing face of the lower rail, i.e. the horizontal and vertical faces. They turned independently on their own axles, which were lubricated at the journals by oil contained within the hollow axles themselves. The journals ran, in fact, in an oil bath.

Substantial braces, just clearing the track, ensured that the car could not overturn if any, or even all, of the wheels should collapse. In such a case the bogie frame, normally carried just clear of the upper track, would drop an inch or so on to the upper rail and glide along it harmlessly.

A movable frame in wrought iron, on the top of the bogie frame, carried four spring posts with heavy spiral springs inside them. Two posts were on each side of the bogie, carried on segmental members of the movable frame. These posts locked by flanges into sockets in the frame of the car. A centre pin ensured that the bogie turned about the centre of the movable frame. The car was thus locked to the movable frame, and this in turn was locked to the bogie by flanges on the bogie frame which extended above the intermediate movable frame.

Another type of bogie designed for the Meigs system, but not built, retained a similar pattern but had the supporting wheels running in the normal vertical position on each side of the track beam. In this design, the supporting wheels had flanges on their outer rims. It appears to have been produced as more suitable for cars worked by electricity. The track is similar to that used for the inclined-wheel design, but has the rails insulated from the girders to enable current to be distributed by and picked up from the rails. The drive from the motors would have been through the horizontal wheels.

The locomotive "frame" was a flat platform truck, supported on two bogies of the type already described, and 7 ft. 6 in. width and 29 ft. 3 in. in length overall. The tender was 25 ft. 8 in. in length, and had room for luggage as well as for water and coal.

On the floor of the locomotive section were mounted two single-cylinder steam engines, each driving a single horizontal driving wheel, one on each side of the upper track beam and opposite one another, half-way between the bogies. The 12-in. × 22-in. cylinders were horizontal and the piston rods connected with independent crossheads sliding on steel guide rods supported by cast-iron standards.

The driving wheels were 44½ in. in diameter, and, like the horizontal wheels of the bogies, were flanged on the lower edge. These wheels were carried on strong but short steel axles extending through a sliding box containing the journals and having a crank at the upper end. The crank pins were allowed to rotate in square blocks sliding in a groove formed in the underside of the crossheads, giving in effect a "slotted yoke" connection.

The slide valves were operated by common link and double eccentrics, the only unusual feature of the valve motion being the rather heavy rocker shafts necessitated by the horizontal rather than the usual vertical position.

Adhesion was provided by applying hydraulic pressure by a cylinder and piston attached to the boxes carrying the journals of the axles of the driving wheels. Adhesion could be obtained irrespective of the weight of the engine—an idea tried also by Fell, it may be recalled. The hydraulic fluid employed was glycerine, supplied from a reservoir maintained at pressure by a hydraulic pump or hydraulic accumulator designed to give one pressure for adhesion and another for operating hydraulic controls, etc. The sliding boxes referred to for the driving axles were intended to let the locomotive traverse curves. Their travel was limited to about 6 in.

The boiler, though only 15 ft. in length, was of the normal locomotive type. Five feet in diameter, it was mounted above the two engines, and rose to 7 ft. 9 in. above the flat floor. There were 208 tubes and 20·25 sq. ft. of grate surface in the firebox. The fuel was to be anthracite, to avoid making smoke in city streets. The boiler could be tilted, safely, to a point where the locomotive was on a gradient of 1 in 6½.

The fireman was at the usual position at the rear of the locomotive, where he could feed the firebox, but the driver was provided with a raised platform with windows looking remarkably like the wheelhouse of a small steamer. On a desk before him were five levers controlling hydraulic valves. These, in turn, controlled the regulator, reversing apparatus, driving wheel adhesion, brake, and couplings of the whole train. Also provided were the usual gauges and indicators, as well as voice-tubes communicating with the fireman and guard. A whistle and bell also formed part of the equipment.

There was talk of fitting a small auxiliary steam engine to throw either of the two separate steam engines over the "dead-centre" points if needed, but this appears not to have been done. The two steam engines driving the opposing wheels were, in fact, quite independent of each other, though it was suggested that they might be linked mechanically or through the valve motion.

The type of car to be hauled by this strange locomotive was equally novel. As with the locomotive, there had to be a strong flat platform as a starting point, in this case built up from 5-in. channel beams. The platform was 7 ft. 6 in. wide and 51 ft. 2 in. in length. The bogies were connected to the platform by the type of interlocking spring post already described.

The body framing was of "T" iron curved to give the exterior of the car a cylindrical shape. The panels attached to these frames, or ribs, were, to quote Francis E. Galloupe again, "covered with upholstering, which covers the entire interior, and sheathed with paper and copper upon the exterior". The purpose of the paper is not clear, unless intended to prevent action between the copper and iron.

The car was in the shape of a cylinder partially cut away where the platform formed the lower side. It was held by Captain Meigs that this shape would diminish wind resistance and stresses by fully one-third as compared with an ordinary railway car—this in the 1880s!

The car had 52 independent revolving upholstered seats of a type designed by the inventor, who also incorporated devices for "securing ventilation at each window without the annoyance of entering dust". The entire interior surface of the cars was intended to be upholstered, except, of course, for the windows. As Mr. Galloupe put it: "If it were ever desirable, one would become more easily reconciled to rolling down an embankment in one of these cars than in that of any other known form, for the entire absence of sharp corners and salient points is noticeable."

The locomotive was to be covered in a similar almost cylindrical sheath.

Yet another feature of the Meigs monorail vehicles was the automatic couplers, which were of very remarkable design. When coupled they interlocked, the nose of one drawbar passing into a socket on the next. This formed a rigid bar coupling between the end bogies of adjacent cars. Hydraulically-operated rods controlled the coupling hooks, so that the driver could uncouple any car in the train from the locomotive.

It was suggested that this hydraulic coupling would be of great assistance in the event of an impending head-on or rear collision. By uncoupling all cars, which entailed a single movement of a lever, the driver could divide the train into sections of one car each, the brakes of such cars being automatically applied as the couplings parted. A head-on collision would thus be broken down into a series of smaller blows instead of a single blow backed by the solid weight of the entire train.

The brakes were intended to operate on the opposed horizontal wheels of the bogies, but could, if required, also be fitted to the supporting wheels. Each of the two methods of braking the horizontal wheels was controlled by hydraulic cylinders.

One method consisted of powerful springs acting on toggle-joints in such a manner as to squeeze the rail between the horizontal wheels—rather as a retarder in a marshalling yard squeezes the wheels of the wagons passing over it, except that in this case the "squeezed member"—the rail—was stationary and the "squeezing members"—the wheels—moving. The other method was the more familiar one of applying brake shoes to the wheel rims. The springs were so arranged as to tend always to apply the brakes, being held off normally by the hydraulic cylinders—in fact, a "fail-safe" mechanism.

Meigs was well aware that the most efficient braking effect is applied when a wheel is braked to the point of almost, but not quite, skidding, and that much of the efficiency is lost as soon as a wheel starts to slide. The hydraulically assisted pressure of the horizontal wheels on the track retarded this point of slipping to well beyond the point at which normal adhesion would fail, and this increased the efficiency of the braking system.

In addition to these special brakes, hand brakes were fitted to each car.

The centre of gravity of these cars was claimed to be much lower than with ordinary railways on the New

York Elevated, as it was only a few inches above the floor, as compared with the four feet or so of other railways. This comparison was perhaps unfair, since it counted height from the top rail and not from the bottom. It will be obvious, however, from the method of bogie construction, that the cars would have been almost impossible to derail. They were claimed to be inherently stable, but this again seems unfair, as only the special rail formation made them stable.

A freak of geometrical forces ensured that the track was actually safer on curves than on the straight, since the form of the girder effectually spread the load. To avoid posts on street corners—the Meigs Monorail was essentially an "over-street" railway—it was found possible to support the track on diagonal trusses thrown across from opposite corners of the streets.

Calculations showed that the special arrangements for pressing the driving wheels against the rail enabled the Meigs 20-ton locomotive to exert as much tractive effort without slipping as a normal 30-ton locomotive. This pressure also enabled the driving wheel diameter to be increased so as to give greater track speed with no increase in piston speed. The inventor predicted that his train would achieve working speeds of between 75 and 100 miles an hour.

If electric working were to have been employed, it would have had similar advantages.

The weights of the vehicles (in U.S. tons) were as follows:

Locomotive complete, in working order, 20 tons.
Tender complete, in working order, 21 tons.
Passenger car, in working order and loaded, 16 tons.

One very successful monorail system which ran in California for four years seems to be almost unknown, yet it was probably the longest and certainly the fastest commercially-operated monorail line ever built, although it would probably have counted as a narrow-gauge line had it been of orthodox construction.

The line, 30 miles long, was built from Magnesium Spur, on the Trona railway, to a deposit of magnesium salts in the Crystal Hills, in barren desert south of the Wingate Pass into Death Valley. During the First World War, these deposits were prospected by the American Magnesium Company of Los Angeles, but communications presented a problem. The nearest place of any size was Randsberg, more than sixty miles by the only passable desert tracks and rather more than half that distance away in a direct line.

The ground between Randsberg and the deposits was broken and rugged; so it is perhaps not surprising that when the decision was made to build a railway to the deposits it was also decided that that railway should be a monorail line, which would cost less to build over country of this sort. The trestle design chosen bore a strong resemblance to that of Lartigue, whose monorails had been used for mining purposes in Europe.

The track consisted of a series of "A" frame trestles, with a single rail at the apex supported by a massive timber baulk. These "A" frames were themselves supported on rather wider, but lower, timber trestles, and horizontal planks ran along the top of the lower trestles outside the "A" frames. The "cross-bars" of the "A"s were carried outside the inclined side pieces, and supported, on each side, a vertical plank. There were thus five available continuous surfaces—the steel rail at the top, a vertical plank on each side perhaps 2 ft. below the rail, and a horizontal plank on each side a foot lower still. In some cases the horizontal planks were, in fact, only a few inches above the surface of the ground.

The steel rail seems to have been in very short lengths joined by angled fishplates. As far as can be seen from photographs, the rail seems to have been spiked to the baulk. All the timber used was Douglas fir, brought by water to San Pedro and then on by railway.

The locomotives and wagons were built on rectangular steel frames, and had double-flanged wheels coming up through their centres. The floors of some of the vehicles sloped downwards and outwards, following the contour of the trestles, so that in effect each wagon had two compartments of triangular section, one on each side of the rail. Others, used for timber carrying, had a narrower frame to which were riveted steel supports following the contour of the trestle downwards and forming two planked "steps" on each side. Timber could be secured to these by chains. Brakes, applied by handwheels, were fitted to the wagons. The couplings used on all rolling stock, including the locomotives, were salvaged from scrapped Los Angeles tramcars.

Of the eight locomotives, seven were driven by Fordson tractor engines, the eighth and largest having a Buda engine. The engines drove through chains, presumably on to one axle only, but the need for adhesion was not very great, as trains usually consisted of a locomotive and only one wagon—sometimes two wagons. A few trains had two locomotives and three or four trailers and must have presented a brave sight.

It was found that at speeds higher than 15 m.p.h. the rolling stock tended to sway, no matter how well-balanced; so steel rollers, 8 in. in diameter and 8 in. wide, were fitted on short vertical axles so that they rolled along the vertical planks on the sides of the "A" frames. Thus three of the five potential bearing surfaces mentioned were actually used. The rollers were held against the vertical planks by springs, and the noise, as may be imagined, was very considerable when the trains were running at speed.

The "Magnesium Monorail" or "Epsom Salts Line" —called locally the "Fastest Moving Monorail in the World"—saw some quite high speeds. The recognized top speed was regarded as 35 m.p.h., but one driver covered the 30 miles of line in exactly one hour, which suggests a good deal more than 35 m.p.h. at some points.

Started in 1922 and finished in 1924, the line cost $350,000 to build. Its operating life was short, for the mine ceased operation in June 1926, apparently as the result of competition from brine-extraction methods of obtaining magnesium. In the late 1930s the rails were salvaged and sold for scrap, and the longitudinal timbers followed suit. In 1958 a long line of "A" frames still marched across the wastes to show where the line once had run.

A picturesque little steam monorail line ran for a short time in Pennsylvania in the late 1870s. This was the Bradford and Foster Brook Railway, better known as the "Peg-Leg Railroad".

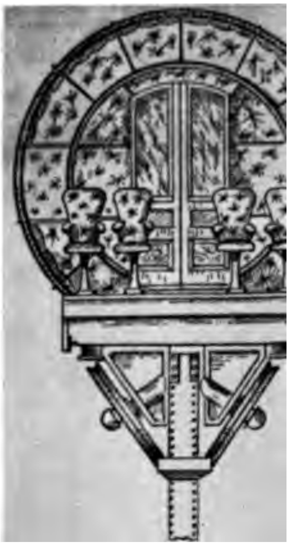
The line was built in the style of a monorail shown at the Centennial Exposition in Philadelphia in 1876, and ran from Bradford up the valley of the Foster Brook to Gilmour, a distance of some four miles.

The railway was proposed in 1877, the articles of agreement between the members of the railway company being dated 2 October 1877. The company's charter was granted only two days later, and with Colonel A. L. Wilcox as President the company started on the construction of the line. After some of the usual troubles, especially with owners of land needed for the right of way, building was pushed ahead; the line reached Tarport (now East Bradford) by January 1878, and was opened to traffic. At that time Tarport had a population of 900. The whole line was open by 11 February of the same year.

In that month Eli Perkins rode over the Bradford and Foster Brook, and he has left the following account:

"The cars run astride an elevated track on a single rail. The rail is nailed to a single wooden stringer

(*Above*) Side view of Meigs monorail car.



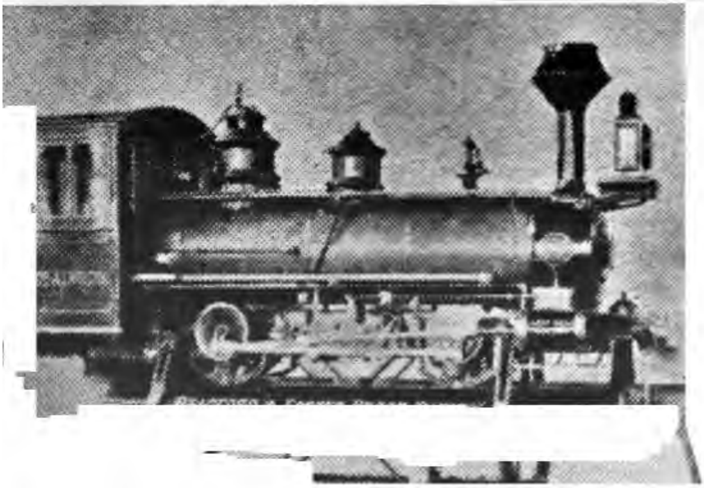
(*Right*) Cross-section of a Meigs monorail car. Note the inclined and horizontal wheels and the "padded-cell" type of upholstery. (*Illustrations from a paper by Francis E. Galloupe to the American Society of Mechanical Engineers*, 1886)

(*Below*) Artist's impression of the Meigs monorail at East Cambridge in the 1880s. Note the streamlining, inclined wheels, and the "ship's bridge" driving position.

(*Top*) Locomotive on the Feurs–Panissières Lartigue monorail line in France (1894).

(*Centre*) The original locomotive on the Bradford & Foster Brook Railway. Note the superficial resemblance to a Lartigue locomotive. (*Photo: Courtesy Charles E. Keevil*)

(*Below*) Locomotive for the Bradford & Foster Brook Railway or "Peg-Leg" Railroad. The photograph is from an old newspaper—hence the poor quality.



which rests on top of piles. So evenly balanced is the train that passing over a pond or creek at the rate of twenty miles an hour, the water is hardly disturbed. The motive for building is economy, the price per mile being $3,000 and the cost of a ten-ton locomotive $3,000. The locomotive is a queer-looking thing. An Irishman here compared it to a pair of boots swung over a clothes line. The boiler is without flue, the engine without a piston and the driver [driving wheel] without a crank. I rode with General Stone round corners and up steep grades at 30 miles an hour."

The reference to General Stone seems to link the railway even more closely with the Philadelphia Exposition, for Stone exhibited a monorail line there. According to accounts seen by the author, however, it was a much more massive affair, and had a double-deck passenger carriage. Nevertheless, that line used a rotary-engined locomotive and so did the Bradford and Foster Brook. It may well have been the same one, which would suggest that General Stone was the man who built the Bradford and Foster Brook.

The Bradford and Foster Brook—we may as well call it the "Peg-Leg", as did the local inhabitants—had stations at Bradford, Tarport, Foster Brook, Babcock's Mill, Harrisburg Run, and Derrick City. In charge of George Grogan, the conductor, the little train made two return trips daily at first.

Technically successful as the Peg-Leg may have been, any hopes of commercial success must have been affected by the fact that the line ran parallel to a narrow-gauge orthodox railway, with stations at the same places. Not unnaturally, the narrow-gauge was not prepared to leave the field to the monorail, and some healthy competition in fares started—soon the fare of 40 cents had come down to 25 cents and ten return trips a day were being made.

Also, the rotary-engined locomotive proved unsatisfactory, and a slightly more orthodox locomotive was ordered—if anything about this line could be orthodox. It proved to weigh 15 tons when it came from the makers (Baldwin's according to some accounts, Gibbs & Sterrett according to others), and was heavy enough to put a considerable strain on the track timbers.

To quote from *Historical Bradford* (1901):

"Races between the Peg-Leg and the Narrow Gauge were frequent. The spectacle was worth witnessing. The Narrow Gauge, its bantam locomotive puffing and snorting like an overtrained race-horse, and the Peg-Leg with its unique equipment which an Irishman wittily described as 'a train of cars running on a fence' humming round the snaky curves like a bicycle scorcher on the home stretch, unquestionably was a sight that afforded the passengers plenty of diversion. But while the little road was a novelty, it was not practicable when measured by cold-blooded business standards. . . ."

The end of the Peg-Leg came on the morning of 27 January 1879, when the 15-ton "upright" locomotive was coupled to a passenger car and a flat wagon and set off along the line. Not far from Babcock there was a boiler explosion, and the passenger and freight vehicles crashed into the creek alongside, while the locomotive turned over on its side. Five men were killed and others were badly injured, among the dead being George Grogan; Charles Shepard, the Superintendent; Michael Hollevan, the fireman; and Thomas Luby, the driver. Among those injured was a man named Sterrett, which lends credence to the school which declares the locomotive to have been by Gibbs & Sterrett. The locomotive is said to have been undergoing trials at the time, and the names of the killed and injured suggest that this is probably true, particularly as the Superintendent and Sterrett were on board.

The Peg-Leg could not survive this disaster. In

February 1879 it was sold to Allen & Skidmore, and in March 1880 sold again by the Sheriff to A. J. Edgett of Bradford and completely abandoned.

Writing in 1901, the author of *Historical Bradford* declared that few, if any, of the old piles which marked the right of way were then standing, and "with the exception of the few survivors of that final trip, and a printed sketch, here and there, little remains to remind the resident of Bradford today of its existence".

5

SUPPORTED MONORAILS (2)

A PASSENGER-CARRYING monorail system which had a short but exciting career ran in 1910 between Bartow Station on the New York, New Haven and Hartford Railroad and City Island (Marshall's Corner), a distance of 1½ miles. It was known as the Pelham Park and City Island Railroad.

The design, first seen at the Jamestown Exposition in 1907, was by H. H. Tunis, and consisted of a single rail laid on short sleepers inside a framework known locally as the "grape-arbour". Rather flimsy braced steel "A" structures, arranged in pairs on opposite sides of the track, carried between them wooden cross-beams to which were attached, on the lower side, continuous angle-bars about 2 ft. apart. Spacers were provided at intervals to maintain the gauge of the bars, and there were also light diagonal bracings. Such photographs as the author has seen suggest that these pairs of "A" frames were provided at intervals of about 50 ft., but they may have been closer on curves—and there were many curves on this short line.

The car—there was only one, known to all as the "Flying Lady"—had four double-flanged wheels in line, running on the single rail. The driving motors were gearless, and were mounted on an extension of the axle outside the bogie frame, making them easily accessible for maintenance purposes. On the top of the car were two "bogies", each with four horizontal wheels on the ends of a framework in the shape of St. Andrew's (diagonal) Cross. These wheels, popularly known as "ears", ran inside the angle irons attached to the cross-beams of the "A" frames, and gave the car the necessary stability at low speeds. The car narrowed at the ends to a sharp prow and stern, and had rows of glass windows along the side—in fact, from the side it might have been taken for a normal single-deck tramcar.

This impression would have vanished if the car had been seen moving. This car was built for speed, and the track was designed for a car travelling at speed. Any speed limits would have forbidden falling below a given speed rather than rising above it.

