Innovative Design Features of Washington's Metrorail System

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Only a few fixed guideway systems have been built in North America during the last 40 years. Consequently, the design of each new system had to be original to advance the state of the art. Many of the features of the Washington Metropolitan Area Transit Authority's (WMATA) metrorail system, still under construction in the nation's capital and in service since 1976, are generally more technically advanced than other previously constructed fixed guideway transit systems.

RAIL CARS

Some of the unique features incorporated in the design of the rail cars are briefly noted below.

- Car-borne monitor tape recorder records 512 bits of information on a 30-min endless magnetic tape. The recorder is controlled by a "G" switch that stops the recorder in the event of a collision, thus providing a history of events prior to the collision.
- Electronic destination signs are controlled by light-sensitive diodes and a light-sensitive transistor that uses a code imprinted on the curtain. A newer version of the sign will use solid-state erasable program read-only memory (EPROM) logic and color-coded magnetic discs to display messages.
- Chopper control of the propulsion and braking system will allow a reduction of the total energy used by the car through the regeneration of energy during the braking mode.
- Automatic leveling system ensures that a constant floor-to-platform height is maintained.
- Structure of the car is such that impacts in the most likely direction of a collision (longitudinal plane) are absorbed, thereby decreasing the impact on passengers.
- Microprocessors are used in the propulsion and braking systems to ensure fast, efficient, fail-safe train operation.
- Fire-retardant material with the least low-smoke emission levels are used throughout.
- Automatic station announcements are capable via signals received from the automatic train control system.
- The frequency responsive governor continually protects against overspeed conditions by using a method that employs an active high-pass filter.
- Remote uncoupling of married pairs can be accomplished from any active cab.

AUTOMATIC FARE COLLECTION SYSTEM

The design of Washington's metrorail automatic fare collection system (AFCS) is unique in several areas and reflects some of the most advanced applications in the fare collection industry. Through the use of this advanced technology, designers and application engineers, with the assistance of a recognized industrial designer, responded to the challenge of translating the AFCS concept of a total service system into one fully responsive to extreme operational demands.

The major direction of the system's early development was to produce functional AFCS equipment that would be readily acceptable to and easily understood by Metro patrons. The AFCS machines were required to be aesthetically compatible with the spacious Metro station interiors and offer a high degree of security

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Design and construction of Washington's Metro tunnels incorporate several innovative features.

Automatic train control system simplifies duties of operator, who can override system in an emergency.

against theft and fraud. An expected continual rise in inflation coupled with a growing consumer awareness and resistance to change imposed an obligation on Metro planners and policymakers to promote not only a cost-effective system for revenue collection but to extend this approach to accommodate ready implementation of future changes. These changes, for example, would relate to fare structure, minimum and maximum farecard prices, bonus features, collection of origin and destination data, and eventually centralization of audit and service data reporting over the Metro data transmission system (DTS) directly to the computerized manager information system.

Metro's automated fare collection system is being continually upgraded. Entry at the fare gate takes only 0.7 s.

A newly developed bill validator device integral to the vending machines is capable of demonstrating higher availability and lower maintenance costs. All farecard transports have been designed to be 18 in long, providing an average throughput for passenger gate processing of approximately 27 patrons/min. All AFCS units stand alone, and each contains it own independent environmental control system because the paper base of the farecards, as well as the sophisticated microprocessor electronics and photo-optic sensors, requires continuous control and regulation of temperature and humidity levels.

The Metro AFCS transcends current systems in several respects. The system points to the future use of the magnetic farecard on the bus as well as the rail system, individual machine farecard-issuing capacity of 3,000 farecards for the farecard vendor, the ability of the farecard vendor to receive and stack two thousand $1 and $5 bills in a secure vault, the 0.7-s entry gate transport processing time, four peak/off-peak fare tables for each gate aisle and each addfare machine, centralized gate mode controls and emergency overrides in each kiosk, an Intel 8080 microprocessor system in each major unit, and, last, the collection of all machine revenues in secure collection vaults.

