Specifics of Light Rail Car Design Versus Rapid Car Design

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The Toronto Transit Commission has a long history of substantial involvement in rail transit, which complements an equally substantial involvement in both diesel and electric buses. The present rail car fleet now comprises 632 heavy rail subway cars, approximately 150 PCC streetcars 90 of which are available for service albeit soon to be retired, and 196 relatively new streetcars. At this moment, contracts for the supply of 126 new subway cars and 52 new articulated streetcars are in process with deliveries to commence in 1986 and completion expected in 1987. All of the 540 PCC cars purchased new by the commission since 1938, all but 6 of the new streetcars, and all but 176 of the subway cars were produced by the same contractor. That contractor also has the contracts for the new subway cars and the new streetcars.

Perhaps it was the foregoing somewhat unusual history that prompted the session moderator to ask that a representative of the commission investigate designs of light and heavy rail cars to determine if there is any substantial flow of technology or less glamorous design ideas from heavy rail car practice to light.

The investigation took the form of discussions with design staff of the commission's principal contractor, Can Car Rail, Inc., and also with a representative of Bombardier Limited, which has experience building both heavy rail cars for Toronto and light rail cars for Portland, Oregon. The information collected is presented as descriptive narrative because it appeared neither worthwhile nor practical to attempt to produce a reference work.

CAR BODY CONSTRUCTION

The majority of the commission's fleet of subway cars has bodies constructed largely of aluminum. Although it is realized that not all subway car operators favor this material, there are many imitators. Freedom from corrosion with adequate protection; a nonhostile environment (i.e., no road salt); and freedom from structural failure, given adequate design, appear to indicate the possibility of achieving the expected 30-plus-year life.

However, there appears to be no acceptance of aluminum for streetcars. The major reason for this is the use of copious quantities of salt to melt snow and ice on streets in northern cities; this, combined with accumulations of sand and other dirt in the presence of water, is not conducive to long life.

Although much aluminum is used for transit bus construction, these vehicles are typically not expected to serve as long as rail vehicles. Some bus manufacturers use stainless steel to provide long life and a smooth, welded exterior. Stainless steel is an optional material for rail cars. Toronto Transit has long recognized its merits but could find no solid reason to require it instead of aluminum. Both, therefore, have been acceptable materials for unpainted cars for many years. Price competition, however, always yielded aluminum as the winner to such an extent that the usual contractor no longer considers any alternative.

A problem in aluminum use is repairability. Street vehicles are subject to collisions to a vastly greater extent than are cars operated on a completely or largely reserved right-of-way. It is much easier to find tradespeople who can repair a steel body than to find those who can do top-quality repair of aluminum. Perhaps repairs could be reasonably easily effected in aluminum if riveted construction were used, but who would wish to have light rail vehicles (LRVs) with riveted sides?

Rail car body framing is typically specified to be able to resist a specified end squeeze load without permanent deformation. Heavy rail cars are required to resist loads in the range of from 200 to 400 thousand pounds whereas LRVs may be obliged to meet much lower requirements, perhaps down to empty vehicle weight times two. The reason behind this quite naturally lies in the much shorter train lengths, including single-car operation, used with LRVs.

The venerable PCC car is believed to have been designed to withstand a 100 thousand pound load, considerably greater than "weight times two." However, consultants now appear to be drawing on heavy rail practice and are requiring LRVs to resist greater end loads, (e.g., 177 thousand pounds for both Portland and Pittsburgh cars and, perhaps, Sacramento cars). The rationale may be to provide greater security for passengers in the event of a collision, but the ability of a car body to "crush" in severe accidents must be considered a limitation on deceleration of the "remainder" of the vehicle.

An LRV operating hazard, not faced by heavy rail, is broadside collisions. It is believed that no specific requirements are directed toward this eventuality.

An advantage for designers of platform-level-loading cars, whether heavy rail or LRV, over step-up cars is in the symmetry of the framing compared to designs with cut-outs for stepwells.

BODY INTERIOR

The incidence of serious fires in heavy rail subway cars has brought vast improvements in materials used for interior appurtenances. Such materials now are more nearly nonflammable and produce reduced smoke and toxic fume emissions. Although the special condition of tunnel operation with its obvious need to have fireproof cars does not apply to every light rail transit (LRT) line, the transplanting of the new material requirements to LRVs has been immediate. Included in the list of items affected are seats (both padding and upholstery), interior lining, window friezes, lighting lenses, floor panels, and floor covering. The drive toward reduced flammability has also included wire and cable insulation in addition to the interior materials.