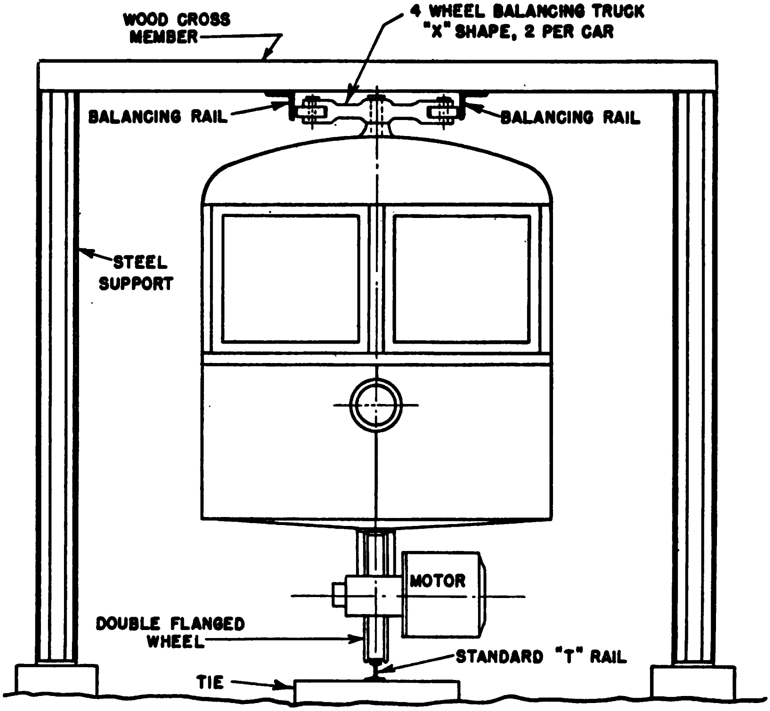


FIG. 1. The Tunis overhead balanced monorail

The line was built by August Belmont, who had seen the prototype car work at the Jamestown Exposition. He was impressed by the car's performance, and especially by the way in which the overhead guide rails caused the car to "bank" on curves so that they could be taken at full speed. This feature was the secret of the car's performance, but was also to prove its downfall.

One morning in April 1910, the car was ready for its first official trip down the track which had been laid on the route of the old horse tramway, in which Belmont had acquired a controlling interest. He had then obtained, in 1909, the consent of the Public Service Commission to the building of the new line.

Reports say that the car listed ominously as it took on its load of notabilities at Bartow Station. It started shakily, steadied as it gained speed, and hurtled round the first curve at 50 miles an hour. In one and a half minutes it was at Marshall's Corner, having covered the 1½ miles, from a standing start to a stop, in even time. This performance would be almost incredible even today, and the car did it every day for four months, shuttling backwards and forwards between Marshall's Corner and Bartow Station. Unfortunately, there had been something of a scramble to finish the line before the franchise expired, and the "A" frames and angle-irons of the track, the "grape-arbour", were not as strong as they should have been. Spikes were used instead of screws to hold the structure together, while sleepers were left on the surface instead of being sunk into the road-bed. Also, the sleepers were too short, and the road-bed was too narrow to support even the short sleepers.

Something was bound to happen, and it did. On 17 July 1910, the car left the single rail and subsided on its beam, "ears" pointed up to the sky. It was crowded with 100 passengers, some of whom were injured, and the legal battles which followed were so costly that the line could never be repaired. The car was broken up where it had crashed.

The official investigation showed that a motorman had slowed down on a curve to be taken at 55 m.p.h. to only 45 m.p.h. Feeling the lack of stability—because of the loss of centrifugal force—he made matters worse by slowing still more. At 30 m.p.h. the "ears" of the leaning car slipped out of the angle bars, which, weakened by poor construction of the frames, could no longer support them. There is a suggestion that the weight of the car caused the inadequate sleepers to move sideways.

Whatever the truth of the matter, it was the end of the City Island monorail. Had construction equalled design, it might have been running still. Certainly nothing like it has been known since as regards speed.

Yet another monorail was mentioned in the study of recent means of transport submitted by Signor R. Maestrelli, General Manager of the Azienda Tranviaria Municipale Milano, to the 32nd International Congress of the International Union of Public Transport in 1957. (This report is of the greatest interest to anyone interested in new means of urban transport, and the author hereby acknowledges his debt to Signor R. Maestrelli for bringing several new systems to his notice.)

This monorail system, advocated by the U.S. Monorail Corporation, was basically similar to those of Kearney and Hastings, and to that used for the City Island monorail, in that it had a single running rail below, and another supporting and guiding rail above. Perhaps the most notable feature was a lattice-girder track structure. Two lattice pylons were to be placed on each side of a central reserved strip in a road. Each would have been about 2 ft. 6 in. wide at the base and 25 ft. high. Another lattice girder stretched between the two pylons at their top and extended over the roadway on each side. Fifteen feet from the ground, another cross-piece projected out to each side. This carried the running rails at its outer ends, and the upper cross-piece carried the guiding and supporting rails. There was thus provision for two tracks, one on each side of the pylon structure. These structures would have been placed about 50 ft. apart to make the main supports for the rail. Signor Maestrelli does not say how the rails were to be supported between pylons, and the author has not been able to find this out from any other source as yet. The obvious manner, bearing the pylon structure in mind, would be upper and lower lattice girders. The cars would have been supported on rubber-tyred wheels, and presumably would have picked up electric current from a trolley-wire on the overhead structure. Two-car trains seating 78 and with room for 174 standing were envisaged. The stations would have been in the middle of the road, between the two main uprights of the pylon structure, and would have been reached by subways from the pavements.

The system is stated to have been considered for Detroit and Los Angeles. No date is given for this system, but it seems probable that, were it being put forward today, the lattice structure would be replaced by something in reinforced concrete or light metal. Undoubtedly, also, the structure would have to be raised to bring the lower part of the track structure more than 15 ft. above street level.

The monorail proposed by Senator Hastings—for many years a State Senator of New York—was very similar to the Kearney system (see *Unusual Railways*) in that it had a supporting rail below the cars and a stabilizing rail above. In the last reported version, the running rail was embedded in rubber and carried on pre-stressed concrete beams. The system was widely known as the Hastings "Railplane"—no doubt derived from the Bennie "Railplane" tried out in Scotland.

Senator Hastings has since abandoned this idea in favour of a conventional two-rail track with somewhat unconventional cars.

The original Alweg scheme and the trials with scale models at Cologne-Fühlingen were described in *Unusual Railways*. Since then, the Alweg organisation has produced a new type of vehicle, based on the old in certain respects, which has been built and tested as a full-scale project.

The new version is intended primarily for urban transport, and, like the earlier version, uses a massive concrete beam as the track. Like the earlier cars, the new vehicles sit like a saddle over this beam. The full-scale demonstration track built at Fühlingen is about 1¼ miles in length, and includes curves of varying radii. There is a station, or roofed boarding platform, and a double-track section is included to demonstrate the Alweg type of points.

The track is made up of reinforced concrete beams mounted on pillars. Each beam section is just over 49 ft. in length, 4 ft. 6 in. deep, and 2 ft. 6 in. high (actual size 15 metres long, 1·4 metres deep, and 0·80 metres wide). By making the beams hollow, the weight of each has been reduced to about 28 tons. ~~The beams are~~ made by a special vacuum method within steel shuttering, and a beam can be produced in only five hours. The beams are cast in an inverted position. The shuttering can be adjusted as required to form curved beams, with a minimum radius of curvature of 650 ft. The beams are vibrated during casting. Roughly one cubic yard of concrete is required per yard of track beam.

Two types of piers have been developed for supporting the beams, the so-called "fixed" and "pendulum" piers. The fixed piers are intended primarily for supporting double track, beam expansion being accommodated by the use of expansion joints. The "pendulum" piers are designed to allow a number of beams to be connected rigidly, with expansion joints spaced at, say, six beam lengths apart. The intermediate piers supporting these rigid lengths are free to move in accordance with the expansion or contraction of the beam. Although concrete pillars are envisaged as more or less standard, steel pillars can be used if required, and where the line crosses a road, railway, or river by a bridge the track beam can be incorporated in the main bridge structure.

Pillar foundations are about 13 ft. square, and the concrete pillars weigh 11½ tons. The maximum load on a column is about 64 tons.

The erection of the line and the transport of the preformed parts is simplified by the use of specially-built vehicles. There need be very little hindrance to street traffic when an Alweg line is erected along a thoroughfare, and it is rarely necessary to rope off a section of the highway. If required, the beams can be built out from an existing section by means of tackle placed on the last beam laid, the apparatus being moved forward beam by beam as erection proceeds. Experience gained with the building of the trial line has shown that, using mobile cranes, a line can be built at a speed of 50 ft. an hour (one beam). This speed is only possible when parts have already been stacked in readiness along the route.

One of the greatest difficulties with a monorail line, and especially one with a track as massive as the concrete beams of the Alweg system, is the provision of points to enable the train to run from one track to another. The solution as far as Alweg is concerned is to have a beam section mounted to allow a rotational movement about a vertical axis. This permits the normal straight section of concrete beam to be swung aside and replaced by a curved section (which can be steel). The points are about 48 ft. in length, and are carried, resting on wheeled chassis, on a series of auxiliary pillars. The pillars have a suitable track on their top faces, and the points can be electrically or hydraulically pushed to one side or the other. Another solution to the points problem is reported as being a "Biegeweiche" or flexible tube member strong enough to support the train but capable of being bent to connect with the appropriate track; still another is a section of beam divided into several sections, each capable of swinging to one side or the other and making a curve formed of short straight sections—rather like the coaches of a train going round a curve. It would be possible to move this jointed section to meet the appropriate track.

The speed of operation of the points, which would need to travel something over 7 ft., would be about 15 seconds.

Stations would be supported on columns of their own, not connected in any way with the columns supporting the track beam. In view of the height above ground, the platform would be fenced all round, except for openings on the track side arranged to coincide with the doors of the trains. A nylon safety net would be stretched below the track at stations in case a passenger should fall.

The trains consist of either two or three articulated cars, but, given sufficient platform space at stations, a fourth car can be added if required. The train of three cars is 96 ft. 6 in. long, made up of two cars each just over 33 ft. long and a centre car just over 30 ft. in length. All cars are 9 ft. 9 in. wide. A certain amount of seating space is lost where housings for the running wheels protrude into the cars, so that the seating capacity of a three-car set is only 76. Standing capacity brings the total number of passengers up to a possible 300.

As these trains are intended for urban service, the high speeds aimed at with the earlier type of Alweg cars (and actually achieved with the large-scale trial train) are not necessary, and the present trains are designed to attain a speed of 50 m.p.h., reaching this speed in 1,300 ft. An average acceleration rate of 3·3 m.p.h. per second and a braking rate of 4 m.p.h. per second is aimed at, but an emergency braking rate of 5·5 m.p.h. per second is possible

Electric traction is used, current being supplied from rails running along the sides of the main track beam, which is recessed somewhat between the upper and lower wheel tracks, of which more later. Current supply is at 1,200 V.; and 600-V., 160-h.p. motors are used connected in pairs in series. The three-car train has six axles, four of which are motored. This gives 640 h.p. for an empty train weight of 28 tons, or 49 tons loaded to full capacity with 300 passengers. Diesel traction can be used if required.

The train proper sits on top of the concrete beam, carried on 12 pneumatic-tyred wheels on six axles. These wheels have steel cord tyres 13·00 × 20, and are inflated to 176 lb. per sq. in. Traction power is also applied to these wheels. On the side of the track beam, at the top and bottom, are smooth running surfaces for guide wheels, which give the train its stability and guide it along the track. These wheels, which are covered by fairings, also have pneumatic tyres, somewhat smaller than those of the running wheels—8·25 × 15—and inflated to only 147 lb. per sq. in. The maximum rating of the running tyres is 10,000 lb., so it will be seen that when the train is loaded to capacity the tyres are working at very nearly their maximum rated load. Even so, the life of the main running tyres is estimated at 60,000 miles—and then they can be retreaded. Emergency runners enable a train with a deflated tyre to be run to a suitable place to get it off the main track. The rubber tyres enable gradients as steep as 1 in 8 to be climbed.

A Bosch air brake system is used, in which disc brakes, subject to continuous application pressure from

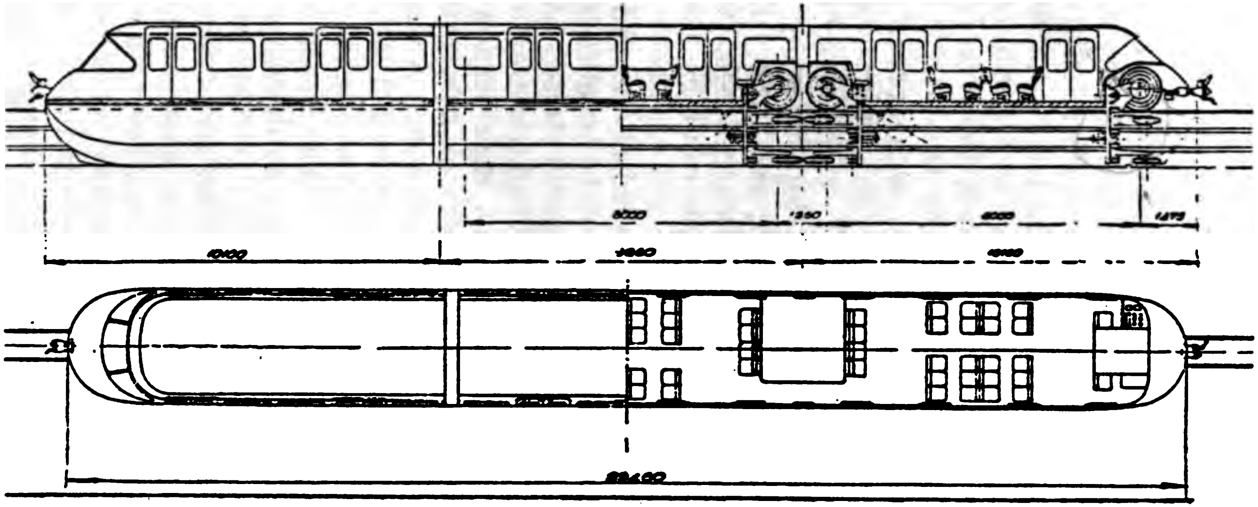


FIG. 2. Alweg train, side elevation and plan

a spring, are held in the "off" position by compressed air. Should the air supply fail, the brakes are applied automatically by the springs.

(Most of the details of the new design of car come from the report of a commission from São Paulo which visited the Cologne-Fühlingen installation when the monorail system was considered for São Paulo. Much of the report was printed in *Engenharia* (February, 1958) and reprinted in *City & Suburban Travel*, the valuable little journal issued by the Transit Research Foundation of Los Angeles Inc., each month.)

The track for the Cologne installation was manufactured in the workshops of Alweg-Forschung G.m.b.H. on the test site at Fühlingen by Hocktief A.G.; Philipp Holzman, A.G.; and Strabag-Bau A.G. The cars are by Linke-Hofmann-Busch, Salzgitter-Watenstadt, and electrical equipment by the firm of Kiepe, Düsseldorf-Reisholz.

The Californian Press reported at the end of 1958 that a 3,600-ft. Alweg line was to be installed in Disneyland, the fantastic showplace which already has several trains on a 3/5 full-size scale. The line was opened in 1959 with two three-car trains each seating 82 passengers. There is about a mile of track, substantially similar to that needed for the normal urban Alweg system.

In *Unusual Railways*, it was stated that the Alweg Monorail Corporation (Bahamas) had been awarded a contract to rebuild the entire public transport system of the city of São Paulo, Brazil, on the Alweg system. This was quite true at the time that book went to the printer, but a peculiar situation has arisen in that although the City of São Paulo gave preliminary approval, the State, which has to approve such contracts, did not do so. Instead, the matter was referred to a Commission of the Instituto de Engenharia, a combined technical and professional society of engineers. According to reports, this commission did not favour the Alweg system, and after reconsideration, a committee was sent to Cologne to study the system on the trial ground at Fühlingen. It is from the report of this committee that much of the information about the new system has been taken. The situation in São Paulo is far from clear, but it is reported that bids for an underground railway system have been invited. A similar situation exists in Caracas, where monorail (not necessarily Alweg) and underground railway interests have been called in in connection with the new transport system for that city.

A number of designs for special transport systems—six monorails and a "Carveyor"—have been put forward for the Seattle Century 21 Exposition, due to open on 10 May 1961, and to continue for 18 months. The requirement was for a system to carry passengers from a point in the centre of the Seattle hotel district near Pine Street and Westlake Avenue, to the exhibition grounds, which cover 74 acres and are just over a mile away. No intermediate stations were required, and the passenger load was expected to remain reasonably constant during the hours of operation, thus avoiding peak-hour problems. The line had to be built in time for the exhibition and removed after it finished. It was to earn its cost in the eighteen months of operation.

Several systems were put forward to meet these requirements, and the one chosen was that proposed by the Lockheed Aircraft Corporation.* Although some features of the Lockheed system are based on the unusual requirements of this particular project, the original conception of this Lockheed saddle-type monorail arose from the desire of the Corporation to be able to offer to air passengers a faster means of transport on the ground.

The track is a box girder or beam of considerable

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*As the final proofs of this book were passed, there were reports from the U.S.A. that this system might not, after all, be the one to be chosen.

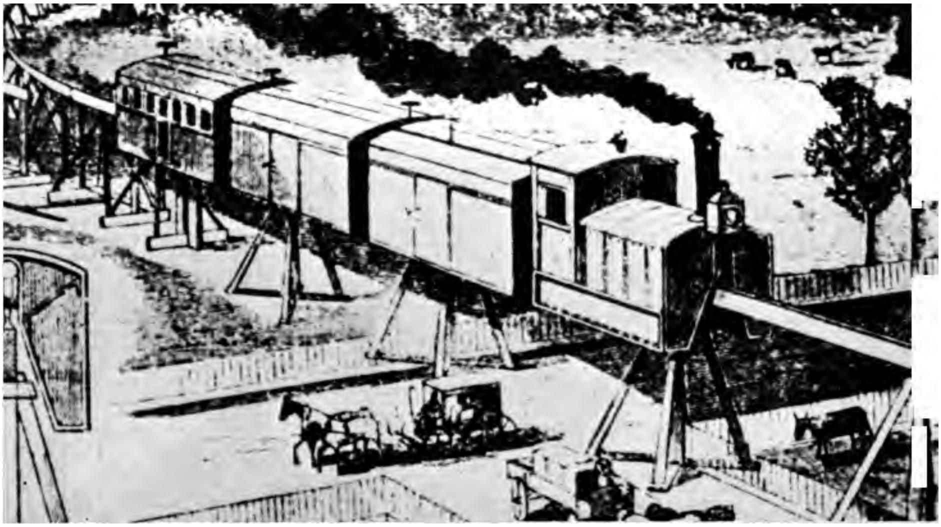
size, 10 in. wide at the top and widening to 18 in. at the bottom, and 40 in. deep. A single standard-type rail is mounted on the top of this beam to carry the main load-bearing wheels. There are also side rails on which run guide wheels.

The track beam will be supported by "T"-shaped structures built down the middle of Fifth Avenue. Each arm of the "T" holds one track—one for inbound and the other for outbound trains. The supports will be 85 ft. apart. At the terminals, the line descends to low level, and loops of 70-ft. radius will enable the trains to turn back. One set of points only will be provided, and this will be at the outer terminal. It will lead into a surface track passing into the shops of the Seattle Transit System, where the trains will be stored. The tracks will be almost 20 ft. above street level, giving a clearance of at least 16 ft. from the bottom of the cars.

Tracks, supporting structures, stations, and foundations, will be the responsibility of the Vinnell Company, Inc., of Alhambra, California, which is working with Lockheed on the development of the system.

The cars will have the inverted "U" shape necessary to enable them to fit over the rail beam. Carrying on the aircraft simile, the designers have tried to give the illusion of "flight" by making the driving compartment resemble the nose of an air liner. It even has aircraft-type controls and instrument panels. The front ends of the passenger compartments are made to resemble jet engine air intakes.

Because of the single-ended operation made possible by the loops, fixed transverse seats facing forward can be used, and six double seats are placed on each side of the track beam. The top of the central arch of the car, through which the beam passes, is roughly on a level with the seat backs, so that there is no effective communication between one side of the car and the other.



(*Above*) Artist's impression of a Lartigue line as it might have been but never was. Note the absence of stabilising rails and the simple track construction.

(*Below*) The "Magnesium Monorail" opened in 1924 in the Californian desert to exploit a deposit of magnesium salts.

(*Below, right*) Another photograph of the "Magnesium Monorail" showing the way in which the cars fitted over the track. (*Photos: American Potash & Chemical Corporation*)

Close-up of part of the beam track of the Alweg experimental line at Cologne-Fühlingen. (*Photo: Alweg*)

Artist's impression of the Lockhee monorail line to be built in Seattl for the Century 21 Exposition i 1961. (*Courtesy of Lockheed Aircra Corporation*)

(*Below*) Alweg supported monorail train on the trial track at Cologne-Fühlingen. (*Photo: Alweg*)

The cars are 21 ft. 9 in. long, 9 ft. 6 in. wide, and 6 ft. 7 in. high. The empty weight is just under 2½ tons. The front car is lengthened by the projecting aircraft-type nose to 24 ft.

Entrance to these cars is by a lifting side. This gives access to all seats on that side, and when the sides are down passengers are confined to their own seats, as there are no aisles in the cars. Standing passengers will not be allowed.

The power units are mounted in a housing behind the driving compartment and running along the centre of the car between the passenger compartments. The electric motors, fed with direct current at 600 V. from the lines of the Seattle Transit System, will be of 25-h.p. continuous rating. Control will be of rheostatic type, and there will be dynamic as well as air braking. Top speed is expected to be about 60 m.p.h.

The wheels are at the ends of the cars. There will be two flangeless main carrying wheels and eight guide wheels per car.

