Alternative Forms of Motive Power for Suburban Rail Rapid Transit

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Unconventional modes of rail motive power are considered. High capital costs of extending existing or new rail rapid transit lines into the more distant suburbs may have been a deterrent to implementation of some proposed extensions. Such high costs are caused, in part, by use of third-rail electrification with the perceived need for full grade separation. The longer the extension, the less the traffic on its outer extremities is a general condition that works against extension of full grade-separated rail transit into the far suburbs. Several forms of motive power are described that could offer much lower implementation costs for suburban rail rapid transit. The same concepts could apply to suburban electrified commuter railroads where electric operation is mandatory on critical center city terminal portions of a system. The proposed alternatives for heavy (i.e., high-platform) rapid transit ought to have costs on the order of those usually associated with light-rail transit, and yet would provide the spaciousness and comfort associated with suburban heavy-rail rapid transit. The unconventional motive power units described herein are intended to allow extension of existing (or proposed) electric rail transit into distant suburbs using nonelectrified railroad track that may be abandoned or used by an occasional freight train. Such existing rapid transit or commuter railroad lines are electrified because of underground operation in center cities. They generally have a roster of existing rolling stock that would have to be modified for use on nonelectrified extensions, and such modifications are described. A moderately deep discussion of technology is necessary to explain what is feasible and why. Precedent is cited in which transit trains have shared track with railroad freight trains.

The high capital cost of extending existing or new suburban rail rapid transit lines into the more distant suburbs may have been a deterrent to implementation of some proposed extensions. Such high capital costs are caused, in part, by use of third-rail electrification with the perceived need for fencing and full grade separation. In general, the longer the extension, the less traffic there is per route-mile. This is a general condition that has worked against extension of rail rapid transit into the more distant suburbs. Although there is precedent for third-rail-equipped suburban commuter electrified railroads at grade, the concept of at-grade third rail has been generally looked on unfavorably by local civic and political groups. It appears that at-grade third rail is an acceptable option only in communities where it already exists, namely in New York City's suburbs and a few locations on the Chicago rapid transit system. Where it does not exist, it is commonly perceived as being far more dangerous than the record indicates. This real institutional barrier stimulated the conceptual development of the alternatives described herein.

At the same time, suburban growth is proceeding at a rapid rate, with low-density suburbanization being the norm nationally. Several studies and papers on the subject have concluded that no form of rail transit is likely to be able to serve such areas. The potential market for transit in such areas is often below that deemed adequate for heavy-rail rapid transit using conventional criteria of population density and origin-destination desire lines. Residents of such areas do not respond in large numbers to bus transit but tend to rely on private automobiles. Typically, use of public transit in such areas is low and, in many areas, public transit does not even exist.

Numerous studies and papers have established that converging low-density suburban growth is a national and, to a lesser extent, an international phenomenon, with the result that traffic congestion within the suburban area is now common, and it is becoming worse. Means are needed to attract a significant number of motorists to public transit. It has been widely reported, and accepted, that it is extremely difficult if not impossible to attract motorists of a many-to-many trip pattern to transit.

Accepting that fact, one should also acknowledge that a still significant number of persons do commute, by driving, to centers of cities. These commuters are potential transit riders if rapid transit can be provided in low-density areas. If suburb-to-center-city motorists can be diverted from driving, the capacity they occupied can be made available to inter-suburban commuting motorists. In this indirect way, transit can assist in reducing suburban congestion.

To attract suburban motorists, a high-quality rapid transit service must be provided. The Lindenwold Hi-Speed Line operated by Port Authority Transit Corporation (PATCO) is an example. It has attracted a large number of motorists to transit in an area of low population density and high car ownership. However, extension of that system has not occurred in part because the areas into which extensions had been proposed had population density too low to justify heavy-rail rapid transit using conventionally accepted measures of population density and potential transit ridership.

To provide at-grade rail transit may be possible using (a) third-rail electrification, (b) overhead catenary electric power distribution with pantograph collection, (c) a diesel-electric power car, or (d) a specially designed rapid transit locomotive (RTL) pulling modified rolling stock in conjunction with high platform stations at ground level. Such stations would be surrounded by a drainage ditch, and the rails would span such a ditch on longitudinal stringers having no cross ties. This would prevent (or at least positively discourage) unauthorized entry without payment of fare, assuming a completely controlled fare collection system. By use of the proof-of-payment (sometimes called "honor") system, simple stations without controlled access could be used the same as is done on most new light-rail systems.