The introduction of higher strength windshield glass into heavy rail cars has been followed by corresponding trends in LRVs. Cars for Portland have such windshields as will cars for Santa Clara and Hong Kong. LRVs operating at speed on private rights-of-way may be attractive to vandals intent on smashing windshields.

As a minor item, backlighted advertising card light fixtures, developed for heavy rail cars, have gravitated to LRVs and also to transit buses.

VEHICLE EQUIPMENT

In the days before the automobile, the industries that produced the predecessors of today's LRVs were probably both numerous and large in order to produce the numbers of vehicles required by city and interurban operations. In those days heavy rail operators probably benefited from advancements, however rudimentary by today's standards, developed for light rail vehicles. Indeed, this phenomenon continued until after World War II as evidenced by the production by the old Transit Research Corporation (TRC) of the rapid transit car specification as an evolution of the PCC car specification.

Several operators, notably Chicago Transit and Massachusetts Bay Transportation Authority, Boston, made great use of the specification in purchasing cars, and the Toronto specification for subway cars is firmly rooted in the TRC work although, at this point, it probably bears little resemblance to the original.

Virtual abandonment of LRV operations after World War II spelled the end of the flow of technology from light to heavy rail and the trend has now reversed. Another important factor in the process of idea development in North America is the influx both of hardware and of designs from the European and Japanese scenes. Thus the industry is quite fluid and soon it may be difficult to recall who developed what.

AIR CONDITIONING

An item of equipment applied to some LRVs with designs rooted in heavy rail is the air conditioning. Systems developed for main-line rail cars, notably the DC motor-driven refrigeration compressor, gravitated to heavy rail transit from which LRV apparatus was developed. An interesting variation in this theme has occurred in Toronto and may be of interest. In the application of air conditioning to the Urban Transportation Development Corporation (UTDC) cars for the newly opened Scarborough line, the evaporator-fan unit was placed in a drop-ceiling volume at the noncab end of the car. Early drawings showing this met with disfavor because of encroachment into an already low passenger space. The designers did a masterful job of squeezing the package, using two fan motors and attached blowers mounted at peculiar angles in the roof corner. This too met with disfavor so it was "back to the drawing board."

However generated, the designers brought forth an arrangement in which the apparatus was made to completely disappear into the ceiling. The design includes the evaporator mounted longitudinally in the center of the car roof and ceiling space at the center of the car. The single-motor blower unit is tucked behind the light fixtures and draws air from each end of the car through ducts behind the fixtures. Air is blown directly across the car through the evaporator. Cooled air emanates from the evaporator and enters a baffle arrangement that turns the air flow sharply both ways into longitudinal ducts in the ceiling. This clever design could conceivably be redirected back to heavy rail cars, given sufficient interest in enhancing interior appearance.

TRACTION CONTROLS

Traction and braking controls have undergone much development in recent years. The availability of thyristors with sufficient current-conducting and voltage capacity for electric vehicles soon yielded regenerative chopper controls on several fronts. First applications were to heavy rail cars in the 1960s. It was inevitable that, as this technology matured, there would be applications of it to light rail vehicles.

Inducements to adopt the new controls include not only energy efficiency and promised reduction in maintenance costs but also smoothness of control. The latter is particularly important if on-street operation is used. LRVs with chopper controls operate not only in Toronto but also in Boston, Buffalo, Philadelphia, Pittsburgh, and San Francisco.

The future may bring greater penetration of induction motor drives in LRVs. Although some vehicles with AC traction motors are in operation in Europe and the equipment is being heavily promoted for sale, it is believed that the system must be more complex and surely more expensive, both to buy and to maintain, than are DC chopper systems. Weight is greater than a corresponding regenerative chopper and energy recovery is not as great. AC drive also brings the need to control wheel diameters within close tolerance. It is therefore expected that operators, especially in North America, may react to the added costs with considerable sales resistance if getting rid of commutators is the only perceived benefit.

TRUCKS

The requirements of trucks for the two general types of car under discussion are considerably different. A street-operating LRV should have resilient wheels to help control ground vibrations. Heavy rail vehicles, on the other hand, have traditionally used only one-piece rolled or pressure-poured steel wheels. Wheel selection has a profound effect on the choice of friction braking because rubber elements in a wheel preclude the use of wheel-tread braking.

Primary springing design is deeply involved in meeting requirements limiting load shift in a truck as one wheel is raised. Such requirements are being used by some LRV operators to guard against failure to negotiate single moving point track switches of old street railway systems. Soft primaries probably bring a need to stiffen roll stability at the secondaries, perhaps by use of an anti-roll bar.