The trains are to be operated automatically, but an attendant will ride in the cab of each train and be able to take control in emergency. Should an emergency arise, passengers can cross from one train to another on the opposite track when the lifting doors of both are opened, and there is space for passengers in the side compartment on the outside to crawl across the main track beam through the connecting portion of the car above the rail.

It is expected that trains of three or four cars will be run, and four or five trains will be in service. The journey will be made in 93 seconds, and the train will stand for 30 seconds at the two terminal stations.

Even load distribution will be obtained by directing passengers up either one or the other of the ramps leading to the two platforms serving the two sides of the trains.

The system as put forward includes automatic block signalling, speed control, and braking as well as radiant heating, indirect lighting, sound-proofing, and public address apparatus. The capacity would be 8,640 seats an hour each way.

The cost is estimated at $5,000,000, and the line is expected to be in operation by 1 November 1960, six months before the exhibition itself opens.

Speaking on the grant of the contract to his company, Mr. Cyril Chappellet, Senior Vice President of Lockheed, stated that the Lockheed design was concerned with providing a system to meet future mass transit requirements, with "airtrains" adaptable to less costly ground-level operation in uncongested areas as well as flexibility for above-street-level or subway (underground) operation in densely developed sections.

It was also concerned with using "weight economies" inherent in aircraft design and construction, thus promoting speed and operational economies while presenting a pleasing, functional appearance of the train and its lighter-weight supporting structures. Another point, he stated, was the reduction of time losses in passenger loading and unloading, while increasing boarding and debarking safety—critical problems in rapid transit.

Finally, there was the aim of optimizing passenger comfort by using highly-effective acoustical materials for reduction of sound levels; eliminating working flanges on wheels for increased quietness, and capitalizing on the supported monorail's characteristics of minimum sway on curves; safety by being raised above the level of surface traffic; and availability of a panoramic view upwards and to the sides with no supporting arches or columns to obscure the view.

"We are optimistic about the future of monorails for urban travel, for speeding passengers to and from airports, for moving people and cargo within the confines of airports themselves, and for other uses," said Mr. Chappellet.

In May–June 1959, the Lockheed Aircraft Corporation presented a monorail plan to the Los Angeles Board of Supervisors. The plan envisages a monorail network with trains running at up to 75 m.p.h. An express system would run over a 20·8-mile route from West Covina into the city, with stops every two miles, except that the last six miles into the city would be run non-stop. The 20·8 miles would be covered in 26 minutes.

A "local" train, with frequent stops, will also cover the last six miles into the city, taking about 20 minutes for the trip.

The cost is reported as $1,500,000 to $3,000,000 a mile, compared with $9,000,000 a mile for "freeways" (multi-lane roads) and $11,000,000 a mile for underground railways.

The Lockheed Corporation suggests that with monorail lines built along the four main "corridors" running from downtown Los Angeles to West Covina, Santa Monica, Reseda, and Long Beach, some 15 per cent of all commuters could be carried by the monorails during the peak morning and evening travel hours.

Just as this book went to the publishers, it was learned from America that Lockheed have released information on a new design saddle-type monorail which, apparently, will have a floor level over the running beam, with casings covering the running wheels as in the Alweg design. Cars seating 60 and with room for 40 standing passengers are to be used, and an unverified report states that the opening sides as proposed for Seattle are to be dropped in favour of more conventional doors.

It may not be generally realized that a form of freight monorail is in commercially successful operation every day in conditions ranging from the heat of Central

Africa to the cold of the Arctic Circle, from the Persian Gulf to Australasia. This is the Mono-Rail transporter, claimed by its makers, Road Machines (Drayton) Ltd., of West Drayton, Middlesex, England, to be the cheapest form of material transporter for construction sites yet devised.

It can in fact, be used for a variety of purposes other than on building sites—carrying agricultural produce or pipes. for example. It will be seen that this system follows the true line of monorail development, for Palmer's monorail of 1825 carried bricks across the Cheshunt marshes and Lartigue's early lines carried esparto grass.

The Mono-Rail transporter is working in Britain, the U.S.A., Canada, Scandinavia, Europe, the Middle East, India, Malaya, Australia, New Zealand and elsewhere. Not only is it a highly successful monorail railway system, but it works without a driver.

The track consists of series of 12-ft. rails, which have a formed running head and channel section projections at the bottom of each rail which form running surfaces for the stabilizing and guiding wheels. The rails are 9 in. deep from the top running surface to the base. There is a simple pin and socket arrangement which enables rails to be connected very easily. Two men can carry the first rail to a site, where its outer end is dropped on to a stand.

These stands are 2 ft. wide, 1 ft. high, and 9 in. deep, and have independently-adjustable legs, which can thus be made to support the track in a vertical position even on uneven or sloping ground. The maximum height adjustment of these low stands is 6 in., but two sets of high-level stands, adjustable from 1 ft. to 2 ft. 6 in., and 2 ft. 6 in. to 4 ft. 6 in. respectively, are available. Each rail weighs 164 lb., and the three types of stands weigh 35, 58, and 90 lb. respectively. A recently-introduced extra-high stand can raise the rail to 6 ft.

A greater height can be obtained for special purposes by using scaffolding as a support.

Once the first rail has been mounted, a second one is brought up, and the pins at its one end are dropped into the sockets in the end of the first rail. The second rail has sockets at the other end; the pins of a third rail go into these, and so on. A stand is fitted at the end of each rail, so that there is a stand every 12 ft. These stands are, in effect, sleepers. Curved rails 6 ft. in length are available to a standard radius of 12 ft.

An improved box type of rail is also available in stock lengths giving 6 ft. and 12 ft. between the centres of stands. About 100 yd. of this track can be laid by two men in half an hour under average conditions. Once the first four rail lengths have been laid, the power wagon can be mounted on the track and used to carry the rest of the rails and stands to the end of the line as it progresses. Buffers are available, and also automatic stops which fit in any one of three positions to any rail and so can stop the power wagon when travelling in either direction.

One difficulty with monorails has always been the provision of points, but foot-operated points are available for this system. They consist of a length of rail pivoted at one end and moving across from the main to the branch rail under pressure from a foot pedal. These points are very simple indeed, and an 8-ft. pair weighs only 200 lb.

The trains consist of a power wagon and one or two trailers. The power wagons are 8 ft. 6 in. overall length, and have a stout frame or chassis to carry the body. At each end is a running unit consisting of a double-flanged wheel running on top of the rail, and two smaller wheels running on the side projections of the rail. The distance between roller centres is 6 ft. 8 in. Two small rollers run also on each side of the rolled top of the rail. Above the main running wheel at one end is mounted a 420-c.c. petrol engine, which drives the wheel through a gearbox incorporating two single-plate clutches operated by duplicated levers giving forward and reverse. "Stop" and forward and reverse controls are provided. For tunnelling work and other conditions where a petrol engine is not desirable, it is possible to use a battery to power an electric motor, or to fit a pick-up arrangement for a live rail or cable. A single-shoe friction-type brake is fitted which can be operated either manually or automatically.

Power wagons and trailers carry double side-tipping skips capable of carrying about 2,000 lb. in weight. The cubic capacity is something like 14 cu. ft. These skips can be replaced by bottom-discharge skips, flat platform bodies, or cradle bodies for pipe carrying.

The power wagon alone can climb a gradient of 1 in 12, or 1 in 18 with one trailer. The operating speed is about 3½ miles per hour. The trailers are of similar construction to the power cars.

Mono-Rail transporters were used in the construction of the Stockholm Underground Railway Extension, so that it could be said that the first railway vehicles to pass through some of the Stockholm tunnels were monorail cars.

More recently a new hydraulic Mono-Rail transporter car has appeared. With this, the power of the 420-c.c. petrol engine is transmitted to two driving wheels by means of a pump and two hydraulic motors, eliminating gearboxes and improving performance.

The engine and capacity are similar to those of the Mk. I type, but the brakes consist of a double-shoe external-contracting brake incorporated in the hydraulic system, giving complete control of the over-run. The power wagon can be stopped automatically or by hand, and there are duplicated operating levers giving "forward" or "reverse".

The performance on gradients is rather better with this hydraulic model, which can climb a gradient of 1 in 9 by itself, or 1 in 17 with one trailer or 1 in 28 with two trailers.

Special monorail bridges, in lengths of 24, 30, and 36 ft., are available for this very complete system.

As already stated, this system is in use all over the world, but an example of its use in connection with main-line railway work was seen at Plymouth in 1958, when a new wing and retaining wall were being built by the engineers of the Western Region of British Railways during alterations at Plymouth North Road Station.

A cutting slope some 20 ft. high had to be excavated, but its toe was so close to the main line that none of the conventional methods of spoil disposal could be used.

A narrow path cut out of the face of the cutting, however, enabled a monorail track to be laid from the foot of the slope to a level just above a rake of open wagons standing in a siding beyond the end of the slope. Sleepers were then laid across the tops of the wagons, and the monorail track was continued across the wagons themselves, ending in an auto-stop at the far end of the rake.

The trains consisted of the power car and two trailers, which, when loaded at the foot of the slope, were allowed to travel unattended up the long slope and on to the wagons, where two skips were tipped into the end wagon, over which they stood, and the third skip into the adjoining wagon. The round trip for the skips took about 4 minutes; only one man was necessary at the wagon end to tip the skips, alter the position of the auto-stop as required, and level out the spoil in the wagons.

The monorail line was extended at a later stage to take materials to a concrete mixer and bring mixed concrete from it. The Western Region also used the monorail apparatus in filling up a disused cutting at Plymouth Friary.

6

GUIDE-RAIL SYSTEMS

In the early 1800s, Ritter von Baader wrote a book. called *Neues System Der Fortschaffenden Mechanik.* In this book, he put forward a railway system of his own invention which would allow road–rail vehicles to be used. He considered it essential that freight vehicles should be able to move on the roads as well as on rails, and gave it as his opinion that this system would be economically superior to the English conception of exclusively railborne vehicles.

Thus, at a time when railways were still comparatively few, Baader was recommending the door-to-door, without transhipment, principle which the railways of today, with "piggy-back" and container methods, are still trying to achieve satisfactorily. Baader wanted freight vehicles to be able to use railways over the trunk portions of their routes, thus gaining the advantages of moving in bulk trains instead of as individual vehicles. His freight carriers would have had road wheels, and would have been guided by rollers engaging with a single central rail. Several systems using the same principle were described in *Unusual Railways.*

Although Ritter von Baader was the first, apparently, to advocate the interchangeable road-rail vehicle for freight, it should be recorded that that astonishing Cornishman Richard Trevithick (1771–1833), who invented or proposed so many things, was advocating at the very beginning of the 19th century that road buses should be capable of running on rails. As he produced *notice shall state the place or places at which the plans of the tramway to be authorised by such Bill have been or will be deposited.*"

Similar notice must also be given to county justices and to proprietors of navigable rivers in respect of their bridges or other works which are proposed to be crossed or otherwise interfered with.

Every notice under this rule must be accompanied by a copy of Rule XVII., omitting the first paragraph, and must state where copies of the draft Provisional Order, when deposited at the Board of Trade, can be obtained.

The modes of effecting the service of the notices are :—

1. Personally.
2. By leaving them at the usual place of abode.
3. By Post.

The first two methods are generally adopted, but when the notices have to be served at a distance the third method will be found convenient. When the third method is adopted the notices must be sent by post in registered letters addressed with a sufficient direction to the usual place of abode and posted at the hours and according to the regulations appointed by the Postmaster General. The notices when posted must be accompanied by duplicate lists of the addresses. These will be examined at the Post Office, and if they correspond with the addresses will be stamped, and one of the lists will be returned to the persons posting the letters.

A letter should be sent with the notice for the persons served to fill up and return acknowledging receipt of notice, and stating whether they assent to or dissent from the proposed application, or whether they are neutral in respect thereto.

The service of the notices can be proved in every case by the production of the written acknowledgments without any proof of the handwriting; and in the case of the posted letters the Postmaster's receipt is good evidence without the acknowledgments, if the letters have not been returned as undelivered.

The words "Parliamentary Notice" must be printed upon the cover of the notices forwarded by post.

When a person entitled to notice is absent from the United Kingdom his agent is the proper person to be served.

110 passengers. A speed of 160–180 m.p.h. was predicted.

This Moscow–Leningrad line was only projected, but the same account states that six cars were ordered from the Moscow Dynamo Works in 1934 for a 30-mile experimental line between Moscow and Noginsk. This line, it states, was to be built by the Government. The cars would seat 50–60 passengers and each be 82 ft. long. Whether this line was ever built seems doubtful.

The Air-Rail system, announced in April 1957 by a company formed with the name of Air-Rail Limited, was designed to give a reliable, rapid and economical link between London and London Airport. In the earliest stages of the project a consultative Study Group was formed as a result of a meeting held at the House of Commons. This group included representatives of a number of professional and public bodies. The main drive behind the promotion of the system seems to have come from Sir Alfred Bossom, M.P., who became the first chairman of Air-Rail Limited. Among the other directors on formation of the company was General Sir William Morgan, Chairman of the Gloucester Railway Carriage & Wagon Co. Ltd.

The Air-Rail system would have high-speed, pneumatic-tyred coaches running on elevated concrete beams high above road congestion. The proposals were worked out to provide a ground-service specifically designed to meet the needs of air transport. They were drawn up with a view to handling any passenger or air-freight load envisaged at London Airport. The journey time from the London terminal (Victoria) to the airport would be about 15 minutes, and, on arrival, the road wheels with which the coaches would be fitted would enable them to be handled like normal road vehicles and taken, if required, direct to the aircraft to discharge passengers or freight.

The company regards the best route as that of the lines of the Southern Region of British Railways from Victoria, *via* Clapham Junction and Feltham, and thence over open country to London Airport. The practicability of this route, from an engineering point of view, is stated to have been recognized by the Chief Civil Engineer of the Southern Region of British Railways.

A London terminal at Victoria would combine the British Overseas Airways Terminal with the Air-Rail terminus at a nodal point of the London Transport road and rail network. The railway terminus and the well-known coach station would be in the immediate vicinity—the Air-Rail terminal could well be over the railway station itself.

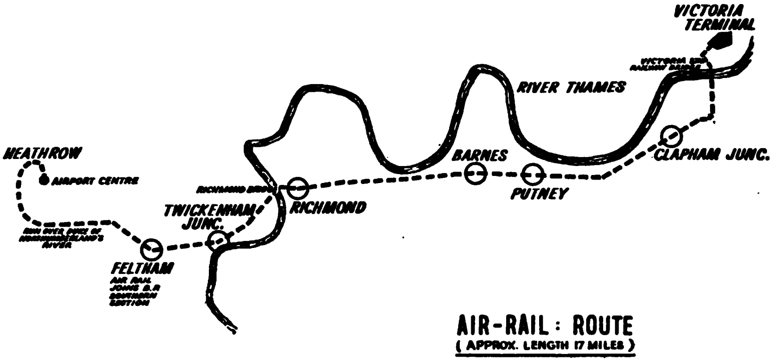


FIG. 3. The proposed Air-Rail route to London Airport

Surveys have indicated that the chosen route would entail the minimum of engineering difficulties, and cause the least possible interference with existing amenity and property rights. The engineering problems entailed in constructing the Air-Rail system over or alongside existing railway tracks are said to "present no difficulties which are not susceptible of a practical solution".

The two-way track would consist of two pre-stressed, pre-cast hollow concrete beams carried above or alongside the existing railway on reinforced concrete pillars, portals, or "A"-frames. The beams, for ease and speed of erection—particularly important in view of the limited time which normal railway operation would allow for working—would be made in 10-ft. sections assembled on site by pre-stressing cables to form 100-ft. lengths, in a manner familiar in modern bridge-building practice.

The track could be at a higher or lower level as required, and could be diverted to avoid the few buildings or bridges lying in the proposed path of the trackwork. The track would descend at the airport to allow the cars to travel on the ground round the periphery of the airport itself. This would avoid the expense—and delay—of constructing a tunnel to take the line into the central group of airport buildings. The Air-Rail coaches could use the existing road tunnel.

The rolling stock would consist of lightweight passenger coaches and freight cars. They have been likened to a Green Line type of coach capable of rising above congested areas and coming down to ground level at termini. They would be capable of a 100-m.p.h. cruising speed, a limit fixed by the performance of the tyres. With an eye to future developments, however, the track has been designed to make possible speeds of 250 m.p.h. The coaches would be fitted with ground wheels capable of carrying them on normal roads, the airport tarmac, etc.

All coaches would be self-powered, diesel driven in the first instance, and capable of operating either singly, or in two- or three-coach units. They would be of ultra-light construction, of magnesium alloy and plastics, aerodynamic in form, 40 ft. in length, with a maximum load of 50 passengers and their baggage, and weighing 12 tons fully laden. The suspension would be by metal-banded rubber bearings from wheels to bogies and by auxiliary airbag suspension from bogies to coach.

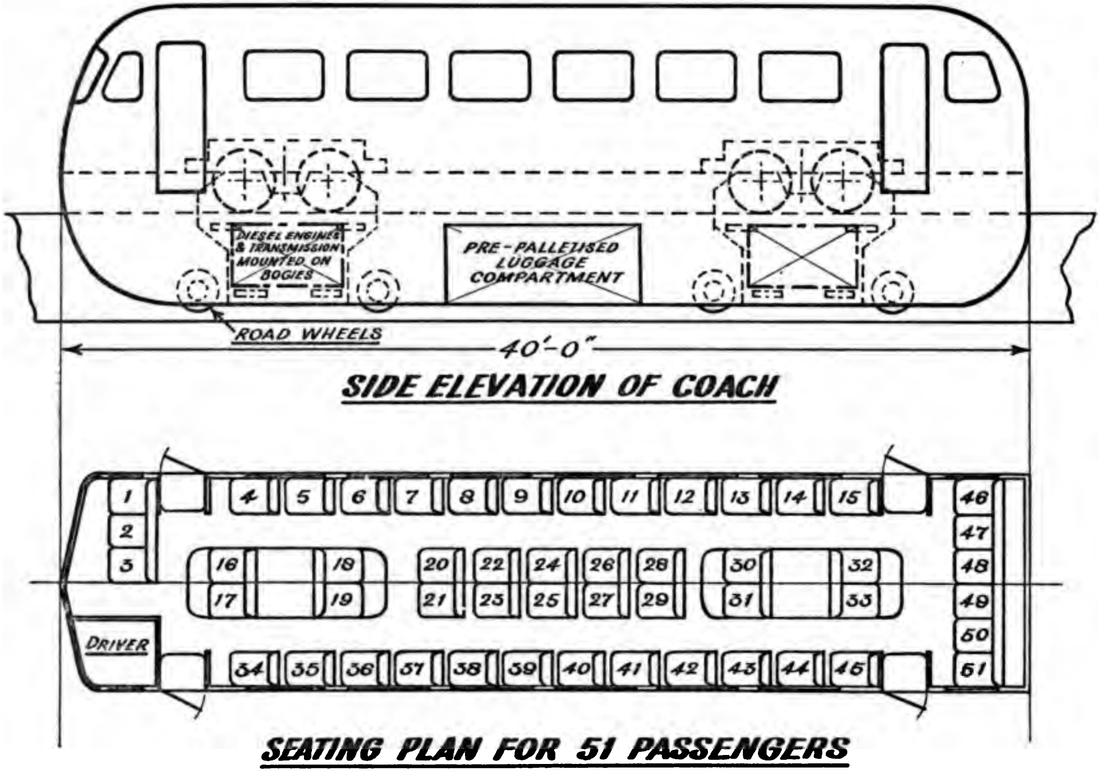


FIG. 4. Vehicle proposed for the Air-Rail monorail line to London Airport

Horizontal wheels would grip the side of the running beam to give stability, but the weight of the coach would be carried by the four rubber-tyred wheels in each bogie, arranged two-and-two, and running on the upper surface of the beam. Swing links and oil-damped spring units would allow automatic banking on curves. The beam would run from end to end through the lower half of the coach, very much as in the Alweg system.

Luggage would be pre-palletized, and carried in special compartments in the sides of the coach between the bogies. It is by no means clear how the four-wheel road bogies would be steered, or how the engines and transmission could be arranged in a bogie shaped like an inverted "U", but doubtless this will be worked out in time.

There would be no intermediate stops; and, at least at first, no junctions. Signalling, with interlocking automatic braking, would be by high-frequency induction loops, in accordance with modern practice. To enable full advantage to be taken of the high acceleration, cruising speed, and braking, the terminals would be designed for rapid clearance of platforms and, as already mentioned, pre-palletization of baggage.

The sponsors point out that the superior braking characteristic of rubber tyres, together with the absence of intermediate stops, would make possible a headway much less than that of orthodox railways. The improved figure would, with three-coach trains, give a capacity adequate for, and beyond, any likely peak load as at present envisaged. With 30 coaches in use, peak capacity could be more than 4,000 passengers an hour in one direction. This capacity could be greatly increased with more rolling stock, which is a relatively small capital outlay in comparison with the cost of the structure.

The question of cost is always of importance with any unorthodox system of transport, and it is therefore of interest to note that although the Air-Rail London Airport scheme would be more costly to build (because of having to build over a railway) than would a line in less congested conditions, the cost still works out at anything down to 10 per cent of the cost of an underground railway, taking it on a mile-for-mile basis.