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Such an approach may permit use of existing underutilized railroad lines, specially so if time separation were ensured between railroad freight trains and transit-type trains.

There is some precedent for operation of rapid transit trains on track used by railroad freight trains. One example is provided by the South Brooklyn Railway's operation of freight trains on the Sea Beach Line of the BMT Division of the New York City Transit Authority. Absolute block operation ensures safe operation.

Another instance was operation of a freight train by Chicago Transit Authority (CTA) on the southbound express track of the north side (Howard Street) elevated line during the midnight hours when no rapid transit express trains were operating (George Krambles, unpublished data). CTA operated the service under contract with and on behalf of the Chicago, Milwaukee, St. Paul, and Pacific Railroad (the Milwaukee Road), former owner of the right-of-way. The service was discontinued in the 1960s with the decline of coal for home heating, the principal commodity handled.

The San Diego Trolley shares track with freight trains of the San Diego and Arizona Eastern Railway.

Precedent indicates that if positive separation can be maintained between passenger-carrying rapid transit trains and railroad freight trains, such operation has been permitted.

ALTERNATIVE FORMS OF MOTIVE POWER

The following concepts are for proposed extensions to existing rapid transit systems that are longer than most existing rapid transit lines and longer than some suburban electrified railroad lines. The most relevant comparison might be interurban electric railways of years past and the electrified route (third rail) of the West Jersey and Seashore (Pennsylvania Railroad) line from Camden to Atlantic City via Woodbury (1906–1949).

Alternative A

Third-rail electrification similar to that already used by most heavy rapid transit lines is suggested. This system uses direct current (dc) at 600 to 750 volts and follows general practice of nearly all existing rapid transit lines as well as two significant suburban railroad services in the New York City metropolitan area: (a) the Long Island Railroad and (b) the Hudson and Harlem lines of Metro-North Commuter Railroad (formerly New York Central).

Strictly speaking, third-rail at-grade is not an alternative form of motive power, although it is an alternative configuration for an urban heavy-rail rapid transit system that is fully grade separated. Dc allows relatively simple equipment on board the cars and is well proven and effective. Car weight is less than with alternating current (ac) distribution systems. Most importantly, any existing rapid transit car fleet would be available for use on such a route when and as required. A dc system using aluminum and steel composite third rail would need relatively fewer substations (say 50 percent) than a system using traditional steel third rail. Package substations, factory-built, are substantially less expensive than traditional substations assembled in the field by highly paid journeymen electricians. The comparative cost of a modern dc third-rail system should be relatively less than in the past.

Grade crossings require gaps in a third rail. This can be a problem for one-car trains, or even for two-car trains. Some commuter railroads use married-pair cars on which all eight third-rail shoes are connected together by a bus cable. This procedure allows the pair to span most streets that are crossed at grade. In any event, a train should coast across such a gap, to prevent arcing. This operation in turn requires careful placement of stations and signals so that a train is not required to stop on or accelerate across such a gap.

As noted previously, there is widespread opposition to at-grade, third-rail, powered rail rapid transit systems. This option, although technically preferable for some applications, might not survive public hearings.

Alternative B

A dc system using an overhead catenary is another possibility. Cleveland's Windermere-Airport Red Line uses such a catenary, as does Boston's Revere Beach Blue Line and Chicago's Skokie Swift suburban feeder. Grade crossings would be less of a problem, but maintenance costs would be higher. The West Jersey and Seashore reported that maintenance costs of its overhead were six times as much per mile as for third rail. This led to converting the Millville-Newfield Junction branch from catenary to third rail within a few years of that line's opening in 1906. Disturbances to service from fallen wires occur occasionally with catenary. It is nearly unknown for third rail to fail.

Most important, most existing rapid transit cars were not designed to carry pantographs. There is insufficient clearance between the roof of most cars and the ceiling of subways to clear a locked-down pantograph. The advantages of the present car fleet would be lost. Dc overhead is not recommended except for cases in which an all-new car fleet would be obtained that would include pantographs unless the interrelationship of the car design and subway clearances would allow installation of pantographs on existing cars.