There can also be similarities between trucks for heavy and light rail vehicles. Maschinenfabrik Augsburg-Nürnberg (MAN) of the Federal Republic of Germany entered the Toronto scene by producing four car-sets of demonstration trucks for the four subway cars of the most recent car order. Success in the demonstration led to the MAN design being selected for cars of the current order of 126 and to the selection of a derived design for the new LRVs. The truck frames for the HRVs will be made by Can Car, those for the LRVs by MAN.

In the case of the new LRVs for Toronto, a repetition of the design of trucks provided under the most recent streetcars was precluded by the commission requirement for both bi-motor drive and inboard frames. MAN apparently was willing to adapt its HRV design to the new requirements while preserving many of the basic concepts. Major similarities will include frame layout, chevron primary and pneumatic secondary spring design, and anti-roll bars for stability (only one leveling valve will be used per truck). Major differences will include solid steel wheels, tread brakes, right-angle drive, and bolsterless design without a loaded center bearing for HRVs and resilient wheels; spring applied, pneumatically released disc brakes; single reduction, frame-mounted, three-gear parallel drive; and a loaded bolster with ball-bearing center bearing for the LRVs. The center truck of the articulated vehicle will not be motored.

The Toronto Transit Commission has opted for a braking system in which regenerative electric motor braking is the only retardation up to a prescribed limit of 17 percent adhesion. For brake requirements in excess of that produced by 17 percent adhesion on the motored wheels, friction brake is increased on the nonmotored axles up to a car full-service brake rate of 3.5 mph per second. As an added technical improvement, there is to be an automatic change from "preferential braking" to equal use of adhesion at all wheels, in the event of detected wheel slide. Change back is also automatic each time the car stops.

An example of design transfer from LRVs to HRVs is force ventilation of traction motors. Although subway car motors on many properties have typically been self-ventilated, LRVs, starting with post-World War II PCC cars, have had force ventilation to help motors survive in the inhospitable conditions under a streetcar, such as those found in Toronto in winter.

There is now a growing body of opinion in support of force ventilation of subway car motors to produce improved performance by supplying them with relatively clean, dry air, drawn from well above track level. Atlanta (MARTA) has been fortunate in being able to duct air from the roof line; the best that has been achieved for the new Toronto cars is to draw air from just above platform level. It is hoped that Toronto will be able to determine if there are benefits, in the form of reduced motor maintenance, to be derived from the exercise. That the motors to be used will be different from any others will certainly help to cloud the issue.

PASSENGER DOORS

There is no standard practice concerning passenger side doors and there are many variations. Perhaps only HRVs use inside sliding, pocketed doors. They also use outside hung sliding doors (Boston), folding doors (Chicago), and sliding plug doors. LRVs are found with folding doors (Calgary, Edmonton); sliding plug doors (Tyne & Ware); and outward hinged, pneumatically opened, spring-closed exit doors (Toronto). It is interesting that the latter was adopted as a standard in Toronto many years ago as a bus exit door that had been developed originally by Vapor as a push door. This apparatus has an excellent safety record and was selected over folding doors, which were to have been used "out of habit," for the latest Toronto streetcars at a late stage in car development.

CAR COUPLERS

Considerable variety exists in couplers used on various HRVs and LRVs, as might be expected where there is no requirement for standardizing from one property to another. Coupler choice is rather important because when a selection has been made, a property tends to retain the design as standard for obvious reasons. Cases exist in which couplers have been changed for performance reasons but instances of this are rare. In Toronto couplers on the original HRVs provided a relatively small number of electric contacts, which required that cars face the correct direction for coupling. This was of little consequence until line expansion provided several places where trains could turn around. A decision was made to not perpetuate those couplers; they were not changed out but no more cars were purchased with the particular coupler. The cars concerned will be replaced within the next 2 years and the problem will have been resolved.

In general, coupler makers will offer devices that use their own technology but in sizes to suit the application. Some may have been designed for LRVs and upgraded for HRVs; for others, the reverse may be the case. As patents expire, competitors may enter the market with compatible models of another's design.

CONCLUSION

In the transit business where individuals, as specification writers, designers, suppliers, builders, or operators, have had the opportunity to become familiar with the particulars of different types of vehicles and equipment it is inevitable that good ideas will be transferred from one vehicle to others. It is the responsibility of the people involved to ensure that the technology being transferred (or first applied) is indeed a correct application.

It is hoped that this discussion will provoke some reflection about the degree to which new vehicles draw on existing practice.