The Metro AFCS represents a new and exciting advance in the state of the art. When the next generation of the AFCS has passed final acceptance tests and manufacturing of production units has been completed, a new assessment cycle will begin and the results of continuous evaluation of the performance and public acceptance of Metro's AFCS will lead to further design refinements.

AUTOMATIC TRAIN CONTROL SYSTEM

Major improvements are embodied in the automatic train control system design. In addition to operation in full automatic and full manual modes, Metro trains can also be operated manually with automatic train protection. The CRT displays are the first to present information in every track circuit rather than in zones that include several track circuits. Previously designed systems used mock-up boards rather than CRTs. Information from and control over electrical and support systems have not previously been available at the level present in Metro's system.

DIRECT FIXATION OF TRACK WORK

Direct fixation of special track work (cross-overs, turnouts, etc.) on concrete slab in tunnels and on aerial structures has been adopted in track work design since 1968. The WMATA method differed from that used by earlier systems, such as San Francisco and Toronto where ballast section is used, and pioneered construction to reduce the maintenance effort. Later, new transit systems, including Baltimore and Atlanta, adopted this type of construction.

FLOATING SLABS

Noise and vibration control has been a primary consideration in the design of the metrorail system. Floating slab is one of the features designed and installed in tunnels for reduction of ground-borne vibration and the resultant noise transmitted to adjacent buildings. It is installed in those areas where the estimated noise and vibration levels from train operations with rigid inverts would exceed acceptable levels. Although the concept is not new, its application in the rapid transit system trackways is the first in the United States.

CONSTRUCTION IN ROCK

Some innovative ideas were incorporated in the design and construction in rock. They included, for example, use of shotcrete and rock bolts as temporary supports during excavation and the use of shotcrete, rock bolts, and steel ribs for permanent support. (Steel rib and shotcrete were designed as a composite structure.) The use of shotcrete and rock bolts for temporary supports permitted the safe excavation of large caverns in rock for the eight stations along the Shady Grove Route. Tunneling through the station or stations under the running tunnel contract has encouraged the use of tunnel boring machines on many of the running sections. Such combinations have achieved economy for construction of the transit structures.

SUBWAY VENTILATION SYSTEM

When the metrorail tunnel design was started, there were minimal analytical data or methods of calculation to establish the design of the tunnel ventilation systems. The design became more complex when it was decided to air-condition all of the underground stations. There were no previously used procedures for making an accurate load analysis by taking into account the numerous interacting conditions in a subway system.

For the preparation of the air-conditioning and ventilation system design, a mathematical method was developed to calculate the requirements that take into consideration all of the variables associated with the operation of a subway system. Air movement caused by train piston action was of special concern, and the innovative design of the blast relief chamber at the inlet to the vent shafts was used to reduce the effect on the station environment.

In 1975, the Subway Environmental Design Handbook was published. This document, which was the result of a Research and Development project conducted by the Transit Development Corporation and funded by the Urban Mass Transportation Administration (UMTA) provided a computer simulation program for deriving air-conditioning loads and ventilation parameters in subway systems. By participation in this research project while in progress, WMATA was able to incorporate most of the knowledge gained into the metrorail ventilation and air-conditioning design before completion of the handbook.

On July 30, 1979, WMATA received funding from UMTA to conduct a research and development program. The program would measure numerous environmental parameters in the operating subway system for the purpose of validating the procedures and data in the Subway Environmental Design Handbook. This project is expected to be completed by the end of 1982.

RADIO SYSTEM

The WMATA underground radio system is uniquely designed to use the same underground antenna system with six different frequencies for six support groups. It has six individual radio base stations at each location. These radios are multiplexed on to one radial antenna system.

Three radios are used by WMATA: operations, maintenance, and security. The other three radios are operated by the local jurisdictions: police, fire, and emergency medical service.