Some existing cars might be modified to carry a pantograph (see Figure 1). This procedure would require changing the low ceiling area at the car's end where an air-conditioning evaporator is housed and may require strengthening the car's structure to carry the dead weight and dynamic load of a pantograph. This procedure may not be simple or inexpensive for a modern rapid transit car.

Alternative C

A further possibility would be a catenary delivering high-voltage ac at 25,000 volts, or 12,000 volts, single-phase, at 60 Hz. The cost per route-mile of electrification would be much less than that for a dc system. But, car equipment would be more complex, more costly, and heavier because the function of current conversion is transferred from a fixed substation to the car. A heavy transformer and rectifier are added to a car. They would not fit under most rapid transit cars. Railroad commuter cars that carry such equipment are 85 ft long and weigh about 50 to 70 tons, as compared to 30 to 45 tons for rapid transit cars.

A transformer-rectifier unit could be added to an existing rapid transit married pair by inserting a third car between the

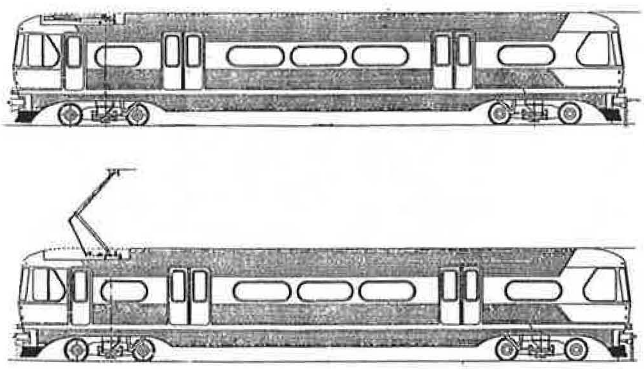

FIGURE 1 Single-unit double-ended transit car (top) with pantograph retracted and locked down for subway operation and (bottom) with pantograph extended.

two existing cars. This car would have no cab, would be semipermanently coupled to its mates, and would carry a pantograph, transformer, rectifier, and such switch gear as would be necessary to supply dc to the three-car set. The center car could be either a trailer or a blind motor car, depending on its duty cycle and propulsion equipment. Such a three-car dc/ac set would follow British Rail precedent. It is technically feasible, but a three-car passenger-carrying set would be a large minimum-sized unit for the market envisaged.

Another variant would include a short transformer-rectifier trailer and diesel-electric power car triplet. It would carry only electrical equipment and would not be a passenger-carrying car.

Overhead catenary is susceptible to damage from wind or weather far more than third rail. Occasionally, a pantograph shoe will snag a wire and pull it down with disastrous results to service.

Generally, high-voltage ac is economic when there are many track-miles versus units of motive power, as in most railroad applications. Dc systems are more economic when there are many cars per track-mile, as for rapid transit. The proposed extensions are a composite but lean heavily towards the economics of rapid transit because of the relatively large car fleet that will be available for expected peak needs.

Any type of electrification, as described in Alternatives A, B, and C may be uneconomic for the long, low-density routes envisaged as opportunities for outer suburban or interurban rail service. Only a site-specific study can indicate whether electrification is a viable option.

Alternative D

Storage batteries have been promoted by some designers for relatively long, light-density extensions of suburban railroad lines based on successful operation of about 400 battery railcars in the Federal Republic of Germany.

Those railcars are used largely on secondary intercity routes, local service, with a moderate number of stops. Most important, the amount of energy that can be stored in even a large battery that occupies all the underfloor space under a railroad-sized (80-ft) railcar is limited. The German cars can maintain a speed of only 50 to 55 mph. Batteries are expensive, heavy, and require attentive maintenance. The German cars have only two traction motors, each about the same horsepower as one of the four motors under a rapid transit car. With half the power, the rate of acceleration is low (about one-third that of a typical rapid transit car) and the top speed is two-thirds that of a modern car's 70 to 80 mph.

Battery cars would be unique and useful only on the extension. Present cars would not be usable. The one advantage, that no investment would be needed in electrification, is not sufficient to offset the disadvantages for most applications.

Battery power is not recommended.

Alternative E

Gas turbine-electric vehicles have been built in prototype form and operationally tested by the Long Island Railroad. These dual-power cars could run on third rail or from on-board gas turbines running generators. Four cars were built by General Electric Co. (GE) and four by Garrett-Airesearch Corp. The cars were operated for a short time in dual-power mode. They suffered a number of technical deficiencies (many of which probably could have been improved). They also suffered from very high consumption of jet engine fuel, a trait inherent in gas turbine engines. Fuel consumption was enormous. Operation was discontinued.