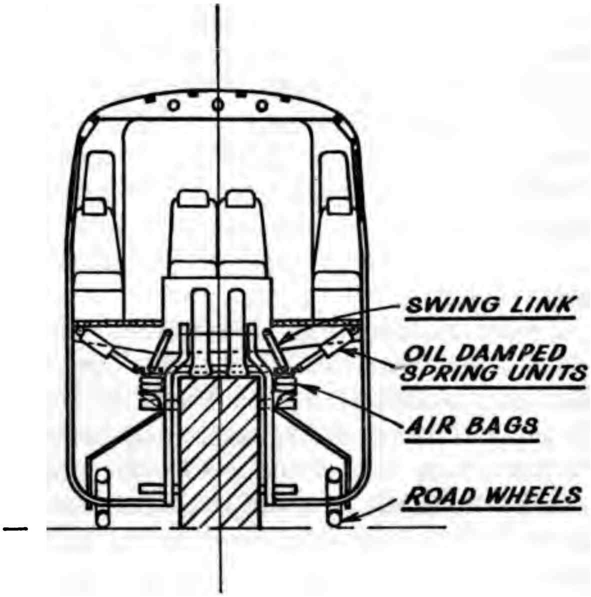


FIG. 5. Cross-section of Air-Rail vehicle at wheelbox

The consulting engineers to Air-Rail Limited consider that the cost for open, cross-country construction might be as little as one-sixth that of an orthodox railway. Subsequent maintenance costs, they consider, would also be markedly less than those for standard railway track.

To give the best returns from the enterprise, and to help London Airport to handle the rapidly-growing traffic in air-freight, freight cars would run as required on the Air-Rail system. It is also suggested that a very considerable amount of residential or "commuter" traffic from the Heathrow, Feltham and Hounslow districts could be accommodated, especially as such traffic would move in the opposite direction from the movement of peak-hour airport passenger traffic. This fact would enable full use to be made of line capacity. The total capital cost was expected (in 1957) not to exceed £8,000,000. This sum includes a suggested compensation figure of £1,000,000 to British Railways for general facilities during the construction of the line, but does not include the cost of the terminal building at Victoria. A return of not less than 12 per cent on the capital was confidently predicted. Construction time would be about three years—possibly much less—and on completion Air-Rail Limited would be willing to lease or sell the line to an appropriate public body for operational purposes.

The organizers declared themselves, on 8 April 1957, to be "ready to negotiate . . . the undertaking to construct the Air-Rail from Victoria to London Airport. . . ." The necessary technical, industrial and financial resources, they stated, had been assembled or could readily be made available as soon as an official expression of a favourable opinion in principle was vouchsafed.

At the time of writing, the Air-Rail scheme, with others, is understood to be under consideration by the Minister of Transport & Civil Aviation.

In Nairobi, on 17 February 1958, Lt.-Col. F. T. Orman, one of the founder-directors of Air-Rail Limited, was reported as saying that he had devised a £15,000,000 scheme to use the Air-Rail type of vehicle to carry coal from the coalfields north of Lake Nyasa in Tanganyika. "If there is sufficient coal in the interior of Tanganyika to justify export," he stated, "our system is the cheapest way to get it out."

Colonel Orman's investigations are reported to have shown that the cost of a monorail system in Tanganyika would be no more than two-thirds that of a normal railway. He explained that by varying the height of the supports to take account of variations in the terrain, the monorail could be kept to a more direct line than would be possible with an orthodox railway. The uniform level of the track would enable cars to travel at high speed. The system, he declared, was suitable for world-wide application, and would be particularly useful for areas such as East Africa, where the terrain hampers access for normal commercial development.

In March 1958 it was announced that officials of the Basildon Development Corporation would make a 156-acre site available for a test track 1⅓ miles long at Basildon, Essex. The cost of the test track was estimated at that time to be £240,000.

Interviewed at the time of the announcement, Mr. John Lowe, one of the original directors, who was described as "designer of the system and managing director of a British company backing the scheme", was reported as saying that they were ready to begin construction, if given Government approval, of an £8 million project that would cut the journey (from the West End to London Airport) to 15 minutes.

A type of guided-vehicle-road was proposed for New York some years ago. Known as the "Aerial Transit" system, it would have had concrete tracks, with raised edges supported at a height of 20 ft. or so above the streets. The 8-ft. wide tracks would have carried trains of pneumatic-tyred cars, possibly in articulated sets, which would have been guided by the raised edges of the track. A system with secondary lines reaching out over a radius of nearly 50 miles was proposed.

Several systems in which vehicles running on other types of surface than rails were guided by rails were mentioned in *Unusual Railways*, including the Larmanjat, "Guideways" and "Uniline" systems.

A "Guided Road" system (Leitschienenbahn) has been invented by Herr Heiner Kuch of Nuremberg. On this road ordinary buses or trolleybuses, including articulated vehicles, can be guided automatically. They retain their normal steering capabilities, and can thus run on ordinary roads also, or change from ordinary roads to the guided-road and back again during a single journey.

There is a guiding rail in the centre of the special road, or alternatively two guiding rails, one on each side, but inside the track of the normal wheels of the vehicle. The road consists in essence of two longitudinal concrete beams, each wide enough to take the road wheels on one side of the bus. There are concrete cross-sleepers between the beams, and the centre guide rail is fixed to these sleepers. If the double-rail system is used, the inner surfaces of the concrete beams can be used as the side rails. If required, both systems can be used simultaneously.

The vehicles are fitted at the front with horizontal guiding wheels, and these are on a common frame with the road wheels. The horizontal wheels are guided by the rails, and thus turn the vertical pneumatic-tyred road wheels so that they follow the concrete track beams. At the rear of the bus are other horizontal wheels, which serve only to keep the bus centrally located on the track and have no actual guiding function.

With this guided principle, special or adapted buses can run over tracks very little wider than the bus, and thus a bus can be taken safely through tunnels in the same way as a railway vehicle—or pass over overhead tracks designed with a width to accommodate the wheels and nothing more. Furthermore, vehicles can be coupled together, given suitable control systems, and run on the trunk portion of their journeys as guided-road trains. The individual vehicles can fan out to serve

SCHEDULE B.—(PART IV.) *See ante, p.* 64.

Deposit of amended plan and section.

RULE XVIII.—Should any alteration of the plan and section originally deposited for the purposes of the Order be made, with the approval of the Board of Trade, before the Order is granted, a copy of such plan and section (or of so much thereof as may be necessary), showing such alteration, shall, before the Order is introduced into a Confirmation Bill, be deposited by the promoters for public inspection:—

In England, in the office of the clerk of the peace for every county, riding, or division, and of the parish clerk of every parish, and the office of the Local Authority of every district, affected by such alteration; and

In Scotland, in the office of the principal sheriff clerk for every county, district, or division affected by such alteration.

Copies of such documents are at the same time to be deposited at the office of the Board of Trade.

Proofs of deposit and advertisement of Order as made.

RULE XIX.—When a Provisional Order has been made, and before it is introduced into the confirmation Bill, the promoters will be required to submit to the Board of Trade the following proofs, viz.:

(1.) The receipt of the clerk of the peace or sheriff clerk, or proof by affidavit of the deposit of the Order with such officer as required by Part IV. of Schedule B. to the Act.

(2.) A copy of the local newspaper containing the advertisement of the Order. This advertisement must have a short heading stating that the Order has been made by the Board of Trade under the Tramways Act, 1870, previous to its being introduced into a Confirmation Bill, and must also state the name of the office where printed copies of the Order can be obtained, which must be the office

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Trade, which will accompany the Provisional Order when delivered to the Promoters.

following of a narrow fixed track can be obtained, and although the main advantage of a true railway—the comparatively small friction of a steel wheel on a steel rail—is not obtained, there is the compensating advantage, for passenger services, that the rapid acceleration and short-distance braking associated with rubber tyres is retained.

It is only necessary to install the guide rails where the vehicles must run with precision, on a narrow track. Elsewhere they run on public roads like other buses. The track can, if necessary, be of steel instead of concrete, and this may have advantages in building overhead structures.

Points are not really necessary, as the vehicles can be steered by hand over the track junctions. If essential, however, in a confined space, points can be provided. They will be of a special counterbalanced type.

In the centres of cities, where traffic congestion is a problem, buses can run on to a guide-rail track and descend a short slope into an underground section. The tunnels need be only slightly larger than the vehicles, since the guide rail ensures that they, and any trailers, will keep precisely to the prescribed track. Because of the ability of pneumatic-tyred vehicles to climb and descend steep slopes, the buses can be brought to the surface at stops without the need for long approach ramps. Alternatively, the buses can climb on to a narrow overhead track instead of descending into a tunnel. There is no technical difficulty in building such overhead tracks with a single line of supports of comparatively small cross-section, so that an overhead guided track could be carried along and over an existing road without taking up more of the carriageway than would a normal central dividing strip. It would be worth making up "trains" of vehicles where such underground or overhead sections were long and the area of street congestion extensive. Such trains could be

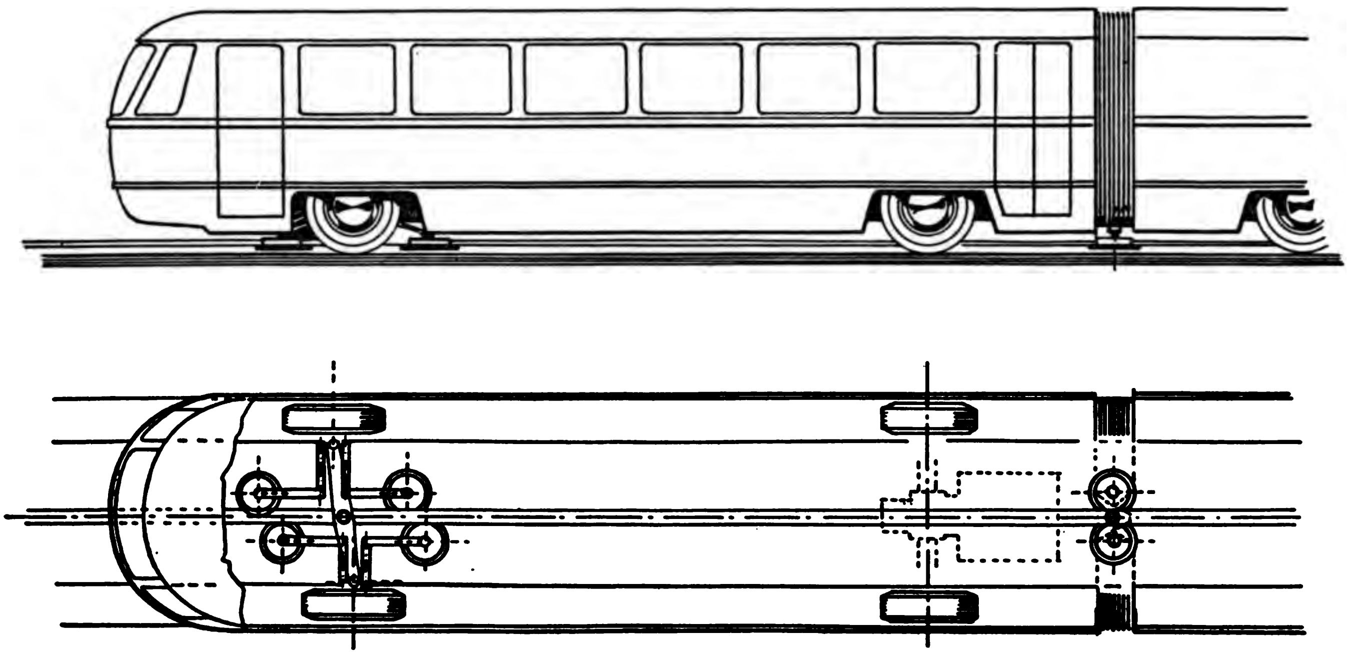


FIG. 7. Vehicles for the Kuch "Guided-Road" system (Leitschienenbahn)

of considerable capacity, as double-deck vehicles could be used on overhead track—or on underground sections, although this would make the construction of the tunnels more expensive.

Another possibility is that suitable flat vehicles, running in the guided-road tunnels, could ferry private cars through the most congested sections of cities. This possibility is perhaps somewhat lessened by the fact that street congestion is usually worst just when the buses—and consequently the tunnels—are at their busiest. Unless rates were very cheap, a driver would probably prefer to drive through a city in the less-congested hours than be carried on the guided-road vehicles.

Transit over such a line would be quiet, as all tyres, whether running or guiding, are pneumatic. The central guide rail can be a long welded rail, avoiding noise at rail joints. An example of the possibilities is already in existence in that the Paris Métro is running trains working on similar principles. The Paris system, described in *Unusual Railways*, is not quite the same as the Kuch system, but it is comparable.

There is no reason why this type of track should not be used for freight transport, so that door-to-door transit could be given by one vehicle, which could form part of a freight "train" for the trunk portion of the route. Special vehicles would be needed, probably, for freight services. A guided-road underground system would not need elaborate signalling, as the braking characteristics of a pneumatic-tyred vehicle are such that the driver can proceed on sight alone, as he does on the public roads.

A model of this system has been built on a scale of 1 : 33, and the vehicle achieved a speed of 40 m.p.h. on a 175-ft. elliptical track.

Some full-scale experiments with a similar guide rail were carried out in 1955 by the Milan Municipal road authority claiming to be compensated in accordance with the provisions of Rule XXII., and in the same manner as the penalty provided in the third section of the Act 17 and 18 Vict. c. 31, known as "The Railway and Canal Traffic Act, 1854," and every sum of money recovered by way of such penalty as aforesaid shall be paid under the warrant or order of such court or judge as is specified in the said third Section of the Act 17 & 18 Vict. c. 31, to an account opened or to be opened in the name and with the privity of the Paymaster General for and on behalf of the Supreme Court of Judicature in England [the Queen's Remembrancer of the Court of Exchequer in Scotland, (according as the railway or tramway is situate in England or Scotland)], in the bank named in such order, and shall not be paid thereout, except as provided by Rule XXII., but no penalty will accrue in respect of any time during which it shall appear, by a certificate to be obtained from the Board of Trade, that the company was prevented from completing or opening such tramway by unforeseen accident or circumstances beyond their control: Provided, that the want of sufficient funds will not be held to be a circumstance beyond their control.

Forfeiture and application of deposit.

RULE XXII.—If the promoters empowered by the Order to make the tramway do not within the time in the Order prescribed, or within such prolonged time as aforesaid, and if none is prescribed, or if the time has not been prolonged as aforesaid, then within two years from the passing of the Act confirming the Order, complete the tramway, and open it for public traffic, then and in every such case the deposit fund, or so much thereof as shall not have been repaid to the depositors (or any sum of money recovered by way of such penalty as aforesaid), shall, from and after the expiration of the time aforesaid, be applicable, and after due notice in the London or Edinburgh Gazette, as the case flat, powered railway wagons. The bus, still carrying its passengers, could work its way through the busy centre of a town on the special wagon, which would run on an elevated railway line, stopping at stations as required. Once through the city, the bus could run off the wagon at a special terminal and revert to ordinary working. The special railway vehicles could equally well run in tunnels underground and they could be made up into trains.

A slightly different idea from that of Kuch, has been proposed by Mr. Richard Hazelett, of Cleveland, Ohio, U.S.A. He suggests, as with other guide-rail methods, that buses using his system should run as ordinary vehicles on the outskirts of cities. Within city limits (or limits of congestion) they would run on a reserved track no wider than a railway track. The vehicles would run on, and be driven through, their normal road wheels.

The track would be of concrete, with a special raised section down the centre to which could be anchored a single horizontal steel rail of channel section. It would have a running face on each side.

The buses, which would have to have an unsprung front end, would be fitted with special double-flanged horizontal steel wheels which would clamp sideways on to the rail. The clamping effect could be achieved either by springs or hydraulically. The horizontal wheels would normally act only as guides, but, he suggests, could be used for additional braking power in icy weather (as in the Fell system for railways). The front wheels of the bus would have to be linked to, and controlled by, the guide wheels, which is the reason for the unsprung front end. Much attention, Mr. Hazelett considers, would have to be given to overcoming problems of insulation against rail-joint shocks and high-riding of the normal wheels in conditions of snow and ice.

7

MOVING PLATFORMS

PROBABLY the first moving platform for passengers to run on rails in Europe was the *trottoir roulant* installed for the Paris Exhibition of 1900. This was really a double-track railway on which ran two endless lines of small trucks, the trucks on each line being chained together and carrying decking designed to give a continuous moving platform on each railway line. The trucks on one line moved at 8 km.p.h., and those on the other line at half that speed. The two platforms ran closely side by side, so that passengers could step from a fixed platform at the side of the tracks on to the slower platform (*trottoir de petite vitesse*) and thence to the faster platform (*trottoir de grand vitesse*). The fast platform was two metres wide.

Travelling on the fast platform, the passenger could be carried along a track 3,300 metres in length, capable of handling 63,000 passengers an hour. The drive was electric, apparently from fixed positions, but the method of imparting the drive to the platforms is obscure.

There was a rather similar moving platform in Britain at the Crystal Palace in 1901. In America, a moving platform with slow and fast sections running side by side appeared at the Chicago World Columbian Exposition in 1893. This had seats on the fast platform.

It is not always realized that escalators are really a series of small trucks running on rails, but it is not proposed to discuss them in this book. Nevertheless, the firm which introduced the escalator in 1900 has adapted the principles involved to a form of moving passenger platform. This is the Trav-o-lator made by the Otis Elevator Company, who have embodied the safety features of the escalator into their design.

The travel-strip is made up of metal platforms faced with an escalator-tread design, cleated for combing at landings and to make it safe to step on to the strip and off it again. The Trav-o-lator has moving handrails similar to those of an escalator. The platforms are linked together to give a continuous ribbon-like surface travelling on a wheel and track system. The track rails can be made to follow any reasonable contours. Inclinations up to a maximum of fourteen degrees are possible, provided that the distance to be travelled is reasonably short. The change of angle is so smooth as to be practically imperceptible to passengers, who at all times have a firm footing. Whatever gradients the Trav-o-lator follows in its passage, it is brought on to a horizontal plane at landings.

The handrails extend beyond the actual platform, so that passengers can grasp them for support before stepping on to the moving platform. Incidentally, this automatically gives the passenger a sense of the speed at which the platform is moving—a sort of swift unconscious acclimatization. The handrail is so designed that there are no gaps between the support and the moving surface in which even the smallest child can trap its fingers. The actual surface of the handrail is of rubber, but concealed within it is a core of flexible steel which prevents stretching.

Safety devices include a speed governor, a broken-chain safety device, a non-reversing mechanism, controlled overload relays, and brakes which can bring the whole platform to a halt smoothly but swiftly.

Under certain conditions, the Trav-o-lator can even be used out of doors. The makers suggest that it could be used in airports, railway stations, and on piers for taking passengers to aircraft, trains, or ships; in shopping centres, schools, and sports stadiums in city centres, and for crossing—by means of a smooth arch—busy traffic arteries.

At present, there are two standard widths in the range available in the U.S.A.: 48 in., which will take two adults side by side, and 32 in., which will take single-file traffic or an adult and child side by side. Assuming a travel speed of 135 ft. a minute, these platforms can carry 12,000 and 7,500 passengers an hour respectively.

Such an installation has been put into service in San Diego, California, at the Cortez Motor Hotel. It runs across a covered bridge over a busy street, connecting the Motor Hotel with the El Cortez Hotel on the other side. The Trav-o-lator, in its glass enclosure, arches 127 ft. across the street.

In June 1957 work started on a Trav-o-lator system in London. This is at the Bank station on the Waterloo and City Line of the Southern Region of British Railways. For economic reasons connected with the British Railways modernization plan, work was practically suspended from the end of 1957 until August 1958, but work was then resumed at as fast a rate as possible.

The difficulties encountered slowed matters down. For example, not more than 80 or 90 men could be employed at any one time, because of the confined space in the tunnel being built for the Trav-o-lator. At street level, work could be carried on only between 7 p.m. and 7 a.m., because no interference to street traffic could be permitted. Pneumatic drills could not be used after 11 p.m., and any functions at the Mansion House meant that work had to come to a complete standstill to avoid interference.

Excavation of the Trav-o-lator tunnel was started by sinking a vertical shaft in an existing subway leading from Walbrook to Poultry. This was really the only practicable way it could be done within the limits of admissible cost, although obviously it was by no means ideal. Tunnelling from the base of the shaft was then carried out in both directions—upwards towards the ticket hall and downwards towards the Waterloo and City station.

The downwards tunnels are 16½ ft. in diameter, and are lined with cast-iron segments. All soil excavated has to be loaded into skips, moved along to the shaft and winched up to the street level, or else taken down to the platform and removed in special trains.

Near the lower end, the tunnel widens to 19 ft. 6 in. to accommodate the return mechanism of the Trav-o-lator. At the lower end the tunnel widens still more to 29 ft. 6 in. to make room for the previously existing passenger tunnel and a rail siding tunnel.

Before the upper part of the tunnel could be driven, a large number of sewers and other services had to be diverted. These included a 4-ft. sewer which ran along Poultry to the Mansion House and down Walbrook. This was diverted along Queen Victoria Street and Bucklersbury. Gas and high-pressure water mains, an L.C.C. fire main, Post Office telegraph cables and pneumatic tubes, electricity cables, and the Exchange Telegraph Company's lines were also affected. Plans for the diversions included the sinking of a 24-ft. shaft connecting with a new pipe subway to carry two 24-in. gas mains, two 20-in. water mains, and many cables.

