

TRANSIT COOPERATIVE RESEARCH PROGRAM

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TCRP Synthesis 12

**Transit Bus Service
Line and Cleaning Functions**

A Synthesis of Transit Practice

**Transportation Research Board
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Synthesis of Transit Practice 12

Transit Bus Service Line and Cleaning Functions

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213-Research for Public Transit: New Directions*, published in 1987 and based on a study sponsored by the Federal Transit Administration (FTA). A report by the American Public Transit Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U

S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, the National Academy of Sciences, acting through the Transportation Research Board (TRB), and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at anytime. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end-users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. TCRP results support and complement other ongoing transit research and training programs.

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the Transit Development Corporation, the National Research Council, or the Federal Transit Administration of the U S Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

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PREFACE

A vast storehouse of information exists on many subjects of concern to the transit industry. This information has resulted from research and from the successful application of solutions to problems by individuals or organizations. There is a continuing need to provide a systematic means for compiling this information and making it available to the entire transit community in a usable format. The Transit Cooperative Research Program includes a synthesis series designed to search for and synthesize useful knowledge from all available sources and to prepare documented reports on current practices in subject areas of concern to the transit industry.

This synthesis series reports on various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on measures found to be successful in resolving specific problems. The extent to which these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

*By Staff
Transportation
Research Board*

This synthesis will be of special interest to transit agency maintenance managers and other maintenance and operations personnel, including general managers, who are concerned with the need to maintain clean, efficient bus operating equipment. It will also be of interest to equipment suppliers, consultants, and others concerned with bus maintenance operations. This synthesis provides a variety of approaches to transit bus service line and cleaning functions so transit agencies can evaluate the effectiveness of their own operations.

Administrators, practitioners, and researchers are continually faced with issues or problems on which there is much information, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered or not readily available in the literature, and, as a consequence, in seeking solutions, full information on what has been learned about an issue or problem is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to the available methods of solving or alleviating the issue or problem. In an effort to correct this situation, the Transit Cooperative Research Program (TCRP) Synthesis Project, carried out by the Transportation Research Board as the research agency, has the objective of reporting on common transit issues and problems and synthesizing available information. The synthesis reports from this endeavor constitute a TCRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to a specific or closely related issue or problem.

This report of the Transportation Research Board updates material contained in the previous TRB synthesis series, *National Cooperative Transit Research and Development Program (NCTRP) Synthesis 1: Cleaning Transit Buses: Equipment and Procedures* (1982). In addition it addresses daily servicing and mechanical inspections, areas that were not originally covered. It contains discussions on defining a clean bus, defining a properly serviced bus, and on labor and equipment costs. Exterior washing, interior cleaning, and graffiti prevention and removal are discussed in detail based on the results

of a survey conducted for this synthesis. Case study examples highlight unique service line and cleaning conditions at New Jersey Transit, Phoenix Transit, and Santa Monica Municipal Bus Lines.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, available information was assembled from numerous sources, including a large number of public transportation agencies. A topic panel of experts in the subject area was established to guide the researchers in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now on hand.

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The Principle Investigators responsible for the conduct of the synthesis were Sally D. Liff, Manager, Synthesis Studies, and Donna L. Vlasak, Senior Program Officer. This synthesis was edited by Linda S. Mason.

Valuable assistance to the Topic Panel and to Synthesis staff was provided by Gwen Chisholm Smith, Senior Program Officer, Transit Cooperative Research Program.

Information on current practice was provided by many transit agencies. Their cooperation and assistance were most helpful.

TRANSIT BUS SERVICE LINE AND CLEANING FUNCTIONS

SUMMARY

Transit agencies inspect, service, and clean buses on a daily basis to ensure their safe operation and to provide an acceptable level of service and cleanliness to the riding public. These tasks are performed on what is called the service line—an area of the maintenance facility where transit buses are fueled, inspected for mechanical defects, and cleaned before being returned to revenue service. As a triage area, the service line is used to evaluate the overall condition of each bus in a relatively short period of time. Minor servicing and cleaning needs are addressed immediately, while more serious items discovered as part of the inspection process are noted and scheduled for attention at a later time.