The four GE cars had their turbines removed and were converted to straight dc power. They operate with any other LIRR electric cars. The four Garrett cars were retired and sold for other uses.

The advantage of turbine power is that the heavy investment in electrification is avoided. Disadvantages are (a) larger first cost of turbine-equipped cars, (b) high operating and maintenance costs, and (c) nonavailability of the existing car fleet.

Turbine power is not recommended.

Alternative F

Diesel-electric power is another option, one that could be useful (a) as an interim measure and (b) permanently in areas where electrification would never be justified by the low potential volume of traffic.

The power car concept would be potentially useful on long extensions having infrequent stations and infrequent service.

The significant, indeed critical, advantage is that this dual-powered mode would permit through operation over the existing electrified rapid transit line and thence over any rail line extending beyond. Existing technology would be employed, using components well proven either in (a) rapid transit service or (b) railroad or industrial railcar freight switching service.

Never before has any rapid transit operator used diesel-electric railcars. It might thus be suitable for funding under UMTA's New Transit Product Introduction Program. Full 100 percent prototype funding might be available under Section 6 (R&D) plus 75/25 funding under Section 3(a)(1)(c) for a small number of introductory production units. Such a small number would probably be sufficient for an initial service.

The concept is simple. Start with an existing married pair, semipermanently coupled. Detach them. Insert between them a power car containing two 500- to 750-hp diesel-electric power plants such as those used in railroad switching, industrial, or branch line locomotives. These two engines would produce 1,000 to 1,500 hp, or 100 hp per axle for a three-car (triplet) unit. This is just enough for the continuous rating of typical traction motors. Acceleration would be less than when on third rail but adequate for service with stops far apart. The power car would look like a transit car, and windows could be simulated. Length should not exceed two-thirds of the length of a transit car. Three power cars would be as long as two passenger cars. A train of three triplets would be the same length as six transit cars, so would fit eight-car platforms (see Figure 2).

The power car would have a side corridor to allow employees and, if necessary, passengers to move from one passenger car to another. Its weight would be within the motors' and trucks' capabilities. Trucks would have steel springs rather than air springs. The power car should have an air compressor and auxiliary power converter to add to those on a married pair, providing redundancy for long-distance service. A failure 50 mi from help could be a problem. The two diesel engines provide prime mover redundancy, preferable to a single 1,200-hp engine. The two engines have an additional advantage. When idling between trips at an outer terminal, one engine alone will provide hotel power, so will conserve fuel. One would also suffice for low-speed yard movement (see Figures 3 and 4).

The power car would be a trailer having no traction motors of its own. Its only purpose would be to make electricity to power the two cars it is coupled to. The latter cars would have to have propulsion equipment adequate to haul the unmotorized, relatively heavy, power car during necessary station stops. It is envisaged that stations would be several miles apart on the type of route under consideration.

This car would be semipermanently connected to both of its passenger cars. Connectors for heavy current used for traction must be sturdy and firmly attached. It is not feasible to couple and uncouple a power car at the end of third rail as proposed by some planners. Moderate-current (400-amp) connections can be made by electrical couplers but heavy current—600 to 1,200 amps—cannot be handled reliably. Therefore, the power car must be semipermanently coupled. It was found that 1,200-amp connectors did exist, but they are manually attached, screw-type connectors made for use

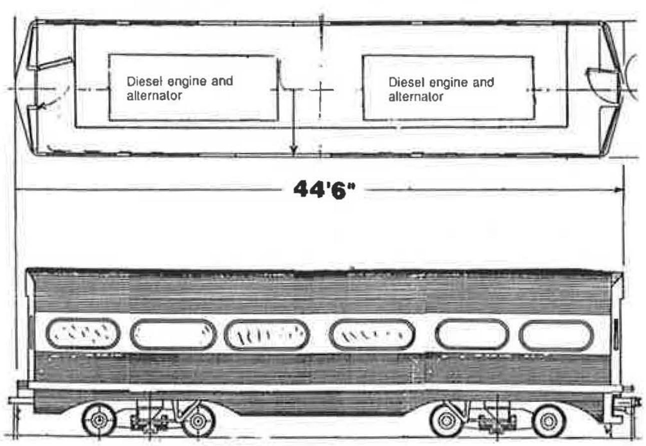

FIGURE 2 Diesel-electric power car concept.