When this book was written, constructional work was still in progress; but later in 1959 the work of installing the Trav-o-lator itself was expected to start. This is no simple task, for 8,000 ft. of structural steel-work has to be laid to form the track on which 3,904 wheels will carry 976 40-in. × 16-in. platforms, forming two separate travelling belts. The work, including the installation of the 10-ton driving machinery, should be finished in August 1960.

Some 40,000 people a day are expected to use the two tracks, both of which will run upwards in the morning peak travel hour and downwards in the evening peak hour.

The Otis Elevator Co., Ltd., makers of the Trav-o-lator, state that the machine is basically an escalator with the steps flattened out. Many of the parts are identical with those used in escalators, including the main driving machine; the motor, and the electromagnetic brake; safety governor; platform tread chains; balustrading; and moving handrail.

It is available for runs of up to about 500 ft., depending on the angle of slope—which the makers recommend should not normally be of more than 10 degrees, although short sections of up to 14 degrees can be allowed. The Bank Trav-o-lators will travel at 180 ft. a minute (maximum) and are inclined at an angle of 8 deg. 7 min. 48 sec. The tread width will be 40 in., and the machines will therefore be comparable with the London Transport type of escalator.

A particular feature is the fine-pitch metallic treads for the platforms, which will not trap even the exceptionally slim heels, almost spikes, which fashion—for the time being—decrees that ladies shall wear on their shoes.

Having dealt with a moving pavement which truly runs on rails, we must turn to a very similar device which runs not on rails, but on rollers. This is perhaps slightly outside the scope indicated by the title of the book, but the system has developed until a new form of rapid transit, using cars for passengers, has been based on it. This latter system is claimed to be capable of being used instead of urban railways, whether above ground or below, and therefore should be of interest to readers.

To deal with the moving platform for foot passengers first: this is the Speedwalk system built by the Stephens-Adamson Mfg. Co. of Aurora, Illinois. It is really a belt conveyor designed, as with the Trav-o-lator, to carry passengers over horizontal or inclined planes in a continuous flow. It is capable of any speed consistent with safety, and of being built to almost any length. Moving handrails can be provided if required. Although rollers can be used to support the belt, it can also be arranged to slide over a special platform of composition material, which causes very little friction and gives firm, uniform support. Speeds of 2-2½ m.p.h. are usual, and inclines up to 15 degrees can be negotiated. The capacity, using a single lane—passengers in single file—is 3,600 persons per hour, but widths giving up to five lanes are available.

The first Speedwalk installation has been running since 1954—the Hudson and Manhattan Railroad installation, which carries passengers from tube trains to the Erie Railroad terminal in New York. It is a three-lane rubber belt running over 600 ball-bearing-mounted rollers. Power is supplied by a 20-h.p. motor. Another belt carries passengers up 22 ft. from a bus terminal in Chicago to elevated rapid transit platforms above; it runs upwards in the morning peak and downwards in the evening, and is a double-lane belt using a composition slider base. Even greater elevation is given by a Speedwalk system at Wrigley Field, which carries passengers 60 ft. up into a grandstand. The system is 40 ft. in length, and is in two sections with four ramps to a section. This is the first moving ramp in any stadium, and can be reversed to take spectators down from the grandstand after the game.

Two other applications of note are at the strip mill of the Weirton Steel Co., where four ramps carry workers between locker rooms at street level and the working floor (41 vertical feet) and another between floors at the Aurora Savings and Loan Association's premises in Aurora, Illinois. This is comparable to a shop escalator, carrying passengers 12 ft. up in a horizontal distance of 50 ft.

The rapid transit system developed from the Speedwalk is known as the Carveyor system; incidentally, it uses a form of guide rail, so that perhaps it is closer to the title of this book than a rubber-belt system sounds at first. The Carveyor is presented by Passenger Belt Conveyors, Inc., a subsidiary of the Stephens-Adamson Mfg. Co., and by the Goodyear Tire & Rubber Company, of Akron, Ohio.

The system combines the features of—no crews; no waiting; no waste of power in starting, or of brakes in stopping; and of trains always halting at every station platform. Passengers on the Carveyor ride in cars of comfort comparable with that of standard underground railway cars, except that, for reasons which will become apparent, the individual Carveyor cars are much smaller.

The cars are carried on conveyor belts in a continuous procession, so that the propulsion machinery and running gear of the normal train is separated from the cars and confined to static locations. This lightens the cars very considerably, and also, since the conveyors run at constant speeds, avoids the surge of power taken by a normal train when starting. A trip by Carveyor starts when, at a station, the passenger steps on to the end of a slowly moving platform, just as he would step on to an escalator—except that as the platform is, and remains, flat, the action is much simpler. The cars come alongside this platform, moving at the same speed and therefore being relatively stationary so far as the passenger is concerned. At this stage both platform and cars are moving forward at about 1½ m.p.h.

The passenger then steps into a car, which moves slowly on along the length of the station platform. As it reaches the end, the doors close slowly and the car runs on to a series of rubber-tyred accelerating rollers which swiftly accelerate it to the "between-station" speed—say 15 m.p.h.—and passes it on to the fast-running conveyor belt used between stations.

These fast belts are made of rubber and fabric, and run on ball-bearing-fitted idler rollers. The car stays on the belt until it approaches the next station, where it runs over a bank of decelerating rollers which slow it down to the 1½-m.p.h. station speed.

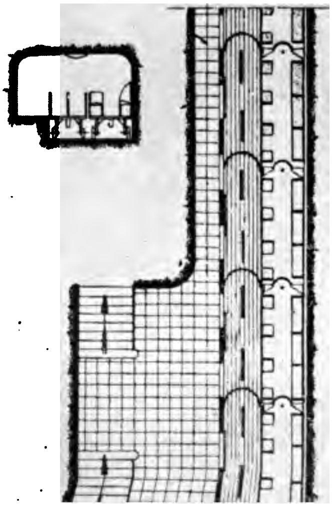
It follows that cars are close together on the slow belt, but as they move on to the fast belt their distance apart is automatically increased by the same factor as the speed differential of the belts—in the case of the speeds quoted, by a factor of 10 to 1.

A feature of the system is that the short cars can turn much sharper curves than on conventional railways, whereas an elevated railway of normal type, built above a street, must swing well out across the roadway when turning from one street to another—and even then must turn more sharply than is desirable. Moreover, the Carveyor cars can turn without crossing outside the pavement. This is done by using "live roll" conveyors on corners, similar to those used for acceleration and deceleration. On corners, the live rolls are set on radial lines and the wheels on the end of each roll are rotated at different speeds. The cars are thus turned smoothly but sharply round corners.

The cars used would be of small size, perhaps 7 ft. long and 5½ ft. wide. Such a car would seat 6 passengers. These small dimensions mean that the Carveyor track could pass through quite narrow openings between buildings, or even, possibly, through buildings without requiring more height than is available in the normal floor of a business building or shops. The track can go underground in much smaller tunnels than are needed

A standard gearbox drive Mono-Rail industrial car crossing a Mono-Rail bridge. The track supports can be seen clearly in the foreground. (*Photo*: *Road Machines* (*Sales*) *Limited*)

Station on the "moving track" designed by Ing. Vittorio Immirzi.



Close-up of part of scale model Carveyor system, showing movi loading platform at station and, foreground, bank of accelerati rollers. (*Photo: Stephens-Adams Mfg. Co.*)

(*Above*) Car ascending the steepest section of the lower incline of the Great Orme Railway.

(*Below*) Cars passing on the upper section of the Great Orme Railway, with the winding station in the background. The overhead wire is for communication only. (*Photos: English Electric Co. Ltd.*)

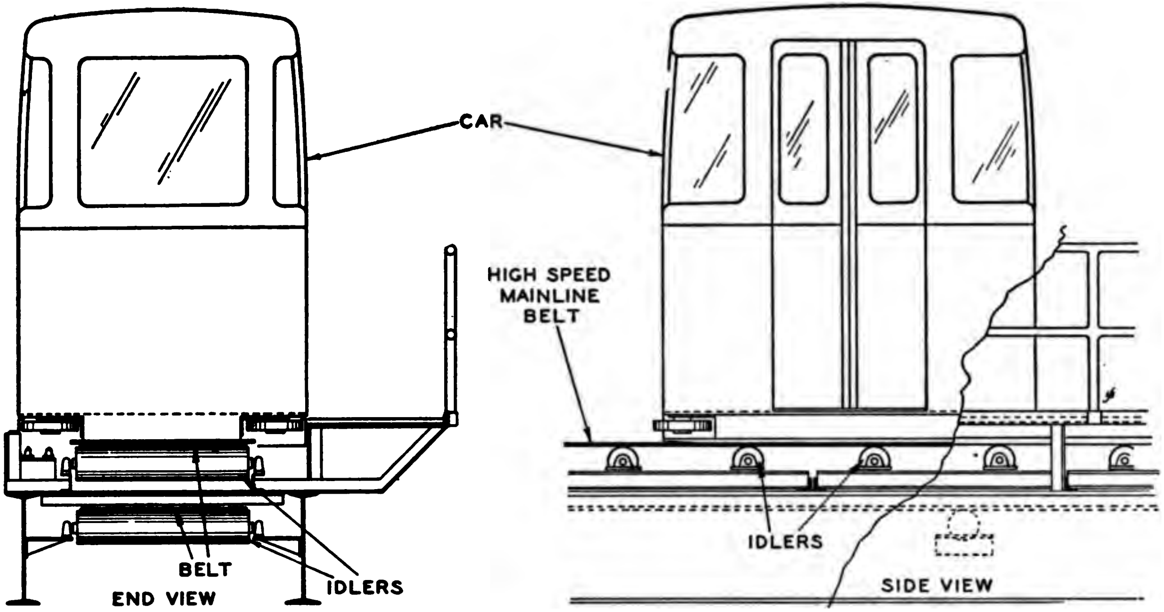


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FIG. 8. Carveyor system

for conventional trains. At first sight it might be thought that such small cars could never provide the capacity given by conventional trains, but in fact it is only a question of having enough cars on the belt, within limits. Up to 6,000 or so seats an hour could be provided with the dimensions and speeds already given. This is by no means the limit, as will be seen later. The number of cars on this system does not, of course, entail an increase in crews, as no staff members are required to ride in the cars.

Interchange between lines can be arranged by bringing two Carveyor tracks alongside a single moving station platform. As there is no waiting, this presents no difficulty. If necessary two tracks can each have their own moving platform, the passenger crossing between tracks on a normal stationary platform.

Studies of Carveyor track possibilities show that with a single track carrying four-seat cars, up to 5,000 seated passengers an hour can be carried in one direction, or double this number if standing is allowed. Cars seating six, eight, or ten increase this number proportionately, and with 10-seat cars it should be possible to carry 11,000 seated passengers an hour in one direction, or 22,000 sitting and standing. Track width increases with car capacity, so that whereas a four-seat car track needs a total width (including a walkway) of 5 ft. 6 in., the 10-seat car track needs 10 ft. 6 in. Double tracks, with the same car size, need 14 ft. and 25 ft. respectively, with intermediate widths for other sizes. The total height required for track and cars rises from 11 ft. with four-seat cars to 12 ft. with 10-seat cars.

So far, this has been theory; but the Carveyor system has advanced beyond that. A careful scheme was drawn up for an actual line, and was described by Colonel S. H. Bingham, the former Chairman of the Board of Transportation of New York City, and retired Executive Director and General Manager of the New York

City Transit Authority, in an address to a joint meeting of the Northeastern Section of the American Section of Civil Engineers and the Transportation Service of the Boston Society of Civil Engineers at the Massachusetts Institute of Technology Faculty Club, Boston, Mass., on 20 February 1956.

Colonel Bingham then stated that when studying the problem of the Grand Central–Times Square shuttle service in New York City, he tried to find a more efficient method of handling the traffic, as the existing shuttle needed rehabilitation and modernization and was very expensive to operate. After eight years of study and research, he stated, there was on the drawing boards—and actually constructed on a small scale, though large enough to carry passengers—a passenger conveyor which he had developed in conjunction with the engineers of the Goodyear Tire & Rubber Company and the Stephens-Adamson Manufacturing Company.

The system satisfied the stipulated conditions—that it could carry more than 12,000 passengers an hour in each direction in safety comparable with that associated with underground railway standards; that it would give a speedy, comfortable, and convenient ride; that it would cost less to operate than the existing shuttle train service, and that it would not cost more than would be needed to rehabilitate the existing shuttle service. It was also desirable that the new system should take up only half the space occupied by existing facilities.

As designed, the Carveyor system envisaged would take 16,000 passengers an hour in each direction, and the trip would take two minutes (with no waiting), the same time as the shuttle service. Only the two centre tracks of the shuttle service would be needed, and maintenance costs were estimated at 40 per cent of that of the existing service.

The general design and belt speeds would be as previously described, but 10-seat cars would be used, and 19 cars a minute would pass the loading area. At the ends of the track the cars would be carried round a loop on a bank of wheels and would then be ready for re-loading.

In April 1953 a working model was shown in New York. Full-scale testing equipment was built during the planning period to test the system. A rubber conveyor belt 60 ft. long and 9 ft. wide, and a mock-up of five full-size cars were set up for test purposes. The cars operated next to the belt, to duplicate actual loading and unloading conditions at Carveyor stations. Also, an accelerating and decelerating system was built to test the rate at which cars could be accelerated and decelerated.

A very large number of people took part as "passengers" in tests of loading and unloading. They included old people, children, and lame persons, as well as people loaded up with luggage and packages, and yet no difficulty whatever was found in boarding and alighting from cars.

Despite the work done on the plans for this system, it has not yet been built to replace the Times Square shuttle.

More recently, proposals for a Carveyor system in Seattle to carry visitors to and from the "Century 21" World's Fair site were put forward by Passenger Belt Conveyors Inc. The original proposal was for a line to cost about $5,600,000, running along Sixth Avenue and involving a number of turns. An alternative proposal was put forward later with a route along Fifth Avenue and an intermediate stop to serve parking areas. This second route was expected to cost $4,100,000.

Instead of weather-protected cars as suggested normally for Carveyor systems, it was proposed to have the entire track enclosed in a ventilated plastic tube. The tube would have been tinted on top, but have had clear side vision. Open cars made of glass fibre, each seating four passengers in lounge-type chairs, were proposed for the line, which would have had a capacity of about 5,000 seated passengers an hour in each direction (or double this number if standing is permitted).

Another moving belt system has been put forward by Ing. Vittorio Immirzi in Italy. This has two continuous belts moving beside a fixed track in a tunnel 12 ft. 6 in. wide and 10 ft. high.

The fixed pavement is 3 ft. 6 in. wide, except at stations, where it is enlarged as necessary to form a circulating area. Beside it runs an intermediate belt, and on the far side of the tunnel is the fast belt. Each belt is really a series of moving platforms, each about 12 ft. long. The intermediate platform is 4 ft. and the fast platform 5 ft. wide. These platforms run on rails, and are very much like a long series of flat railway trucks. They are close-coupled with interlocking ends, so that there is no gap in the intermediate belt and only small gaps in the fast belt.

The trucks of the intermediate belt have a handrail and barrier, and move at a variable speed in accordance with a predetermined cycle. This cycle consists of a 15-second stop, an acceleration period of 12 seconds, and a period of 15 seconds during which trucks run at the same speed as those of the fast belt. The intermediate track then slows to a stop again. The fast belt has seats and runs at a constant speed of 15 m.p.h.

Passengers wait on the fixed pavement until the intermediate belt stops. They then board it through the gaps in the handrail, and wait until it accelerates to the same speed as the fast belt, which they then board. The reverse takes place at the destination station.

Power is supplied from a central power station, at which there are also automatic speed controls for the belts. Vertical electric motors, one for each belt, are spaced about 100 yd. apart. By means of pneumatic-tyred horizontal wheels, which engage a central strip underneath the trucks, the motors drive the belts at the given speeds. The capacity is estimated at 94,000 passengers an hour. Two complete sets of tracks would be needed for simultaneous transit in both directions.

For connecting other areas with his moving tracks, Ing. V. Immirzi has proposed a vehicle which would run at high speed in a small diameter tunnel. Holding up to 80 standing passengers, the cars would be suspended from a central rail, or two side rails. They would provide a rapid shuttle service to the main belt transit system.

8

RAILWAYS ON GRADIENTS

A FULL description of the Fell central rail system appeared in *Unusual Railways*, and in that book mention was made of a patent for a similar device taken out on 13 July 1847 by A. V. Newton. Some more details of the Newton system, less well known than that of Fell, which it antedated by 16 years, may be of interest.

Though patented in the name of A. V. Newton, the invention was that of George Escol Sellers, who built a number of locomotives embodying his ideas. Several were built for the Panama Railroad. These were 4-4-0 locomotives, with the usual pair of cylinders which worked the coupled driving wheels when the locomotives were running on the level and on moderate inclines.

Above the normal cylinders were a pair of extra cylinders. These drove, through bevel gearing, an extra pair of wheels working on vertical axles and gripping a middle rail. These extra wheels were used on steep inclines, and were so arranged as to be capable of applying almost any required degree of adhesion. The central rail stood about 4 in. above the normal running rails. Each pair of cylinders had its own regulator, and could thus be independently controlled.

Four or five engines of this type were built for the Panama Railroad, but there seems to have been some realignment of that railway which obviated the need for the extra rail; in fact, the locomotives were never used in Panama, and were eventually broken up without ever having performed any useful work. Two more locomotives were built in later years for a Pennsylvania coal company's railway, but these, too, were never put to work.

High above the sea at La Costa Mesa, Malibu, an arrow-shaped house sits on a ridge of rock, its head pointing out to sea. The architect and the owner agreed together to build the house in an apparently inaccessible position, making use of a private funicular railway to give access from the nearest street, 120 ft. below. The railway runs up to the end of a terrace serving one side of the house and the inclination is approximately 1 in 1·5.

The narrow-gauge line with its tiny car, capable of carrying six people (or 1,500 lb.) is automatic in operation and works very much like a modern lift. There are call buttons at the top and bottom of the track, and controls in the electrically driven car itself.

The car is tested to a load of 5,000 lb. and is inspected by the state lift inspectors annually. Spring-operated brakes would come into use should the cable part. An Austrian skier and engineer, Sepp Benediktor, was the designer. The expenditure of some $4,500 on the funicular has converted a bare ridge into a building site worth an estimated $10,000–$12,000.

Quite a number of shorter funiculars have been installed in the Los Angeles area to serve large private houses. They run from the road to the house—often only a comparatively small distance and height, and are really only a form of mobile step. There are several examples in Beverly Hills, the district best known as the home of many film actors.

One of the shortest funicular railways in the world to be operated by a regular company must be the 60-metre branch of the funicular between Wildbad, in the Black Forest in Germany, and the Sommerberg, some 2,400 ft. above. This branch line has its own small car specially designed to carry invalids, and takes only four at a time. It runs between the funicular station and the main bath house. There is no driver, as the car is operated automatically from the terminal stations. It runs at a speed of only 5 m.p.h.

One British railway which is certainly unusual, but was not mentioned in *Unusual Railways*, is the Great Orme Railway at Llandudno. Its unusualness lies mostly in the fact that it is the only passenger-carrying cable-hauled railway of its type in Britain—if we ignore the cliff funiculars, although of course there are many cable railways elsewhere in the world.

This 3 ft. 6 in.-gauge railway climbs to the summit of the Great Orme headland at Llandudno, a rise of some 550 ft. The line is in two sections. There is a lower incline 800 yd. long with sharp curves, and with an average maximum gradient of 1 in 4·4 on the steepest part of the route—a length of about 100 ft. At the top of this section is a half-way station where passengers change from one car to another to make the ascent of the second incline. The second incline is 827 yd. long, and has a maximum gradient of 1 in 10·3 over the steepest 200 yd.

Part of the lower section is laid with a common middle rail embedded in concrete and flush with the surface of the road along which it runs. The remainder of the section is single track. The upper section is entirely single track except for a mid-point passing loop. The lower station, known as Victoria, is in Llandudno itself, and the midway station, where the winding and control gear are situated, is known as Halfway Station.

The lower section came into use on 31 July 1902, and the upper on 8 July 1903. At present it is worked only in the summer, when it is well patronized by holiday-makers. As many as 220,000 have been carried in a single season.

When the line was opened, a single locomotive-type boiler manufactured by Robey of Lincoln supplied steam at just over 100 lb. per sq. in. to two engines, one for each section. A Sandicroft engine, which developed about 120 b.h.p., drove the cable-winding drums of the lower incline, and an 80-b.h.p. Musker engine drove those of the upper section.

The steam engines were replaced in the winter of 1957–58 by new winding gear installed by the English Electric Co. Ltd. The equipment consists of an "English Electric" 125-h.p. slipring induction motor for 415-V., 3-phase, 50-cycle supply which drives the cable drums for the lower haulage, and a similar 75-h.p. motor for the upper haulage. Both motors have their speed controlled by rotor resistances operated by a drum controller. The original cable drums are now driven through new gear units to convert the motor speed of about 730 r.p.m. to the drum speed of 25 r.p.m. on the lower haulage, and 35 r.p.m. on the upper haulage.

On each incline, two cars are connected by cables to their respective cable drums, so arranged that one car is ascending whilst the other descends. The cars on the upper incline are linked also by a cable passing round an idle pulley at the summit terminus.

