A Modern Streetcar For North America

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ABSTRACT

The City of Portland, Oregon, is supplementing the existing Tri-Met Metropolitan Area Express (MAX) regional light rail system with a 2.5-mile streetcar line designed to serve the neighborhoods in the central city core. This application required a vehicle considerably different than the standard light rail vehicle (LRV) – one designed to operate exclusively on urban streets in mixed traffic. The operational requirements mandated a narrower vehicle capable of operating in 3 m wide traffic lanes with high adhesion for stopping and grades. The neighborhood requirements mandated a shorter vehicle which "fit the neighborhood environment". Cost constraints precluded the development of a new custom vehicle.

The solution was importing an "off-the-shelf" European streetcar and upgrading it to meet United States safety standards, Americans with Disabilities Act (ADA) compliance, and passenger comfort. The selected streetcar was manufactured in the Czech Republic using systems from several European countries. Major changes from the base design included: converting a single-ended, single-sided vehicle to a double-ended, double-sided configuration; strengthening the underframe; incorporating ADA requirements; and adding air conditioning to the passenger compartment. The paper describes the various design details, and identifies the several subsystem suppliers.

Seven streetcars have been ordered for Portland, of which five will be placed into service in Summer 2001. Another three, with slight differences, have been purchased under the same contract for a new 1.5-mile streetcar line in Tacoma, Washington. These will be delivered in November 2001.

These vehicles are for the first new streetcar system developed in North America in nearly fifty years and offer another solution for transporting people on public transportation in our congested cities.

BACKGROUND

The City of Portland is installing a new streetcar system to meet the transit needs of a compact, revitalized urban core. The intent is to move people within and between city neighborhoods, rather than the more common use of light rail transit for movement between the suburbs and the urban core. Portland's system is strongly supported by the neighborhood and business associations of the areas through which it passes.

Conceptual design for the system began in 1989, resulting in adoption of a 3.5 km alignment in 1994. Preliminary design was initiated in 1995 and progressed into final design in 1997. Contracting and procurements were completed in 1998 with actual construction beginning in 1999. Opening is scheduled for July 2001.

The basic philosophy of the project was "Keep it simple. This is a streetcar not light rail." This permeated all aspects of design including the trackway, stations, power supply, communications and fare collection, and the topic of this paper, the vehicle. (1)

Portland Streetcar Incorporated (PSI), a community service non-profit organization charged by the City of Portland to manage the design, construction and operation of the streetcar line, initiated a vehicle procurement process in the fall of 1997. The intent was to purchase four modern streetcars with minimal changes. Changes to the basic design were to be limited to those required to meet the ADA, the addition of air conditioning and safety standards used in the American Market. The vehicle was to be "off-the-shelf".

The procurement process was a modified two-step, which included publication of a specification, technical negotiations with interested carbuilders and a competitive bid. Three carbuilders participated: Adtranz, Siemens, and Inekon/Skoda. The contract was awarded to Inekon/Skoda with a base vehicle price of $1.35 M.

This paper highlights some of the features of this rail vehicle, in particular those which were modifications to the "off-the-shelf" design.

VEHICLE CONFIGURATION

The operating environment for a streetcar is different than the typical LRV. The streetcar operates almost exclusively in mixed traffic on urban streets through neighborhoods. This is reflected in the shorter length and narrower width. Whereas the typical LRV is 25 - 30 m long and 2.65 m wide, this streetcar is 20.13 m long and 2.46 m wide. The car consists of three sections connected by articulation mechanisms. The two end sections have floors at 780 mm above top-of-rail and are supported by fixed trucks. The center section has a low floor of 350 mm above top-of-rail and is suspended from the end sections. This section also includes steps to provide access to the higher end sections. Each end section has one 700 mm-wide door to the right of the operator's position. The center section has two 1300 mm-wide doors on each side. The AW2 capacity of the vehicle is 115 passengers, based in 30 seats and standing room for 85 passengers at a density of 4 per square meter. The maximum speed of the car is 75 kph, although for Portland it will be limited to 50 kph, approximately half that of the typical LRV.

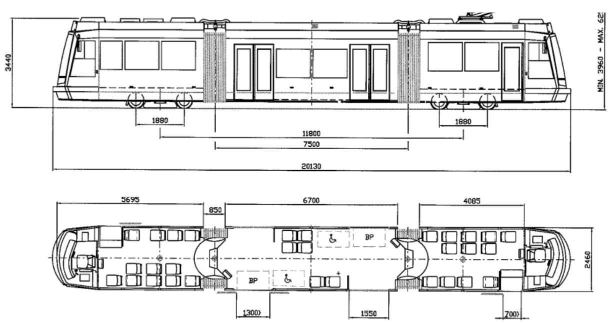

Figure 1. Vehicle General Arrangement.

The vehicle is designed to operate on existing streets with a minimum of reconstruction. Vertical curves as tight as 250 m in either crest or sag are routinely encountered at intersections. Grades of up to 9% are accommodated using a design with all wheels powered, 100% adhesion. Horizontal curve capability must be 20 m. Basic technical data is shown in the table 1.

The vehicle is designed to operate as a single unit with built-in redundancies to provide "limp-home" capability. The redundant systems, configured one per truck, are the propulsion system, friction brake system, and auxiliary inverters. The auxiliary inverters are configured to shed the auxiliary loads on one end in the event of failure and transfer the operation of the propulsion blowers to the remaining inverter to maintain full propulsion capability. In the event of a loss of the pantograph or contact wire, the vehicle can move a limited distance on battery power to clear an intersection.