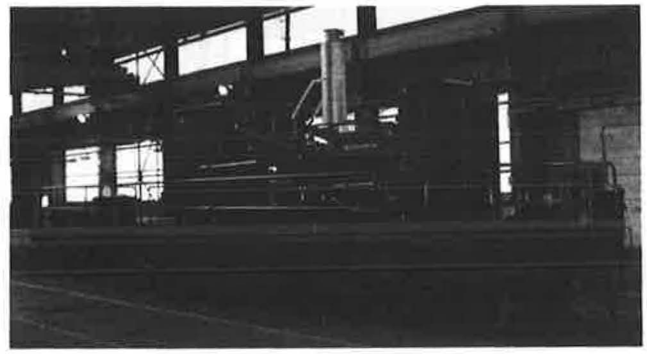

FIGURE 3 Diesel-electric power plant.

POWER PLANTS

Model No. .... Cummins, KTA-1150L
Number Cylinders 6
Cylinder Arrangement . In-Line
Stroke Cycle 4
Bore .... 6 1/4 in. (153mm)
Stroke .... 6 1/4 in. (153mm)
Full Speed .... 2100 RPM
Idle Speed .... 650 RPM
Aspiration .... Turbocharged/Aftercooled

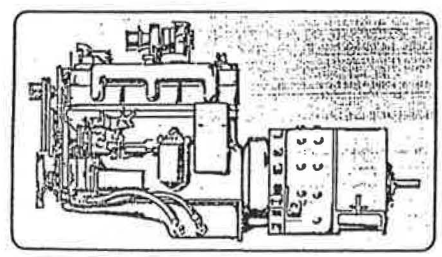

FIGURE 4 Power car would use two engines of this general type, 600 hp.

in oil fields. Glad-hand-type connectors commonly used to connect third-rail shoe cables to transit cars' main knife switch are contemplated as the only practical way to connect a power car's output to adjacent rapid transit cars. These are semipermanent, so they necessitate a semipermanently coupled triplet.

At first, an idea that seemed attractive was that of a diesel-electric power car that would be coupled to the end of a rapid transit train at the end of third rail. Power for traction and auxiliaries would be transmitted by coupler-mounted button connectors or jumper cables attached manually. It quickly became evident that this arrangement would not work because the current would be too high for any available connectors. A six-car train would need about 1,000 amps per car (at 600 Vcd). Thus, 6,000 amps would be transmitted from the power car to the first passenger-carrying car. It would be necessary to carry 5,000 amps through the first car to the second, then 4,000 amps to the next, and so forth. The cables would have to have nearly the same cross section as a third rail. Six heavy screw-type connectors requiring several minutes each to connect would be needed. This combination would be untenable.

Performance of a triplet would equal the top speed of the original existing rapid transit (or commuter railroad) cars but would have a lower rate of acceleration because of the weight of the power car and the limited output of the power car as compared with the virtually unlimited power from a third rail. For instance, in the PATCO case performance was calculated as follows:

- For a married pair, seated load, on third rail, 0 to 75 mph in 53 sec.
- For a triplet, seated load, on third rail, 0 to 75 mph in 75 sec.
- For a triplet, seated load, using diesel-electric power, 0 to 75 mph in 174 sec.

Acceleration drops markedly, but on a long line with few station stops, the lower rate should be tolerable. The rate of acceleration is about the same as for a locomotive-hauled commuter train.

A disadvantage is that the costs of operating three cars are incurred to have two carloads of passengers. This is a relatively large increase. It would be partially offset by eliminating maintenance of wayside-fixed electrical plant. However, the latter requires relatively little maintenance.

Another disadvantage is that a transit-type cab would be leading a train. This would place the train operator and possibly several passengers in a potentially vulnerable position in the event of a grade crossing collision. It may be preferable to use specifically designed cars with end construction like Long Island Railroad M-1 cars, which are designed to resist grade crossing collisions. It should be recognized that railroad passenger equipment is designed to withstand grade crossing collisions as well as collisions with other trains. The latter is reflected in an FRA requirement for 800,000-lb buff strength. The former is reflected in pilots to deflect items (such as motor vehicles) from the track as well as small end windows in cab cars (both electric multiple unit and push-pull for locomotive-propelled trains). The equipment described in this paper would operate at speeds comparable to railroad trains, namely 60 to 75 mph, so would need the same protection.