The single-deck cars have two four-wheel bogies, and weigh 6½–7 tons unladen. They seat 48 passengers, compared with the 20 seats of the original four-wheeled cars used when the line was opened. The cars on the lower incline have screw-down brakes controlled by handwheels from the end platforms, and governor-controlled skid brakes which bear on the concrete road surface if speed becomes excessive. They can also be hand operated. The upper incline cars have screw-down brakes on the wheels, and slipper brakes acting on the rails. The authorized speeds for these cars are 5 m.p.h. and 7 m.p.h. respectively, and the cars carry speed indicators so that the brakeman knows when brake applications are needed.

The cables for the upper incline are of $\frac{7}{8}$-in. diameter steel, and run on guide pulleys exposed between the rails; but on the lower track, the cables, of $1\frac{5}{16}$ in. diameter, run in conduit down the centre of the embedded track, which thus resembles in appearance the former conduit tramlines in London.

Communications between the cars and the half-way station are by telephone and bell through an overhead wire, to which the cars connect by trolley poles. This arrangement often leads visitors to think the cars are electrically driven, like tramcars, and the haulage cables in full sight when they get to the upper section give them something of a surprise.

In the motor house at the half-way station, the two drives are controlled from a common driving platform, each with its drum controller, tachometer, ammeter, telephone, bell communication, and emergency stop switch. In addition, on the platform there are handwheels operating screw-down brakes on the coupled winding drums.

Elaborate safety measures are associated with each drive. For example, a weight-operated brake is held in the "off" position by an electro-hydraulic thruster when the power circuit is made. When the emergency stop button is pushed, the power circuit is broken, thus applying the thruster brake. There is also a centrifugal trip on the motor which breaks the power circuit at 15 per cent overspeed, again bringing in the thruster. The screw-down handbrake on the driving platform has full electrical interlocking with the "power on" button on the control panel and the control handle. Before power can be obtained, this brake must be full on with the control handle in the "neutral" position.

On the lower incline cars, the skid brakes operate automatically at $6\frac{1}{2}$ m.p.h., being controlled by centrifugal governors mounted on the cars themselves. Teeth on the undersides of the skids grip the concrete of the road-bed, and bring the car fairly smoothly to a stop in eight yards on the steepest section of 1 in 4·4.

Before the conversion to electric drive, a fully loaded car on the lower incline could not cause overspeeding, because of the friction on the cable. The Ministry of Transport and Civil Aviation requires that overspeed tests should be made annually, and therefore some method of speeding up the drive from the induction motor had to be provided. This is done by means of vee-belts driving via a layshaft on to the other end of the first motion shaft of the gear unit. Bolts which normally join the brake path on this shaft to the motor shaft extension coupling are withdrawn, and the belting is fitted, thus giving a speed sufficient to operate the car brakes. This is equivalent to 690 r.p.m. on the induction motor, and the arrangement retains the use of the weight-operated brake in an emergency.

It has been found that the modern drive gives easier control with cleaner conditions, and an economy estimated at £1,400 per season. At the peak of the season the cars can make eight runs per hour. The normal timing is six minutes for the lower section and five minutes for the upper.

In passing, it is interesting to note that the original boiler was hauled to the Halfway Station by a traction engine. Not unnaturally, this could not haul such a load direct up such steep inclines, and it proceeded in stages, first climbing unloaded to a suitable point and then hauling the boiler up to it by a cable passing round the winch drum with which the engine was fitted.

An early suggestion for improving the hill-climbing properties of steam-powered trains was made by M. Flachat, who in 1860 published a comprehensive pamphlet on a proposed railway over the Alps.

At that time, tunnelling was an even slower and more expensive business than it is today, so the line was to be taken over the St. Gotthard Pass, involving gradients of 1 in 20 and with curves of only 66 ft. radius—something out of the range of any normal steam locomotive.

Steam traction, nevertheless, was to be used. M. Flachat proposed that a boiler carriage of great size should be built, with quite small cylinders and driving gear sufficient only to propel its own weight. The tender to the great boiler, and all the carriages of the train, were also to have cylinders and driving gear, steam being supplied by a flexible pipe running along the train from the boiler.

The boiler was to have 3,981 sq. ft. of heating surface—about the same as a large Beyer-Garratt articulated locomotive of today—and would have weighed 18½ tons, plus 6½ tons of water contained in it. The total weight of the boiler carriage—it can hardly be called a locomotive—would have been about 40 tons, or 62 tons with the tender. The steam supply was calculated to be sufficient for a train of total weight of 204 tons—quite a respectable weight for the 1860s.

Another curious thing about this steam multiple-unit train would have been that each axle would have carried only one wheel, so that the wheels on each side of the train would have been independent, helping to overcome the problem of sharp curves. This was not, in fact, a new idea, but had been patented as far back as 1826 by Robert Stephenson. M. Flachat would have used eight wheels to each carriage.

This scheme was only part of a very comprehensive plan for building and operating steam railways in mountainous countries. Had the plan been executed, one fears that trouble would have been experienced with the long, jointed live-steam pipe running the length of the train.

This was not the first proposal for a multiple-unit train, however, for in 1823 an idea on rather different principles had been put forward by W. H. James in

England. A train was actually built to his design, and achieved some surprising results.

The James train had a locomotive with a vertical engine. This drove, through bevel gears, a shaft fitted with universal joints. Each wagon or carriage of the train had a similar shaft, and these could all be connected end-to-end when the train was coupled up. Every axle had its own bevel gear driven from the shaft, so that the engine at the front was driving every pair of wheels in the train, the universal joints making it possible to round curves of any normal radius.

On a short test track, the James multiple-unit train climbed gradients of 1 in 12. To appreciate this to the full it is necessary to remember that even today the absolute limit of adhesion traction by locomotive is considered to be about 1 in 11. The James train was conceived six years before Stephenson's *Rocket,* in days when the slightest slope was considered to need rack rails or cable traction, and the idea of a locomotive with smooth wheels being able to pull a load on smooth rails on the level was only just being accepted.

James had another brilliant idea for his trains. The coned wheel which today enables curves to be negotiated with comparative ease lay in the future, but James proposed that his wheels should be double-flanged, with the tread immediately inside the flanges of normal wheel diameter. In the centre of the tread, however, there would be a depressed section, so that the centre of the wheel would be of smaller diameter. The rails on his railway would also be of variable section, according to the curve being negotiated. By careful laying of the track, the wheels on the outer rails of curves would run on the larger section of the wheels, and the inside wheels on the smaller, thus enabling curves to be taken more smoothly.

There is not much doubt that passengers would have had a bumpy ride, and the wheels and rails would soon have become badly worn, but James, in 1823, was looking ahead to a problem still being investigated today, as will be seen elsewhere in this book.

To bring the story of unusual multiple-unit trains right up to date, there is a grand-scale plan which originated a year or two ago in Russia. The scheme is for an atomic-powered railway across the Himalayas, linking Russia, China, and India. The track would be built to the enormous gauge of 14 ft. 9 in., and on it would run locomotives weighing 5,000 tons. Atomic energy would generate steam for a turbo-generator, providing current for electric motors giving a total of 100,000 h.p. The wagons would each carry 1,000 tons, and would themselves have electric motors powered from the generator on the locomotive. The route would lie largely through the mountains and deserts of Southern Russia, Western China, and Northern India.

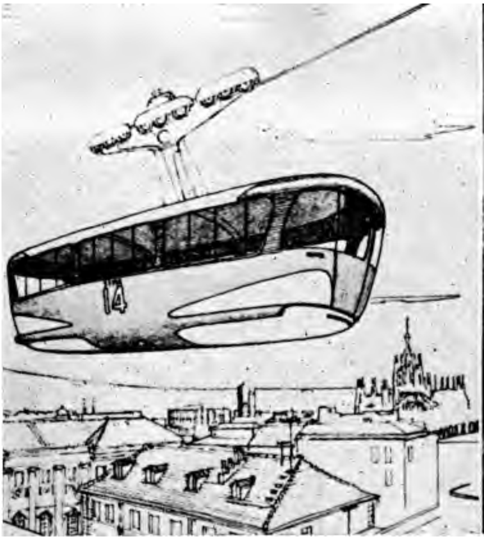
The principle of mounting the motive power unit on the passenger carriage is not only found in multiple-unit trains, but also in railcars, so that a few words about an early "steam-carriage" may be of interest.

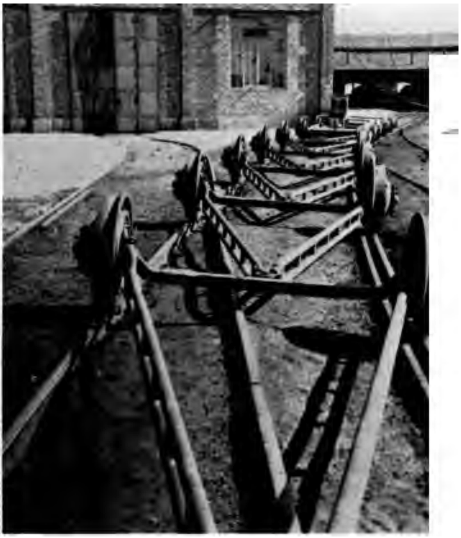
In 1847 a tiny locomotive was built by Adams & Co., of Fair-Field Works, for the engineer of the Eastern Counties Railway, Mr. Samuel, who proposed to use it as an inspection vehicle. Charles Hutton Gregory, Engineer of the Bristol and Exeter, saw this tiny locomotive, and thought it could be incorporated in a mixed power-passenger vehicle. The resulting vehicle—possibly the first railcar in the world—was given trials on the West London line (a mixed-gauge line at that time). The following account from a contemporary journal gives a good description:—

"The order for this Steam-Carriage was given to Messrs. Adams & Co., by Mr. Charles Hutton Gregory, the engineer of the Bristol and Exeter Line, under the sanction of his directors, after a single trial of the Lilliputian Locomotive of Mr. Samuel, which is christened the *Express*. The conviction was conclusive in the mind of Mr. Gregory, that light steam-carriages were not only practical, but economical, and that by their agency profits might be made on branch lines which previously had yielded only losses.

"Still, though the *Express* was a little 'fact', the passenger-carriage had yet to become a greater fact, and doubts in abundance were circulated. But united purpose grew from the conviction of mechanical truth; for it was not regarded as a problematic scheme, but as a well-ascertained plan.

"The design and plan of the *Fair-Field* is by the Patentee. It was approved by Charles Hutton Gregory, who gave the carriage its name. The engine is peculiar, as will be seen by the View we have given. The frame is, for convenience, made to bolt to the carriage firmly, in a separate length, so as to remove with facility, in case of repairs. The boiler is tubular and vertical, 3 feet in diameter, and 6 feet high—150 tubes, 4 feet in length, 1½ inches diameter. Fire box, 2 feet high, 2 feet 6 inches diameter. This will give 20 square feet of heating surface in the fire-box, 150 feet tube surface in the water, and 50 feet in the steam, which has great effect in drying it before it leaves the boiler. The vertical tubes are found to generate steam very rapidly. The cylinders are 8 inches in diameter, and of 12 inches stroke. The pistons communicate by their connecting rods with a separate crank-shaft, on which are plaeed the eccentrics. The driving-wheels (4 feet 6 inches in diameter), the axle of which is in front of the boiler, are put in motion by side rods or crank pins. Thus, when the side rods are removed, the whole becomes an ordinary wheel carriage. The tank is in front of the boiler, and will contain 220 gallons of water. The coke-box is attached to the carriage end. The fuel and water would be sufficient for a journey of about 40 miles. The first-class compartment is fitted for 16 passengers, but 6 extras would find room.





(*Above, left*) Aerobus for the proposed Milan télépherique. Note the high stations in the background. (*Design: Ing. d'Alo and Ing. L. Adler*)

(*Above, right*) Series of articulated-wheeled triangular frames used in early Talgo experiments in Spain.

(*Below, left*) Rear view of American-built, Spanish-designed Talgo train as used in service in Spain. The train is on a siding in this photograph.

(*Below, right*) End of a section of a Talgo train as used in Spain. Note the coil springs and that the wheels come between, not under, the sections. This view also shows the double diaphragm used where the sections join and the side connections used to keep them in alignment. Other features will be recognised from the text. (*Photos: Red Nacional de los Ferrocarriles Espanoles*).

***(Above)* Rear view of the original Spanish-built Talgo train used for trials.**
(Photo: Red Nacional de los Ferrocarriles Espanoles)

(Below) The "Fair-Field" railway steam carriage—one of the first self-propelled railcars.

The second class will carry 32, but on occasions 48—total, 70. The running wheels are 3 feet 6 inches in diameter, and run independently on their axles, as well as the usual movement of the axles in the journals. The frame is within 9 inches of the rails, and no steps are required. The total weight is estimated at 10 tons; and the consumption of coke will be under 10 lbs per mile.

"The steam-carriage was delivered on to the West London before she was in thorough working condition, in order to test her powers. The result has been that she has exceeded a speed of 35 m.p.h. up a 3 mile incline of 1 in 100; and 41 miles down the same incline, with the disadvantages of a very sharp curve and no run at starting, very loose rails, and one of them deeply rusted from disuse, grinding in the flanges with great friction. There is little doubt that, when in order, she will make 60 m.p.h. on good rails on a level. We understand that, when completed, it is the intention to run her for several days on the West London, to give directors and engineers an opportunity of trying her.

"We should mention that in the trimmings of the carriages, is worked the monogram of the Railway Company—a tasteful novelty, introduced by Payne and Son, of Great Queen-Street, Lincoln's Inn-fields."

Among the many ideas put forward from time to time to enable railways to climb steep gradients was Grassi's screw locomotive. An account dated 1857 described this as follows:

"GRASSI'S SCREW LOCOMOTIVE ENGINE FOR ASCENDING STEEP GRADIENTS ON RAILWAYS

"This invention, which has been patented by M. Grassi, consists of an application of the Archimedean screw to locomotive engines for taking trains up steep ascents on railways, which it is anticipated will prove more economic than the ordinary system of tunneling and embanking. Captain Moorsom, civil engineer, member of the Institution of Civil Engineers in London, and lately selected by the English Government to discharge the important and difficult duty of making a general survey for a complete railway system in Ceylon, has undertaken to study the Grassi system, and to report on its practical value. Captain Moorsom proposes to construct a locomotive engine with 18-inch outside cylinders, 4-ft. driving-wheel, and 24 inches stroke, with boiler capacity sufficient to provide steam (with proper expansion gear) for a speed of not less than 12 m.p.h. on the incline, with a gross load of not less than 100 tons, including the weight of the engine and tender, which would probably amount to about 28 tons. On the driving-axle of the engine a bevelled wheel will be fixed so as to connect by means of one intermediate motion with the crown-wheel on the end of the shaft of the screw. The driving-wheel and screw revolve in exact ratio to each other, so that the screw will advance exactly as the driving wheels advance, or, in other words, each revolution of the driving-wheel sends the screw forward 12 feet to 7 inches nearly. Thus, 12 turns of the screw are made for every turn of the driver. Captain Moorsom believes that the wheel will make about 13,000 such revolutions per hour on the level, and that when we apply the same motive power to turn the screw on the incline of 1 in 20, the steam power will overcome the additional resistance arising from gravity and friction of the machinery, at a speed not less than from one-third to one-half of that attained on the level with the same load. The thread of the screw will be of 13 inches diameter, winding round a cylinder or shaft of 7 inches diameter, and with a pitch of 12½ inches. The cylinder screwed will be about 5 feet 4 inches long, and will always hold two of the rollers in its grasp at one time. The rollers or pulleys will be plaeed 3 feet 2 inches apart from centre to centre, and will be about 8½ inches in diameter, and will revolve into a longitudinal balk of timber, and will be lubricated in the same way as the wheels of the carriages. The bearing timbers for the rollers will be a single line of balks about 10 inches wide by 8 inches deep; thus each mile will require 2,933 cubic feet of timber, and 1,668 rollers. The rails will be bridge rails, weighing 65 lbs per yard, and screwed to balks equal to a section of 10 inches by 8 inches at the least. The total cost per mile will be £3,701. The cost of the engine (which will carry her tender upon her own frame), with screw and connecting gear complete, in the shops in England will be £3,000. The rails have no additional expense to bear on account of this peculiar construction.

"From the above it is obvious that a large economy is to be attained by use of the screw-engine."

One of the steepest street tramways in the world closed down on 24 February 1956. This was the Maryhill cable tramway in Dunedin, New Zealand, which on part of its route had a gradient of 1 in 3½, believed to have been equalled only by the line on Telegraph Hill, San Francisco, which had a similar gradient.

The line was opened on 16 March 1885 by the Mornington Tramway Company as an extension of the Mornington cable line. It was about half a mile long, and was single-track, with a passing loop. Curiously, trams kept to the right on the passing loop, a relic of American tramway influence in New Zealand. One terminus was at the tramway depôt, near, but at an angle to, the Mornington line. From there the line fell at a gradient of 1 in 4, steepening to 1 in 3½ for about 530 ft. Reaching a public road, the line ran along this and passed through the loop, climbing then at about 1 in 15 to the outer terminus.

Although built for use by more than one car, in fact only one was ever used. This was one-man operated, the gripman who operated the cable grip also collecting fares *en route*.

The line had a chequered history. It was closed for a time in 1903 when the depôt and engine house were burned down, and passed to the Mornington Borough Council in the same year. The Dunedin City Council took over control in 1916, but closed the line again because its poor state of repair made it dangerous. It was eventually repaired with serviceable materials from another closed line, and was reopened in 1919. A new cable was installed in August 1955, but was used only for a few days before labour troubles caused the line to be closed again. In the meantime, the track was being badly damaged by road traffic, and it was decided to close it completely.

The original motive power was a Marshall engine developing about 37 h.p. When the Dunedin City Council reopened the line in 1919, this was replaced by an electric drive with a 57·5-h.p. motor. The winding gear was also replaced at this time by the old gear from the Mornington line, and this equipment was still in use when the line closed finally in 1956.

Cableways, or "télépheriques", are really outside the scope of this book, but a few words about three—one existing, one proposed, and one being built—all intended for urban transport instead of climbing mountains, may be of interest.

The existing télépherique is in Algiers, where the principality had reserved space for the track of a funicular as far back as the 1880s. The funicular was to connect the part of the town by the sea—really the business area—with the plateau rising just behind, now used extensively for residential purposes.

The funicular was never built, but as the importance of the plateau grew with the building of two towns—Diar el Mahçoul and Diar es Saada—it was decided that a téléphérique should be built, using the reserved track. The cable rises in a single span from a station in the Rue de Lyon to Diar el Mahçoul 356 ft. above, crossing several streets and boulevards on the way. The télépherique, operated by the Algerian Tramway Company, came into use in February, 1956. The double-track cables are about 785 ft. long, and the two cars are so arranged that one ascends while the other descends.

The cars weigh 3 tons 18 cwt. each, and can accommodate 30 passengers. Each car can make up to 50 journeys an hour, as the journey time, including the loading and unloading of passengers, is only 72 seconds. The resulting capacity of 1,500 passengers an hour in each direction is ample to meet the demand.

Much more startling is the proposal made in 1952 by Ing. d'Alo and Ing. Leonardo Adler for the construction of a circular télépherique route in urban Milan. This line would be 5½ miles in length, and would have a branch to the centre of the town. The branch would be nearly 3½ miles long.

A large number of cars could run simultaneously on the cable, which would provide a double track with cars moving in both directions. The route would actually be a huge polygon, with stations in supporting towers at the corners.

The cars would leave at two-minute intervals, each carrying 40 passengers, giving a capacity of 1,200 passengers each way—very small for an urban installation. The speed would be about 15½ m.p.h. between stations, or, with stops, an average speed of 12½ m.p.h. To obtain the maximum speed possible, stations would be provided as far as practicable at distances apart equal to multiples of the distance the cars are apart on the cable, thus ensuring that stops would be simultaneous.

The stations would be high towers, reached by lifts. Because of the amount of cable sag on long spans and the need to clear the highest buildings along the route by a substantial margin, the stations would be about

250 ft. up. A suggested use for the high towers necessary is as vertical multi-storey garages.

Attractive as this line might be for sight-seeing purposes, its capacity seems too small to make it a serious contender as a means of urban transport. The ring of high towers round the city would probably be regarded with some disfavour, as these would of necessity be higher than most of the existing buildings.

The third, and most unusual, funicular was being built in Haifa, in Israel, as this book was written. It is an underground line just over a mile long, with four intermediate stations spaced at regular intervals. It connects the Lower Town with the busy shopping and entertainment district of Hadar Hacarmel, and also with the residential district of Mount Carmel.

The new funicular, which has been under construction since 1956, climbs 985 ft. in a straight line, the whole of the track being in tunnel at depths between 23 and 115 ft. The maximum gradient is 1 in 3. Four cars will be used, each carrying 165 passengers. The power plant will be at the top of the slope, at the Mount Carmel terminus, and will include two 675-h.p. motors for winding the cable. The cars will travel at nearly 20 m.p.h. between stations.

The track used will resemble that used experimentally on the Paris Métropolitan, described in *Unusual Railways*, but the flanges of the railway wheels will be available for guiding the cars, and asphalt strips will be used for the pneumatic-tyred wheels. The line was completed and opened when this book was passing through the proof stages.

A téléphérique was once built in Britain, at Brighton. This was the Telpher Cable and Cliff Railway, which was carried across the gorge known as the Devil's Dyke. It was the invention of W. J. Brewer, a civil engineer who, while serving in India, thought of the idea of spanning mountain gorges in this fashion. This

Brighton cableway is thought to be the first of its type ever to be built. It was opened in October 1894.