Length of vehicle	20130 mm	(ft. in.)
Width of vehicle	2460 mm	(ft. in.)
Height of vehicle (without pan)	3440 mm	(ft. in.)
Height of low floor section above TOR	350 mm	(ft. in.)
Height of high floor section above TOR	780 mm	(ft. in.)
Operating range of pantograph	3960 - 6250 mm	(ft. in.)
Weight of empty vehicle	28,000 kg	(lbs.)
Number of seats	30	
Number of standees @ 4/m^2	85	
Maximum acceleration	1.34 m/s2	(mphps)
Maximum service brake deceleration	1.50 m/s2	(mphps)
Maximum operating speed	50 kph	(mph)
Maximum design speed	75 kph	(mph)
Wheel diameter (new/worn)	660/530 mm	(1 in.)
Continuous Output	4x85 kW	

Table 1. Basic Technical Data.

The primary systems suppliers are shown in the table below.

System	Supplier
Carbody	Skoda Dopravni Teknika
Trucks	Skoda Dopravni Teknika
Propulsion	Elin
Friction Brakes	Knorr
Auxiliary Inverter	Skoda Dopravni Teknika
Pantograph	Lekov
Doors	Bode
HVAC	Thermo-King
Communications	Meister

Table 2. Primary Systems Suppliers.

MODIFICATIONS FOR ADA

The existing design on which this "off-the-shelf" vehicle was based is the Astra, supplied by Inekon/Skoda to several cities in the Czech Republic. This vehicle was surprisingly compliant with ADA requirements without modification. The audio visual announcement system was standard, along with a bridgeplate for boarding in the low floor section. The main modifications were to normalize the slope and dimensions of the bridgeplate and create two wheelchair locations in the low-floor center section.

The bridgeplate was designed and manufactured by CTS-Servis of Podebrady, CZ. There is one bridgeplate per side for a total of two per vehicle. Modifications necessary to comply with ADA standards included adjusting the slope, providing for manual deployment and retraction in the event of an electrical failure, and interlocking with the vehicle "doors closed" signal.

The wheelchair locations were created in the center section adjacent to each bridgeplate-equipped door. A pair of double seats were removed at each location to open up a space in excess of 1220 by 760 mm. An aisle width of 770 mm is maintained to enable passage between the doors. Each location is provided with an emergency intercom station, bridgeplate/stop request pushbutton and tape switch, and handrails located below the window.

SAFETY STANDARDS

The largest task in this respect was the development of a Fault Hazard Analysis for the safety-related systems on the vehicle. The task was the development of the documentation itself - modifications required to the vehicle design were minimal.

Modification to the existing carbody structure were required. The minimum strength of the carbody was set to 1.1 g based on the speed limit of 50 kph. This required strengthening of the vehicle frame to withstand a compression load on the anticlimber of 290 kN. A finite element analysis was prepared as part of the redesign and a series of structural tests were conducted which reconfirmed both the actual strength and the finite element model.

The no-motion detection scheme was redesigned to provide for safety-critical design guidelines. The motion point is determined independently by each of two propulsion units and brake units. These signals are then logically compared in sets of three such that the no-motion signal requires three of the four units to agree. Normally all four units agree. If only three agree instead of four the operator is instructed to return the vehicle to the shop.

The door system was modified to include a sensitive edge to detect obstructions down to a 10x70 mm bar or a 20 mm cylinder. Visual indication of door and bridgeplate movement was added to the existing audible indication.

HVAC

A heating, ventilation, and air conditioning system was added to the passenger compartment by Thermo-King, CZ. The system was incorporated into the existing vehicle without a redesign of the roof structure. The 20 m length of the vehicle and the amount of equipment mounted on the roof precluded the use of two larger HVAC units. The problem was solved by using six 6 kW capacity units. Two were mounted on each carbody section, eliminating the need for ducting across the articulations.

The air conditioning units are stainless steel encased, self contained roof-mounted units. They are fully hermetically sealed and use a Copeland scroll compressor. Power is supplied by 400 Vac, 3-phase, 50 Hz and 24 Vdc control voltage. Overhead heat from the ac supply is also incorporated.

The small size and fully hermetically sealed design of the units enables a smaller authority to easily remove the entire unit for servicing at a facility of the manufacturer's local representative.

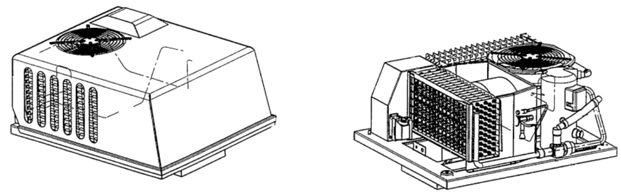

Figure 2. HVAC Unit.

SUMMARY

A major challenge of this Project was to find an "off-the-shelf" streetcar which could be adapted to the urban environment of Portland without requiring significant, costly modifications. Some changes could not be avoided, such as those for ADA compliance, passenger amenities and safety. The result was a streetcar that fits well with Portland neighborhoods and its streetscope at a very attractive price.

The streetcars will be tested in Portland starting April 2001 and accepted in time for service to begin on July 20, 2001.

This demonstrates yet another alternative for moving people throughout our congested cities by public transport.

ENDNOTES

1. Charlie Hales and Thomas B. Furmaniak, "Portland Central City Streetcar Line", APTA/TRB 8th Joint Conference on LRT Report #M-38, November 2000.