In contrast, light-rail vehicles typically operate at speeds of 25 to 45 mph in areas where grade crossings are prevalent. This is in part a reflection of the lighter vehicle with a more vulnerable end design.

Commuter rail, whether railroad or rapid transit, has a different operating environment than light rail.

The main advantage of the power car concept is the elimination of capital costs related to electrification. An additional advantage is that the power car concept probably could be implemented relatively quickly as compared to an alternative needing major civil engineering improvements.

Operationally, a triplet would be much like a rapid transit train with the addition of train-lined diesel engine control (start up, shut down, alarms, etc.). Transition from third rail to diesel-electric power could be made in motion or at a station. A passenger would not necessarily know that the change took place. The train would look like a transit train and generally would operate like one. To the passengers and the public it would be rapid transit. To the operator it would be a transit train with a one-person crew. Stations should be unattended with automatic or self-service fare collection equipment. Transit operating costs would result, rather than those of commuter railroad.

Alternative G

The locomotive-hauled rapid transit train is an innovative, perhaps improvised, alternative; yet, for several reasons it is an alternative that appears attractive for inauguration of fast, infrequent rapid-transit-type rail service.

A primary benefit of using a locomotive to haul rapid transit trains would be to have a sturdy locomotive leading the train over each grade crossing. The locomotive pilot is designed to fend off motor vehicles, and the locomotives' weight provides significant protection to the trailing cars should the train encounter a heavy motor truck on a crossing. The steeple cab design places the train operator above most impacts, and one engine or generator set is always ahead of him. This is the key reason for suggesting the use of rapid transit locomotives. Technical details follow on how this might be done.

The concept of a head-end power car that would be coupled to a rapid transit train was discarded because it is not feasible to trainline the heavy currents that would be required. Therefore, the locomotive option was considered.

Rapid transit trains would operate to the end of the third rail in the normal manner. A specially equipped rapid transit locomotive (RTL) would back from a siding and couple to the rapid transit train. This diesel-powered locomotive would be a steeple-cab, double-end unit designed for one-person operation (see Figures 4 and 5). It would have a control console similar to that in rapid transit trains. It would have the same coupler with a low-voltage (37.5-Vdc) electrical head mounted below or beside the coupler. All relevant trainlines would be usable although one, propulsion, would be commanded to coast when the locomotive is running. Other controls, such as doors, heating/ventilating/air conditioning (HVAC), lights, public address, etc., would be used in exactly the same way as when on third rail.

Auxiliary 650-Vdc power would be provided to the transit cars from the locomotive, either from its main generators or from an auxiliary generator (preferably the latter, but that would be a designer's decision), and transmitted by 650-volt bus train lines, two (or more) in parallel. On each side of the

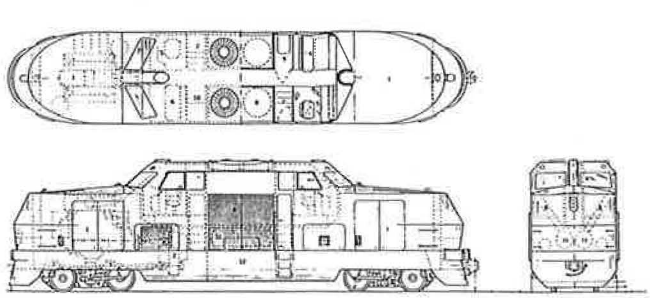

FIGURE 5 A streamlined, lightweight (50- to 80-ton) diesel-hydraulic locomotive designed for roadrailer freight service may be suitable for suburban service if equipped with a diesel-electric head end power supply.

coupler would be 650-volt, 400-amp, button connectors. The hotel load for each car is about 100 amps, maximum, so that 800-amp capacity should suffice for a six-car train and should marginally handle an eight-car train. At 650 volts, 100 amps provides 87 hp, so a six-car train would need about 525 hp just for the auxiliary load under maximum heat conditions.