This synthesis updates material contained in *National Cooperative Transit Research Program Synthesis 1: Cleaning Transit Buses: Equipment and Procedures*, a 1982 publication of the Transportation Research Board. Included are some of the more innovative methods and technologies introduced since the original study was conducted. This synthesis also addresses mechanical servicing and inspections, areas not covered in TRB's original report.

The information collected for this synthesis revealed that most of the productivity gains made during the past 13 years have been evolutionary in nature, rather than revolutionary. Most of the gains have come in the areas of data collection, revenue transfer and security, and the treatment of waste water. Interior cleaning, however, continues to be labor intensive and has experienced little in the way of productivity improvements. Furthermore, the increasing incidents of graffiti and vandalism only serve to exacerbate the cleaning process.

The service line and cleaning functions addressed by this synthesis include mechanical servicing and inspections, exterior washing, interior cleaning, detailed cleaning, and graffiti removal and protection.

Most transit agencies include refueling, checking and replenishing fluid levels, farebox vaulting, and identifying mechanical defects and accident damage as part of their daily service line function. Some agencies also integrate tire inspections and undercarriage inspections as part of this process. Service and inspection functions lend themselves to automation and hold great promise for productivity gains. Advanced data collection systems for several service line functions are slowly being introduced to the transit industry. Data collected from the bus can be used to track its overall performance and schedule maintenance activities. Advanced systems are also being developed to provide an immediate warning of impending failures to reduce the time, materials, and money required to maintain transit buses.

The automated brush washer continues as the most popular piece of exterior washing equipment in use today. Pressure washing equipment, once considered "state of the art," is actually used on a very limited basis, while automated gantry washers are beginning to attract some interest. Equipment maintenance and window crazing, two problems typically associated with automated brush washers, still persist today but to a lesser degree. Automated diagnostic systems have been developed to monitor bus washing equipment and identify maintenance needs. Window crazing, a phenomenon that occurs to thermoplastic windows as abrasive brush washers remove the window's protective coating, has been mitigated through the use of glass windows, barrier coatings, and new brush designs.

Other issues associated with automated washers include bus speed through the washer, the need for additional detailed cleaning, and water intrusion into the bus. Water reclamation and sludge removal are attracting greater attention among transit agencies attempting to reduce the amount of water and hazardous or toxic waste generated from bus washing facilities. Sophisticated water treatment systems have been developed with advanced filtration technologies capable of processing all of the nonseptic water generated from maintenance facilities.

Transit agencies perform some level of interior cleaning on a daily basis. Interior cleaning has not changed very much during the past 13 years, is extremely labor intensive, and does not easily lend itself to automation. Productivity improvements lie primarily with the efficient allocation of labor.

The cyclone vacuum, introduced more than 30 years ago, continues as the primary piece of mechanized interior cleaning equipment in use today. The cyclone is a large-capacity vacuum cleaner with a main orifice that fits over the entire front door of a bus. Dust generated by the cyclone, which settles on interior surface areas and requires additional cleaning, has caused many to abandon its use and revert to broom sweeping. Airborne dust and noise generated by the cyclone also create health concerns among workers. Sophisticated electronics used in buses today also are affected by the airborne dust generated by cyclones. An alternative to the cyclone involves the use of central vacuum systems.

In addition to daily cleaning, transit agencies perform a more detailed cleaning to their buses. Detailed cleaning typically occurs in a separate area adjacent to the service line. Most agencies perform the task "in-house," although some contract with independent cleaning companies. The frequency of detailed cleaning differs from one agency to another and depends on several factors including operating environment and the degree of cleaning performed on a daily basis.