A small station was built on each side of the gorge, which at that point was about 230 ft. deep. Two track cables were erected, each suspended from a single supporting cable, the latter having inverted "T"-shape hangers below it, one arm of the "T" supporting one track cable and the other arm the other. The track wheels of the car were so arranged as to pass over these hangers, but yet were held in such fashion that they could not leave the track. The cars were moved by an endless cable hauled by a Crossley oil engine. The width from anchor to anchor was about 1,200 ft., and the effective width between the supporting towers about 650 ft. The transit time was 2 min. 15 sec. According to the contemporary account from which this information has been taken, there was provision for making curves, points, and crossings with this form of suspension. In some ways, this line seems to have been a forerunner of some modern monorail—or rather duo-rail systems, such as Davino's.

The contractors for the Telpher Cable and Cliff Railway were Heenan & Froude, and the steel wire cables were by Haggie of Sunderland.

In the chapter on Funiculars in *Unusual Railways* we described briefly the Swiss urban line from Ouchy to Lausanne. It may be of interest to note that since this description was written, the line has been given new rolling stock, and converted to rack working. At the time it was built, over 80 years ago, the engineers considered that a funicular was needed to overcome the gradient. The new rolling stock can travel, mostly in two-car trains propelled by an electric locomotive, at 19–20 m.p.h.—double the former speed. Incidentally, reports on the modernization put the maximum gradient at 1 in 8 or 1 in 9 (accounts vary!) and not at 1 in 13 as stated in *Unusual Railways.*

9

TALGO AND SIMILAR SYSTEMS

In 1837, William Bridges Adams published his *English Pleasure Carriages*, in which he proposed a system of two-wheel railway vehicles so coupled as to "permit of the greatest flexibility in passing through short curves".

Another scheme for articulation of vehicles was that proposed, about 1840, by Achille de Jouffrey. With the Jouffrey system, which reached the working model stage, locomotives were to have three articulated trucks, the wheels of two being carrying wheels running on the flat surface of a rail (or plate) and the centre truck carrying a large flanged wooden driving wheel running on a grooved centre rail. Wagons were to be carried on two articulated trucks. It was thought that this scheme would improve both adhesion and performance on curves, and Jouffrey went into these factors very thoroughly. The Jouffrey scheme found a good deal of support, but despite this it never came to anything.

In his *Locomotive Engineering* (1871), Zerah Colburn, commenting on the Adams design, remarked that it was evident that "without special couplings of great strength, such carriages would have a decided vertical unsteadiness; nor could the equal loading essential to keeping them in balance be depended upon".

Nevertheless, other men have worked on the same idea for many years, and from it has come the "Talgo" train.

The "Talgo" trains of the Spanish National Railways had been running for some ten years when this book was written, and may be taken to have proved themselves to the hilt so far as Spain is concerned. Experiments in the U.S.A. have been less conclusive, as will be seen later. The trains were conceived to provide railway vehicles with low weight, but capable of high speeds with economy, while remaining comfortable and perfectly safe.

The name "Talgo" is derived from "Train Articulé Léger Goicoechea et Oriel". The inventor was the Spanish engineer A. Alejandro Goicoechea, and Oriel was the name of the man who financed the invention. Goicoechea thought of a railway vehicle which would have short, rigid units, articulated together, and from this came the train made up of a series of triangular frames with wheels below the articulations. In fact, Goicoechea had re-invented William Bridges Adams's idea of 1837.

With a train made up of these two-wheeled isosceles triangles, guidance on curves is given to each successive triangle by that ahead, with assistance from the flanges of the wheels. If a little thought is given to the behaviour of the wheels and flanges of a rigid four-wheel bogie or wagon on a curve it will be seen that the Talgo principle offers considerable advantages in reducing friction. The sharper the curve, the greater the advantage, as anyone who has heard the wheels of a railway coach rounding a tight curve will appreciate. Without going into the technicalities of wheel behaviour on curves, it can be said that the safety factor, with the Talgo design, actually increases with speed on curves.

The articulation is such that the triangular frames are kept in proper line and also in correct horizontal relationship to each other. Thus, it is possible to consider the wheels and axles in rather a different light from that in which the wheels of a normal train are examined. As the triangles turn to follow the line of the rails, no great harm is done if a wheel is relieved of its any portion of the tramways, it is represented in writing to the Board of Trade by twenty inhabitant ratepayers of the borough, or by the lessees, that under the circumstances then existing all or any of the tolls and charges demanded and taken in respect of the traffic on the tramways or on such portion of the tramways should be revised, the Board of Trade may (if they think fit) direct an inquiry by a referee to be appointed by the said Board in accordance with the provisions of the Tramways Act, 1870; and if such referee report that it has been proved to his satisfaction that all or any of such tolls and charges should be revised, the said Board may make an order in writing altering, modifying, reducing, or increasing all or any of the tolls and charges to be demanded and taken in respect of the traffic on the tramways or on such portion of the tramways in such manner as they think fit, and thenceforth such order shall be observed until the same is revoked or modified by an order of the Board of Trade made in pursuance of this Section: Provided always, that the tolls and charges prescribed by any such order shall not exceed in amount the tolls and charges by this Order authorised.

Opening of Tramways to the Public.

As to user of tramways and tolls thereon when open to be used by the public.

38. The Promoters may from time to time by resolution declare the tramways, or any part thereof, to be open to be used by the public, and for such periods and subject to such conditions and restrictions as to motive power and otherwise as the Promoters may, subject to the provisions of this Order, think fit, and such user may be either concurrently with the lessees or otherwise; and so soon as the Promoters have passed such resolution any corporation, company, or person may use the tramways, or any part thereof, in accordance with the terms of such reso-

lution, with carriages having flange wheels or other wheels suitable only to run on the rail of the tramways, and may demand and take for the like purposes for which tolls or charges are authorised to be demanded and taken by this Order any tolls or charges not exceeding the tolls or charges by this Order authorised to be demanded and taken for such purposes.

Tolls if tramways open to be used by the public.

39. If the tramways, or any part thereof, be declared to be open to be used by the public, the Promoters may demand and take from any corporation, company, or person so using the tramways, or any part thereof, the following tolls and charges in respect of such user; namely,

For every passenger travelling in or upon any of the carriages of such corporation, company, or person or persons, any tolls or charges not exceeding for any distance traversed in the same direction at one time the sum of three halfpence inside and one penny outside for each single journey of such passenger, whether with or without change of carriage;

For any animals, goods, minerals, and parcels conveyed in or upon the carriages of such corporation, company or person, any tolls or charges not exceeding for any distance in the same direction one half of the tolls and charges specified in the Schedule B. to this Order annexed, in respect of such animals, goods, minerals, and parcels so conveyed, subject to the regulations in that behalf therein contained;

and the Promoters may, if they think fit, commute such tolls or charges so that the commuted sum may be as near as possible an equivalent of such tolls or charges.

Servants of the Promoters

40. Any corporation, company, or person so using the tramways, or any part thereof, declared to be open to be

The frame is formed of a centre "U"-section beam in rolled aluminium alloy sheet. The side beams are of "Z" section, as are longitudinal and cross stays. The side walls and roof have "U"-section ribs drilled to reduce weight, and the outer skin is of corrugated aluminium alloy sheet. The inner surface is of veneered metal sheet, and the ceiling is of aluminium sheet. The space between inner and outer surfaces is packed with glass wool for insulation. The internal arrangements vary according to the use to which the particular section of the train is put. The sections are connected by double rubber sheeting to make a continuous tubular structure. There are three mechanical connections between the sections. The main one is in the centre at the bottom, and takes the form of an articulated drawbar through which traction forces are transmitted. There are also two side connections which hold the sections in alignment while allowing the necessary amount of play.

There is one axle for each section, the wheels lying between the intersections and supporting the front of the train section in rear as well as the rear of the section ahead, to which it really belongs. The fixed axle is "U"-shaped, with bent arms at the outer ends carrying roller-bearing journals. The wheels turn freely and independently on these journals. The "U" shape of the axle makes it possible to lower the floor and thus reduce the height of the whole train. The centre of gravity is, in fact, only 39 in. above rail level.

The wheels themselves have a compressed rubber ring between hub and tread, and thus have a certain amount of elasticity. The axle is braced to prevent it from turning. Vertical suspension is provided by two coil springs surrounding hydraulic shock absorbers. At their lower end, these are fitted on to the ends of the axles by means of articulated universal joints; at the upper end they are attached to points on the body. These upper points have spherical swivel joints with rubber inserts in the connection with the body. A torsion bar arrangement deals with lateral displacement of the body relative to the axles. Lateral shock absorbers are provided to damp such movements.

This train is made up of 16 sections, each 20 ft. long (between couplings). The maximum width is 10 ft. 6 in., and the interior height is 7 ft. 0½ in. Each passenger section weighs 3½ tons, and has a low centre of gravity —the bottom of the frame is only 9½ in. above rail level.

The train is made up of three five-section units, each unit including four passenger sections and seating 64 passengers, 16 in each section. The seats, resembling aircraft seats, are arranged in twos on each side of a central gangway. The fifth section is a service unit containing a kitchen, toilets, air-conditioning equipment, a cloakroom, and the entrance doors (there are no doors in the normal passenger sections).

This accounts for 15 of the 16 sections. The last section is a special streamlined observation unit, with rows of armchair-type seats down each side (14 seats) and two seats in the rounded tail. Later, after some experiments in running this train, the passenger section at the head of the train was converted to a luggage van to give extra space for that purpose.

The meal service on these trains compares much more closely with airline practice than with that of the normal restaurant car. Everything is prepared in advance, and stored in cupboards in the small kitchen. Meals are served in compartmented trays to passengers sitting in their normal travelling seats. The trays are rested on small tables fitted to the backs of the seats in front.

Because of the unusual design of the train, and the small headroom, there is little room for luggage near the seats, so that all luggage has to go into the luggage van. It is handed in and taken out on a cloakroom-ticket system. Passengers' coats are taken and put in the cloakroom in each five-car unit: they are returned shortly before the passenger reaches his destination.

The windows of the train are sealed, and, as stated, air-conditioning plant is fitted. Each five-car unit has its own plant, installed in two compartments in the service section. A supply of electricity for the units is taken from the locomotive, which has two diesel-driven alternators supplying 50-cycle current at 120/206 V. All air, whether drawn from outside or re-circulated, passes through oil filters. Ducts for admitting and extracting air are incorporated in the ceiling structure, and are continued from section to section by flexible joints. Cover plates seal the ducts at the ends of each five-car unit.

Fluorescent lighting is used in the passenger sections, current being supplied from the generators on the locomotive. The tubes are fitted above the windows. There are also D.C. incandescent lights for use at night (or as emergency lighting). These lamps alternate with the fluorescent tubes, and are combined into a continuous strip covered with corrugated plexiglass shades. The d.c. lighting comes into use automatically should the a.c. supply fail for any reason.

All cold water is carried on the locomotive, and is distributed through the train by a pressure system. The pipes have special valves at the ends of the units which close automatically when units are uncoupled. There are small electrically-heated tanks in each service section to supply hot water for the kitchen and toilets.

Each five-car unit has a crew of three, two waiters and a chef. Apart from dealing with meal service, they also look after the cloakroom facilities. A bell system enables passengers to call waiters. There is a telephone between locomotive and observation trailer, used particularly when the train has to set back—since the train, with its peculiar design, is really a unidirectional vehicle and cannot run at speed in reverse.

Westinghouse brake equipment is fitted, the actual braking force being applied by internal-expansion shoes in drums of the automobile type attached to the wheels. The weight of a 16-section train is 120 tons 10 cwt. and the length is about 370 ft.

An indication of the success of the Talgo trains is the fact that when first put into service they reduced the time taken for the 396-mile Madrid–French Frontier run from 11 hr. 55 min. to 8 hr. 25 min., and this over steeply-graded track rising from sea level to 3,000 ft. where it climbs the Col de la Brujula and 4,100 ft. through the Col de la Cañada.

Writing in the January 1955 *Bulletin* of the International Railway Congress Association, from which many of the details of the trains have been taken, Mr. M. R. Mazarrasa, Chief Engineer, Operating Department, Spanish National Railways, declared that to obtain an equivalent average running speed an ordinary train would need a locomotive of more than 4,000 h.p. The special Talgo locomotive, however, is of only 650 h.p.

One advantage of the Talgo train is its low weight, which reduces wear on the track, and another is that should the track not be in the best condition, the method of suspension allows the trains to run faster over poor track than could be the case with orthodox trains.

Because of the train's inability to run in reverse at other than low speeds, turning loops were installed. During train reversing movements, the guard is stationed in the rear observation coach with the telephone previously mentioned to keep the driver informed as to the state of signals, etc.

The 650-h.p. diesel-electric Bo-Bo locomotives each have two 405-h.p. Hercules engines, but these are limited to 80 per cent of their theoretical power. The axle-load is 15·3 tons, giving a total weight of just over

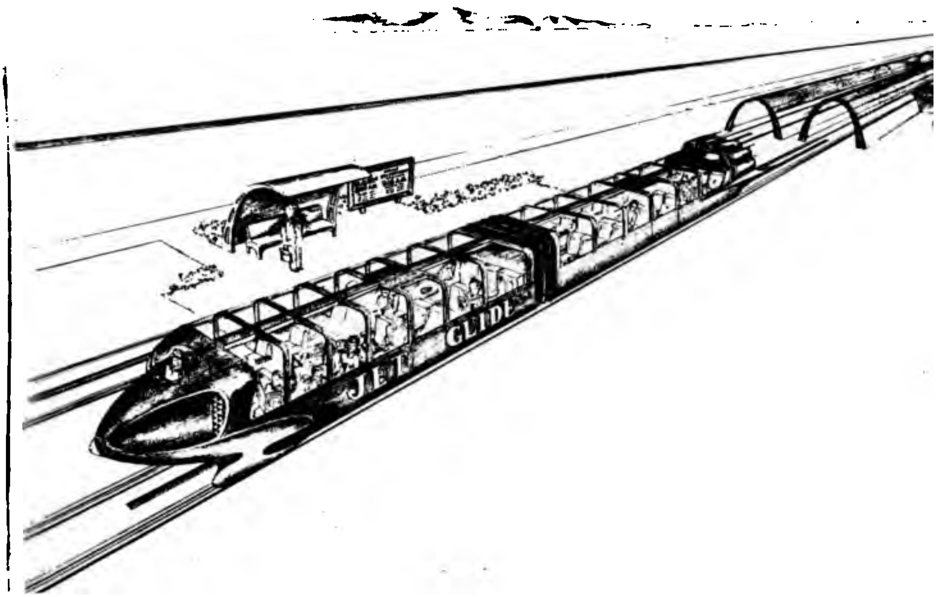
61 tons. With modern hydraulic or even mechanical transmission, this weight could be reduced somewhat, but there was considered to be no effective substitute for electric transmission when these locomotives were built. Three such locomotives were built for the trains.

The Spanish National Railways were sufficiently impressed by the trial runs to purchase the trains, and were soon thinking out improvements, including a form of axle-guiding which would enable the train to be run at full speed in reverse, by making the wheels follow the curvature of the track even more closely.

When the International Railway Congress was held in Madrid in the autumn of 1958, Talgo trains were running from Madrid to Irun, from Madrid to Granada, Malaga, Cadiz and Huelva, to Saragossa and Irun, from Saragossa to Tarragona and Barcelona, and to Valencia, Alicante, and Cartagena, as well as from Madrid to Leon and Vigo, Corunna, Gijon, and Santander. They have proved very popular, once passengers have become used to them. The usual formation is 14 sections, but 12 or 16 sections are sometimes used. There is a supplementary fare for travel on these trains.

At the time of writing the Spanish Railways were considering the acquisition of further Talgo trains; the latest five-year programme provides for 15. This is understood to depend to a great extent on the ability to reduce the weight of the train still more, and the obvious line of approach is the reduction of locomotive weight, which at present accounts for half the weight of the train. Five of the new trains were believed to be under construction in Spain as this book was written, and facilities for manufacture there have improved considerably in recent years. Meanwhile the three existing Talgo locomotives have been re-engined with Maybach MO.320 engines of 450 b.h.p.—two per locomotive.

As we have seen, the first Talgo trains for commercial



(*Above*) The "Jet-Glide" railway, running in ice channels, proposed by William H. Reinholz. (*Drawing: W. H. Reinholz*)

(*Below*) The latest Hastings proposal for a standard-gauge lightweight railway system, as put forward for the Seattle Exposition. (*Photo: John A. Hastings*)

(*Above*) One of the Geoghegan narrow-gauge steam locomotives (No. 23) at the Guinness Brewery in Dublin.

(*Below*) Narrow-gauge Geoghegan locomotive mounted in a "haulage wagon" to enable it to work over broad-gauge track at the Guinness Brewery in Dublin. (*Photos: Arthur Guinness Son & Co.* (*Dublin*) *Ltd.*)

use were built in the U.S.A. to Spanish designs, so it is not surprising that American builders and railways looked at Talgo when endeavouring to find means of reducing the weight and running costs of trains in the U.S.A. At the end of 1955 or beginning of 1956, A.C.F. Industries Inc. had exhibited a Talgo-type car which embodied the results of experience gained with the Spanish trains.

Talgo-type trains were built for the Chicago, Rock Island and Pacific, and the New York, New Haven and Hartford railways, and were modified to meet requirements in the U.S.A. For example, units were made up of three sections only, and individual cars were to be interchangeable. A prototype ran successfully and smoothly at up to 90 m.p.h.

The bodies of these trains are so built as to be suitable for fitting as "parlour", or dining cars. The overall length of the cars is 34 ft. 6½ in. and the width 10 ft. 2 in. The cars are designed to withstand a buffing load of 400 tons (U.S.). Special Tightlock couplers are fitted. The weight per passenger is only 700–800 lb., or half that of conventional trains in the U.S.A. The floor level is only 26–28 in. above rail level. As with the Spanish trains, each unit has its own air-conditioning equipment.

The Rock Island train began running between Chicago and Peoria (161 miles) in February 1956. It had seats for 288 coach passengers and 20 parlour-car passengers, the latter in a combination unit including a dining car. The cost worked out at $2,300 a seat compared with the then current cost of $3,800 a seat for conventional trains.

For some time this train ran two round trips a day (644 miles), but in 1957 it was withdrawn from the Chicago–Peoria service and transferred to the outer suburban service between Chicago, Blue Island, and Joliet. The train was altered for this purpose by adding a three-car unit from the prototype train mentioned previously. The dining-car accommodation was removed, and the seating increased to 500. An unusual feature was the installation of automatic machines to sell coffee, cold drinks, cigarettes, confectionery, etc.

The New York, New Haven and Hartford Talgo-type train, the *John Quincy Adams*, was running between New York and Boston. It is a 15-section train powered by two Fairbanks-Morse 1,720-b.h.p. diesel-electric locomotives, one at each end. The locomotives are fitted to pick up third-rail current while running on Manhattan Island, since only electric locomotives may run into Grand Central Terminal. As this book was written, this train was out of service for modifications.

Another type of train resembling the Talgo is being built by Pullman Standard under the title of "Train X". One such train is already in the hands of the New York Central System. This has five units with two cars per unit. Each unit has seats for 88 passengers. There is a separate 1,000-h.p. locomotive.

The train owned by the New Haven, the *Dan'l Webster*, has five three-car units, and is powered by two 1,000-h.p. diesel-hydraulic locomotives, one at each end. There are also a few electric motors on the train for use in low-speed running on Manhattan Island. This train, too, was out of service when this book was written, and it seemed likely that it and the *John Quincy Adams* might be out of service for some time.

Much of the initial work on the Train X design was done on the Chesapeake and Ohio, and a single trial car was run in 1951. The Talgo design in the U.S.A. seems to have been influenced by the construction in Germany in 1953 of two "gliederzuge", which, although they avoided the use of Talgo patents, were undoubtedly influenced by the Talgo design.

In 1954, the German Federal Railway started to use two articulated trains built on Talgo lines, though not actually using any Talgo patented methods. These trains were known as the *Komet* and the *Senator*.

During the first experimental period of running, the trains ran for some two months (23 May-30 July 1954) without attention. The *Komet* ran every night between Hamburg and Basle (570 miles) and the *Senator* ran every day from Frankfurt to Hamburg and back (670 miles).

After this initial period the trains were withdrawn for inspection, and some minor improvements were carried out. The *Senator*, which was fitted with single axles between each pair of units, developed lateral oscillations when travelling at speed, and the modifications were designed to overcome this. The *Komet*, a sleeping-car train, had an extra unit added to the original seven. At the time of its trial runs, it was the only German sleeping-car train worked by diesel power. Its riding proved equal to that of the ordinary sleeping cars in use in Germany. The designed speed of both trains was 75 m.p.h. but during the reconditioning period the locomotives were fitted with superchargers to make them capable of running at speeds up to 100 m.p.h.

In Argentina, development work has been undertaken on a new type of railcar understood to incorporate ideas derived from the Talgo system. The prototype vehicle has independent wheels and springing. The height and centre gravity are low, 9 ft. 10 in. and 39½ in. respectively. The body, 60 ft. in length, is tubular and has reversible seats for 40 passengers. The empty weight of this car is believed to be 19 tons. Two 125-b.h.p. Leyland engines are fitted, using mechanical transmission. A photograph of this car shows drop windows at the sides, so it is to be assumed that air-conditioning is not fitted. Development work was being carried out by the D.F. Sarmiento Railway at the Liniers works.