A drum switch serving as a single-pole, double-throw (SPDT) switch would be energized by trainline (two trainline circuits would be needed; spares are usually provided in existing car fleets) to connect the auxiliary panel (a) to the knife switch (as at present) and thence to third-rail power, or (b) to the auxiliary 650-Vdc trainline, but never to both. The master controller in the locomotive cab would have only four power notches (P1, P2, P3, P4) rather than the eight commonly used in locomotives, but for the service intended four are enough:

P1—switching at restricted speed, 15 mph;
P2—reduced speed, about 30 mph;
P3—medium speed, 40 to 50 mph; and
P4—maximum speed, 75 mph, possibly 79 mph.

The locomotive would be wired so that the trainline wires would command coast to the trailing cars whenever the locomotive's master controller was in any power notch.

For braking, the WABCO RT5a P wire braking system or whatever is standard on that rapid transit system would be used. Dynamic braking both in the locomotive and trailing cars could be used, with friction brake for the final stop. Trainlines for those functions would be energized accordingly. Application of RT5a hardware would be designed to allow for the different braking characteristics of the locomotive versus the cars. The train operator needn't be concerned.

Only application engineering design will be needed. All components exist and are in reliable use in different places. They merely need to be brought together.

Severe brush and commutator wear might be expected on the traction motors in the transit cars when being hauled dead behind fast locomotives. However, such has not been the experience. Three examples follow.

1. The New York Central Railroad Company ran multiple-unit (MU) trains between Grand Central Terminal, Manhattan, N.Y., and Poughkeepsie, N.Y., from 1906 until about 1950 when rail diesel cars replaced the electric MUs. The MU trains ran on third-rail power to Croton-on-Hudson (a short distance north of Harmon). At that point, steam locomotives were attached, and the MU trains were towed to Poughkeepsie. The cars were equipped both with electric and steam heat. The literature does not indicate if there was severe commutator wear. The fact that the trains operated for 40 years indicates that whatever wear there was must have been tolerable.

2. New Jersey Transit Corporation towed a Jersey Arrow III MU car in Matawan-New York service for a number of weeks in 1984 with its traction motors cut out. The purpose was to investigate whether there would be abnormal commutator wear to towed cars. NJT contemplated towing MU cars on the New York and Long Branch line beyond the need of electrification at Matawan to Bay Head Junction. It was reported that no abnormal wear was observed.

3. Several railroads use fuel-saver controls on multiple-unit consists of diesel-electric locomotives by which certain trailing units are idled with their motors coasting, when their tractive effort is not needed. The extra units' power is needed and used only to accelerate the train and to ascend grades. This procedure saves stopping a heavy freight train to add or uncouple units, and so allows trains to keep moving as fast as possible (Richard C. Beck, unpublished data).

Fuel-saver units are also used in high-speed high-mileage service. It has been reported that commutator wear is worse than on motors that work all the time, and more maintenance is needed. However, the practice continues because the benefits are substantial and the problems tolerable.

Therefore, a towed transit train would probably not experience severe commutator wear, but if it should, such wear would be tolerable. The benefits from providing through rapid transit service to outer suburbs should well exceed a minor or moderate maintenance program. The practice of using the traction motors as generators in dynamic braking during those stops should keep the commutators filmed, and so less likely to their being damaged from being towed.

The primary benefit of having a locomotive haul a train would be to provide a major degree of safety to those passengers in the train and to the train operator in case of a grade crossing collision. The probability of collisions is more than zero; they will occur. The locomotive will provide substantial protection to the train, its operator, and its passengers. A second benefit is that it would not be necessary to haul a power car over third-rail territory where it would not be used. Hauling weight costs money—the added miles would increase maintenance costs. A third benefit would follow from the second in that the hazard created by hauling diesel fuel (or any other fuel) into a subway would be avoided.

The track layout at each terminal would have to provide run-around capability for the locomotives, but this would be a small price to pay for greatly enhanced safety.

The use of a locomotive ahead of a train composed of rapid transit cars not designed to withstand grade crossing collisions appears to be one means of protecting such cars.

The use of RTLs to haul rapid transit trains appears feasible.

RTL DESIGN

Sizing the RTLs should take into consideration both peak and offpeak traffic. If the locomotive were large enough to haul a six-car train, it would be much larger and heavier than needed for a two-car train. Traffic forecasts usually indicate that much of the time traffic will be light, and easily handled by a two-car 160-seat pair of cars. Yet, at peak periods, six- or eight-car trains may be needed. Therefore, it is suggested that RTLs be sized to efficiently haul a two-car train and adequately handle three cars, and that the RTLs be capable of MU operation by which two coupled RTLs could adequately handle a six-car train. One RTL and two cars (or two RTLs and six cars) should accelerate at 1.0 mph/sec. It is desirable that two RTLs be able to handle an eight-car train at a reduced rate of acceleration. Such trains, if needed, could run express. In all cases, a one-person locomotive crew should be sufficient.

The steeple-cab locomotive concept has traditionally been used in low-speed yard and branchline service. The main generator, traction motors, gearing, and truck design were intended to translate horsepower into high tractive effort at low speeds (in the range of 10 to 12 mph). The GE 144-ton, 1,200-hp unit is designed to be heavy to attain adhesion for high tractive effort (see Figure 4).

In contrast, the RTL would be designed for high speed and low tractive effort. Trucks for fast-freight (85-mph) locomotives might be appropriate, or those from four-axle passenger locomotives. The main generator (or alternator-rectifier), traction motors, and gearing would be designed for fast acceleration of a light load (three cars of 45 tons each) to 75 or 79 mph. The locomotive should be as light as possible consistent with safety requirements. About 700 hp is needed per car (600 hp for traction plus 100 hp for auxiliaries), plus perhaps 700 hp to propel the RTL itself. Therefore, an RTL might need 2,100 hp. Two engine-generator (alternator-rectifier) sets of 1,000 to 1,200 hp each appear necessary. This is a size commonly used in switching locomotives. Railroad traction motors are generally in the range of 750 hp, so that four such motors could absorb 3,000 hp. Such motors should, therefore, perform very reliably at the 2,100 hp indicated for the RTL.

The cab and hoods of the RTL could be streamlined sufficiently to ensure that wind resistance is tolerable (see Figure 5).

Design will entail significant effort for the RTL concept because it will be a new application. The fleet of RTLs will have to absorb all the design costs because no other applications for the manufacturer are apparent. A small fleet would have a relatively high design cost per unit. That should be kept in mind when deciding how many RTLs should be obtained.

Modifying existing railroad general-purpose-type locomotives as RTLs may be possible. These locomotives would probably be heavier than a purpose-built RTL, but their costs and availability might be low enough to justify their use.

Modification to a significant part of an existing car fleet would be needed, adding new draft gear, the coupler contacts, changeover switch, and two 4/0 trainline cables. Perhaps $100,000 per car might be required.

The budget for rolling stock might be roughly estimated as follows for a typical initial installation:

Item	*Amount*
Six RTLs @ $2 million	$12,000,000
Design of RTL	1,000,000
Forty cars, modification @ $100,000	4,000,000
Budget for rolling stock	$17,000,000

It may be desirable to permit use of remanufactured components such as trucks and traction motors with the dual objectives of faster delivery time and lower price.

The budget illustrates a dilemma, in that third-rail, single-track electrification could cost in the neighborhood of $30 to $40 million for a 40-mi route, sufficient for half-hourly service with no need to modify rolling stock or obtain RTLs.

Use of RTLs should not affect a transit line's status as a nonrailroad because it would still not be part of the general railroad system of the United States. The transit line would remain exempt from the regulations of a railroad.

The buff strength of most rapid transit cars used in the United States is 200,000 lb, whereas recent railroad passenger cars are built to 800,000 lb buff strength. It is undesirable and probably not permitted under FRA regulations to operate only transit-strength trains on trackage shared with railroad trains.

However, there are many railroad lines that have one freight train per day or two or three per week. Such lines may be useful for transit service if the track were time shared in a manner that provided exclusive occupancy by the freight train for a certain time period each day or week.

Usual rapid transit draft gear is not designed for the train to be pulled. Draft gear of cars to be pulled by RTLs should have been designed for that purpose. Fully automatic couplers operated from the cab would be used to permit rapid coupling or uncoupling. These are commonly used for rapid transit and are used on some electric MU commuter railroad equipment.

RECOMMENDATION

It is recommended that RTLs be given consideration as one means of extending rapid transit service to outer suburbs or nearby cities. This proposal should be compared with railroad commuter trains and single-track electrified rapid transit lines and the costs and benefits of each alternative should be compared.

REFERENCE

1. D. R. Phelps. Feasibility Study: Diesel-Electric Power Cars for Possible PATCO Atlantic City Service. In *Transit and Railroad Products Application Engineer.* General Electric Co., Erie, Pa., 1981.

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