There are several other forms of lightweight trains in the U.S.A., such as the "Aerotrain" of four-wheel coaches, the "Keystone" tubular train of the Pennsylvania Railroad, and the coaches and multiple-unit cars of the "Pioneer III" type built by the Budd Company. None of these, however, departs as greatly from conventional practice as those already described.

Before leaving this section, however, it is worth mentioning a Swedish lightweight train, known as the KLL, which has some particularly interesting features. The train was designed and built by the A. B. Svenska Jarnvagsverk-Staderna of Linköping, and is light in weight, has a low centre of gravity, and is capable of high speeds.

The first train to be built has seven coaches, each 37 ft. 6 in. long, about half the length of a standard railway coach. The height above rail level is just over 10 ft. Various seating arrangements are possible, and the original train allows either 24 or 40 passengers per coach. Construction is of steel; roof, sides and underside are made of spot-welded units, and final assembly is made by riveting. The complete coach body forms a tubular unit, with a smooth underside. The floor is 22½ in. above rail level to suit average platform height in Sweden.

Each unit has an axle at both ends, so that a unit seen by itself is in effect a four-wheel vehicle.

Each pair of wheels, the axle, brake drums, rubber springs, torsion arm bearing, and the coupler, forms a complete unit. The rubber pads give the wheel sets considerable freedom of movement, and turn the wheels and axles into what is really a truck unit. The merging of the coupler with the axle gives some of the guiding features associated with Talgo trains, but the great point is that the couplers lock the axles at the ends of adjacent coaches into a solid four-wheel bogie, making the train into an articulated unit with four-wheel bogies. As the wheels turn freely and individually on the axles, some of the difficulties associated with normal bogies are avoided.

A special locomotive has been built for this train, powered by two Cummins VT-12 diesel engines and rated at 1,020 h.p. It is a diesel-hydraulic locomotive, each engine driving both axles of the bogie with which it is associated. It weighs only 36 tons, and is capable of 100 m.p.h. The train of seven coaches, locomotive, and full load of passengers and baggage weighs only 116 tons.

It has been found in trials that this train can negotiate curves at a speed some 25–30 per cent higher than can standard trains.

At the end of 1958 it was reported that the Pennsylvania Railroad and the Curtiss-Wright Corporation were jointly considering the possibility of a lightweight fixed-formation train to be powered by a 3,000-h.p. Wright engine, driving a reversible-pitch propeller. Although there were proposals in France just before the 1939–45 war for a propeller-driven diesel-engined car, the only conventional track car to be driven by a propeller was the 1931 Kruckenberg railcar (apart from the experimental vehicles which led to its construction). Propeller-drive has been proposed for monorails, and was actually used on the trial line built for the Bennie Railplane (see *Unusual Railways*).

10

SOME OTHER UNUSUAL RAILWAYS

Much has been heard in recent years of "Piggy-back" services, in which one vehicle (usually road) is carried on another vehicle (usually rail). Somewhat unusual, however, is a railway with piggy-back locomotives, but such is the Guinness Brewery Railway at St. James's Gate, Dublin.

The brewery, one of the most famous in the world, and the largest in Europe, was established in 1759, when horse-drawn trams and carts were used for internal transport. As the production of the brewery grew rapidly in the second half of the last century, more efficient methods of transport were needed, and it was decided to lay down a proper railway system.

The designers faced a problem of gradients, for the brewery, on rising ground on the banks of the Liffey not far from the centre of Dublin, is on three different levels. The railway was built between 1873 and 1877, the rise from the middle level of the brewery to the upper level being overcome originally by the use of a hydraulic lift which carried railway vehicles up to the level of the brewhouses. There are now 8½ miles of railway track in the brewery.

Much of the efficiency of the railway was due to Samuel Geoghegan, who was appointed Head Engineer of the brewery in 1875. He increased the weight of the rails on the 22-in. gauge line, and designed a two and a half turn spiral tunnel to take the line from the middle to the upper level. He also built new wagons and locomotives.

The tunnel—surely the only spiral railway tunnel in the British Isles—raises the line through a height of 25 ft. It has a radius of 60 ft. and a gradient of 1 in 39.

The first locomotive for the line was built in 1875, but its weight and power were inadequate for the comparatively heavy loads to be handled. Samuel Geoghegan purchased two further locomotives in 1876. These weighed 5 tons, and had large flywheels over the boiler rather in the manner of a road steam roller. They rejoiced in the appropriate names of *Malt* and *Hops*. These were followed by two six-ton locomotives, and in 1882 Geoghegan himself designed a locomotive with a weight of 7½ tons.

The first of the design was built by the Avonside Engine Company of Bristol. This was followed by 18 other locomotives to the same design, built by the Dublin firm of William Spence, Cork Street. This firm is now defunct.

As may be guessed from the number built, the Geoghegan locomotives proved very successful. They have two cylinders located over the boiler, driving by flexible-jointed, vertical side-connecting rods. They are tank engines with side tanks attached to the main frame plates. The tanks hold 80 gallons of water, and 3½ cwt. of coal can be carried in the bunkers. These four-wheel locomotives can haul 75 tons at slow speed on the level, or 18 tons on the steepest gradient on the system. The present tense is used because four of the Geoghegan locomotives are still available for traffic when required, and gave a good account of themselves during the oil shortage after the Suez incident, when they replaced the diesels normally used.

Each has a 29-in. diameter boiler and 72·6 sq. ft. of heating surface. The working pressure is 180 lb. per sq. in. The two cylinders are each 7 in. in diameter, and have an 8½-in. stroke. The wheels have a diameter of 1 ft. 10 in., and the wheelbase is only 3 ft.

The decision that diesel traction should take over duties on the line was made in 1947, when maintenance of the steam locomotives had become uneconomical and the quality of coal had deteriorated. Twelve 7-ton "Planet" 0-4-0 diesel locomotives by F. C. Hibberd & Company are now in use. One of them was shown at the Festival of Britain in London in 1951.

There is a semicircular engine shed in the centre of the main yard of the brewery. This has all the usual appurtenances of a roundhouse, including pits and a turntable.

There are nearly 300 wagons on the Guinness railway, over 200 of which are tipping wagons, four-wheeled, weighing about 15 cwt. and having a capacity of 80 cu. ft. Seventy-five are flat bogie wagons each weighing about 30 cwt. There are even some passenger vehicles, very old four-wheel wagons fitted with back-to-back seats and canopies. These seem to have been built as passenger vehicles, or converted to that purpose very early in the history of the railway, and are still used to take special visitors round the brewery. The flat wagons carry casks and sacked hops; the tipping wagons, malt, spent hops, and spent grain.

Apart from the narrow-gauge railway, there are 1½ miles of broad-gauge railway in the brewery on the Irish gauge of 5 ft. 3 in. This connects, through Kingsbridge depot, with the main-line railway network of Coras Iompair Eireann. It crosses a public road on its way, and is subject to the St. James's Gate Tramways Act, 1901, during its passage. Following the provisions of the Act, a man on foot, carrying a red flag, precedes the locomotive across the street, and the motion of the locomotive is covered in order that horses shall not be frightened by it.

It is on this broad-gauge line that locomotive "piggy-back" working takes place at times. An electric hoist lifts a complete narrow-gauge locomotive on to a broad-gauge "haulage wagon" specially built for the purpose. The wheels of the locomotive rest on friction wheels in the wagon, and these in turn are coupled by gearing to the track wheels of the wagon. When the locomotive wheels turn, the drive is transmitted to the track wheels of the wagon.

The broad-gauge line is usually worked nowadays by a 202-h.p. Hudswell Clarke diesel locomotive with Davey-Paxman engine, and by two Hudswell Clarke steam locomotives dating from 1914 and 1919 respectively. Like the broad-gauge diesel, these steam locomotives weigh 32 tons. They have 15-in. × 22-in. cylinders, and have a working pressure of 175 lb. per sq. in. The wheelbase is 6 ft. One of the Geoghegan locomotives has been presented to the Belfast Tramway Museum; another, No. 13, has been given to the Talyllyn Railway Preservation Society, and is now in the Society's museum.

The *Illustrated London News* of 7 September 1850 gives an account of the Weston "Nova Motive" system, a rather complicated version of the atmospheric propulsion idea which interested so many railway engineers, from I. K. Brunel downwards.

The Weston system must have had some merit, for it reached the working model stage successfully, as the *Illustrated London News* account reveals. It says:

"At the Polytechnic Institution is a new mode of propulsion now being demonstrated, which, under this title [Nova Motive] consists of a series of carriages travelling along with their own motor, in the form of a tube, which is flexible and air-tight. This tube has a series of side valves, entirely under the care of a guard, who, by levers, has perfect control over his train. The application is very ingenious, and is the invention of a mechanic. Along the whole line of railway is laid a pipe of any given diameter, in connexion with which a series of pistons are fixed between the rails intended to receive the tube above-mentioned in its passage. In these pistons are atmospheric valves opening into the fixed pipe, which is always kept exhausted, so that, when the train passes over the pistons, the side valves in the tube are opened by means of inclined planes communicating with other levers, which levers are raised up on the train passing. The atmosphere existing in the tube consequently rushes from the tube to supply the vacuum, and the train is impelled by external atmospheric pressure. The inventor, Mr. Weston, with several other practical mechanics, formed into a society, called the Inventors' Protection Society, has executed the illustration of a system by which the inventor states great saving may be accomplished."

The sight of a steam locomotive running across country would lead most people to assume that there must be a railway line underneath it. This would not necessarily have been the case in Canada and Russia in the second half of the last century.

In 1860, Nathaniel Grew built a small locomotive—about 15 ft. in length—designed to run on ice. In the next year he followed this by a larger locomotive. The original locomotive was sent to Moscow for use on cross-lake merchandise traffic. It was a saddle-tank locomotive with wrought-iron frames and had only two wheels. These were 4-ft. driving wheels, almost in the centre of the locomotive, driven by two 6-in. diameter pistons with 16-in. stroke through connecting rods. The cylinders were horizontal, and were placed behind the wheels and outside the frame on each side of the footplate. The driving wheels had broad tyres in which steel spikes could be fixed. The rear of the frame was carried on a pair of iron-shod sledge runners, and the front had a similar but smaller sledge. Both sledges were fitted with leaf springs, and the driving wheels were sprung in a manner which allowed the distribution of weight between driving wheels and sledges to be varied according to the nature of the surface over which the locomotive was running. There was a tubular boiler with a working pressure of 100 lb. per sq. in. The front sledge could be steered by a lever (looking rather like a screw-brake handle) on the front of the frame.

Grew's second locomotive, built by Neilson & Co., was much more like an orthodox locomotive. It, too, was a saddle tank, but whereas the first engine had rather clumsy tanks with a box-like appearance, the Neilson engine had a properly shaped saddle, behind which was a steam dome. The 5-ft. driving wheels looked just like those of an orthodox locomotive, except for the tyres, and the upper parts of the wheels, above the frame, were enclosed by splashers. There were two cylinders, 10 in. in diameter and of 22-in. stroke. These drove an intermediate shaft on which were the eccentrics, and coupling rods connected this intermediate shaft to the wheels.

The wheels were set further back than on the original locomotive—just forward of the footplate—and there was no rear sledge. The front sledge was longer and more massive—about 11 ft. in length compared with the total locomotive length of 22 ft. 6 in. over buffers—yes, buffers! This sledge was steered from a platform in front of the smoke box, the steering mechanism consisting of a handwheel like a ship's wheel, and worm gearing. This locomotive weighed about 12 tons.

It is recorded as having regularly worked on Russian rivers in the winter of 1861–62, hauling passengers and goods. Some accounts say that it ran a regular mail service between St. Petersburg and Kronstadt, hauling three standard railway coaches mounted on sledges.

The final fate of these two remarkable locomotives does not seem to have been recorded.

These two Russian examples are by no means the only ice locomotives, however, for many were used later in the last century and in the earlier years of the present one to haul lumber in Canada and the U.S.A. Many such locomotives were built by the Phoenix Manufacturing Company of Eau Claire.

The first such locomotive was tried out in Wisconsin, and proved a complete success—so much so that the company was practically swamped with orders. A typical locomotive of this type was carried on a leading sledge (taking the place of a leading bogie), and heavy caterpillar treads taking the place of driving wheels. A cab was provided for driver and fireman, as in normal railway practice. On the front was a large steering wheel, with a seat for the steersman. The boiler, of normal locomotive type, had a working pressure of 200 lb. per sq. in., and was 15 ft. in length and 3 ft. in diameter. The firebox was large, and was designed to burn wood—plentiful in lumbering areas. The frame was of heavy channel iron, reinforced where necessary.

The locomotives had four cylinders, 6¼ in. in diameter and of 8-in. stroke. Power was transmitted to the 12-in. wide caterpillar tracks by spur and bevel gearing.

The cab fittings resembled those of an orthodox railway locomotive in every way, even to the reversing mechanism. Speed was low—for it must be remembered that these locomotives operated on what were essentially logging roads, though covered with ice and snow—and averaged 4–5 m.p.h. In really good conditions about 15 sledges with 5,000–7,000 ft. of logs on each could be hauled.

Great attention was paid to the surface of some of the busier tracks, easy curves and gradients being cut and the frozen snow being watered to produce a hard, glassy surface. In some cases, regular ruts were worn, which, treated with water, made tracks which the locomotives and sledges could follow as well as an orthodox train follows the rails.

On the longer runs, a water sledge and a caboose sledge for the crew were attached to the trains.

At least one of these locomotives came to Europe, and was run experimentally in Finland.

Another strange locomotive, this time with legs, was William Brunton's "Steam Horse" (1813). This was propelled by two mechanical legs, and ran for about two years at Newbottle before ending its career in a spectacular explosion. It was popularly known as the "Grasshopper". Another Brunton locomotive worked at the Rainton mines.

Incidentally, a road steam-coach with legs was built at about this period by David Gordon. The coach had four wheels, the front wheels being turned by a hand steering gear. Between the front and rear wheels were six "legs" or propellers, which were designed to work in the same way as the hind legs of a horse, being alternately forced out backwards against the ground and then drawn clear of the ground again. These legs were operated by a six-throw crank driven by a steam engine carried in the body of the carriage. The legs carried a form of shoe, or "foot", at the ends. The legs themselves were iron tubes with a wooden core, a combination which was supposed to combine lightness with strength.

Sir Joseph Paxton, who started his career as a gardener, became superintendent of the Duke of Devonshire's gardens at Chatsworth when he was only 25. He rose to fame as the designer of the buildings for the Great Exhibition of 1851, and is well known as the builder of the Crystal Palace. The Palace was, in fact, the 1851 Exhibition building transferred, under Paxton's direction, to the site at Sydenham still known as Crystal Palace.

One of Paxton's schemes which has had much less attention was for a great railway girdle round London, which would have obviated any tunnelling work. The railway would have run in a sort of extended Crystal Palace 11½ miles long, built of iron and roofed with glass. It would have been 72 ft. wide and 180 ft. high.

The great glass structure would have run from the Royal Exchange, crossing Cheapside opposite Old Jewry, and then across the river by a wide bridge at Queenhithe—which, like the old London Bridge, would have had houses on each side of it. Passing through Borough and Lambeth, the girdle would have reached the South Western Railway, from which a loop would have been built to cross over a new bridge near Hungerford and ending at Regent's Circus. The main girdle-line would have crossed the South Western Railway, run over a bridge at Westminster, and thence via Victoria Street through Belgravia, Brompton, Kensington Gardens and Notting Hill, to Paddington and the Great Western Railway. From there the girdle would have run to join the London and North Western Railway and the Great Northern Railway, and onwards through Islington to the starting point at the Royal Exchange.

Houses and shops would have been built on both sides of the railway "boulevard", with an ordinary road running between them. Behind the houses would have run four lines of railway, built on top of a "raised corridor" about 26 ft. above the road level—high enough to cross over existing streets without trouble. Under the "raised corridor" would have been shops or flats (or "tenements", as Paxton called them). These shops or flats were to have double walls with air passing between them—what are now known as "cavity walls" —to prevent the noise and vibration of the trains from penetrating.

At least there would have been no smoke or fumes from the railways, for they were to have been worked on the atmospheric principle.

The cost of this gigantic enterprise was estimated at £34,000,000, and it was hoped that a Government guarantee of 4 per cent interest would be forthcoming. A profit of £400,000 a year was expected on the enterprise, but the whole thing seems to have been on much too grand a scale to win support.

Some interest was aroused by the mention in *Unusual Railways* of various lines laid with wooden rails. One or two more examples of such lines may be of interest.

An American railway contractor named J. B. Hulbert invented a particular type of wooden rail in the 1860s, and offered to build lines using his rails in Canada, particularly in Quebec Province. He was sufficiently successful to induce the passage of an Act through the Provincial Parliament, in 1869, to encourage the building of wooden railways of this type by guaranteeing interest at 3 per cent, up to a cost of $5,000 a mile, on the cost of railways of this nature finished before mid-1872. The Act also guaranteed interest on the cost of major bridges.

The first railway to take advantage of the Act was the Quebec and Gosford, of which some 25 miles were laid by 1870, closely followed by the Richelieu, Drummond and Athabasca. The latter built a 50-mile line between Sorel and Drummondville, and had trains running before the subsidy offer expired. The line was taken over by the South Eastern Railway the next year and rebuilt with iron rails.

The Levis and Kennebec and the Sherbrooke, Eastern Townships and Kennebec Railway, later to become part of the Quebec Central Railway, started work on the track formation in this period. They were prepared to lay wooden rails, and actually had a considerable quantity on hand, but changed to iron before, or soon after, track work actually started, it being evident by then that the Hulbert rail was not successful.

Two further railways, the St. Francis and Kennebec and the Three Rivers and Piles, changed plans at the last moment and used iron rails instead of the Hulbert Rail.

Hulbert himself built the Quebec and Gosford, using his own design of rail. These were baulks of maple 7 in. high and 4 in. wide, set in notches cut from heavy wooden sleepers. The rails were only 14 ft. long, but scarf joints were used, and the sleepers were so spaced that the scarf joints always occurred where the rails rested in a notch. The rails were held in the notches by wooden wedges driven like the keys in modern bullhead track, and these were the only fastenings used. The timber used was cut locally.

The locomotive for this unusual line was built by the Rhode Island Locomotive Works. Named the *Jacques Cartier*, it was a 4–4–0 with special wheels made to cover the entire 4-in. width of the rails. The *Jacques Cartier* reached Quebec in June 1870, and was driven under its own steam along a tram track and then over temporary rails to the end of the railway. The wood-burning locomotive, with its tender, weighed 28 tons.

Most of the wagons built were flat platform vehicles, but four were fitted with passenger bodies and were said to have been luxurious and smooth-running. Speeds of 35 m.p.h. were recorded on this line.

Wet weather, however, proved the downfall of the Hulbert rail. The baulks warped and wedges fell out, and many times the train left the rails. After about a year of struggling against difficulties the line was abandoned.

One of the strangest schemes to win official approval was the three-tier railway of James B. Swain, sometime Engineer to the State of New York. Swain was a competent and enthusiastic engineer, and carried the State Legislature with him, so that in 1872 a charter was granted to a company to build the line.

Swain proposed to buy a right of way right through existing buildings, where necessary, and to lay three tracks, one above the other. The bottom level would be for freight, the middle one—just below normal road level—for foot passengers, and the top level for cars

(*Above*) Miniature car on the automatic Post Office railway in Brussels.

(*Below*) Brussels Post Office railway car with container in place. (*Photos: Administration des Postes, Brussels*)

(*Above*) Ice locomotive built by Nathaniel Grew for service on Russian lakes and rivers. (*Photo by courtesy of "The Engineer"*)

(*Below*) The Snort track at Inyokern China Lake, California, in use. The pilot's seat is being ejected from a mock-up of the X-15, the aircraft built to fly out of the atmosphere into the fringes of space and return, carrying the first man into space. (*Photo: U.S. Air Force*)

China Lake, and numerous tracks have been built since. The China Lake track held the world's speed record for a land vehicle until 1959. It is officially known as the Supersonic Naval Ordnance Research Track, contracted, in the delightful manner which makes one suspect that things in the U.S.A. tend to be named with their initial letters in mind, to SNORT. There is a second track, prosaically named G-4, at China Lake. This track is also interesting and will be referred to again later.

The SNORT track was built and aligned with the greatest precision. The U.S. Coast and Geodetic Survey marked out a series of points at roughly 2,000-ft. intervals, 300 ft. west of the actual line of the track. These were the "master" points, from which the contractor for the rail track laid out further points at 500-ft. intervals only 50 ft. west of the track. These were accurately placed to 1 part in 100,000. The concrete track beam was laid with reference to these markers. The track was surveyed and re-surveyed no less than five times. Optical surveying was done on still nights when the temperature was less than 70 degrees. Concrete for the 4·1-mile, 6 ft. 7⅝-in. wide, track beam was poured to a vertical tolerance of –0, +¼ in., and pouring continued night and day until the whole beam was completed. Immersion vibrators were used to compact the two courses placed. A typical track bed, in which the concrete was placed, was about 12 ft. wide and 8 ft. 6 in. deep, properly compacted.

Sleeper units were placed at 50-ft. intervals, but only alternate sleepers were used, so that the track was supported by sleeper units at 100-ft. centres. The alternate sleepers, also at 100-ft. centres, could be used if necessary in the future. At joints, double sleepers were used. The sleepers could be adjusted both vertically and horizontally.

The rail used was the Bethlehem Steel Company's