Many agencies continue to experience dramatic increases in graffiti and vandalism. Quick removal and repair are among the most effective ways in which to deter graffiti and vandalism. Some agencies are taking more aggressive measures to prevent graffiti and vandalism from occurring in the first place. Specially designed products are available that make graffiti harder to apply and easier to remove. To leave a permanent marking of their work, vandals have resorted to the use of sharp etching tools. The most troubling aspect of etching is that it thwarts the primary graffiti countermeasure-its immediate cleanup. Different types of graffiti and vandalism react differently to specific bus surfaces (e.g., glass windows, plastic windows, seats, panels, etc.), and require different procedures to remove.

CHAPTER ONE

INTRODUCTION

This synthesis updates material contained in an earlier TRB publication that addressed transit bus cleaning equipment and procedures (1) (Pertinent information contained in that report is included in Appendix A). In addition to cleaning equipment and procedures, this synthesis also addresses daily servicing and mechanical inspections, areas not covered originally. As a study of practice, this synthesis examines how transit agencies in the United States and Canada collectively approach service line and cleaning functions. Included are traditional approaches, as well as some of the more innovative methods and technologies introduced in recent years.

The importance of a properly serviced bus cannot be overstated. As a triage area, the service line essentially represents the "front line" of an effective preventive maintenance (PM) program. It is where the bus returns every day after completing its scheduled work to be inspected, replenished with fluids, and readied for the next day's operation. Minor adjustments and servicing are done as part of a daily routine, while more serious defects are noted and scheduled for attention at a later time when resources are available.

In addition to ensuring mechanical readiness, the service line is the point where transit buses receive a daily cleaning. Coarse refuse is removed, the floor is cleaned, gum and light graffiti are removed and windows, seats, the driver's compartment and other areas are cleaned on a daily basis. Buses in need of additional cleaning or graffiti removal are addressed off the service line when time is available. As was recognized in the original TRB study, exterior cleanliness indicates to nonriders that the transit service is worthy of their support, while interior cleanliness shows existing customers that the agency values their patronage. As a mobile public facility, a clean transit bus reflects well on the overall community and helps to increase ridership. Figure 1 shows a typical sequence of service line and cleaning functions.

As funding for public transit becomes limited, any activity that promotes customer satisfaction and ridership is to be encouraged. Speaking at the 1994 American Public Transit Association (APTA) Annual Meeting, APTA's vice president of marketing stressed "It will take a thousand little things to improve ridership" (2). Maintaining a clean bus fleet goes well beyond one of the "little things." In fact, many transit managers regard a clean transit bus fleet as essential to improving customer satisfaction and ridership.

Service line workers who service, clean, and inspect buses on a daily basis play critical roles in every transit bus operation. Despite the importance, these are typically entry-level jobs requiring minimal educational and skill levels. The repetitious nature of the work requires constant supervision and typically results in high turnover as workers seek better positions. The nature of work also makes it difficult to achieve a consistent level of job quality.

Making the job more difficult are a myriad of unpleasant working conditions, which include exposure to exhaust emissions, fuel, extreme weather conditions, poor lighting, and poor ventilation. Of all bus maintenance jobs, service line workers tend to have the greatest exposure to work related injuries. Floors are often wet and

when combined with lubricants and fuel can cause potentially slippery conditions. Also contributing to a harsh working environment is an archaic interior vacuum system at some transit agencies, which generates large amounts of airborne dust and noise. Furthermore, service line workers are exposed to a growing number of bio-hazard materials left by passengers, including potentially infectious paper tissues, hypodermic needles, and other objects that may spread disease.

In addition to the harsh working conditions, service line personnel must deal with the activities of a growing segment of society that appears intent on vandalizing transit buses. The vandalism of interior and exterior panels, windows, trim molding, seats, and other bus components only serves to make their jobs more difficult, time consuming, and costly to perform.

Service line and cleaning functions performed by transit agencies actually have changed very little over the years. Buses may look different today, but they still need to be fueled, serviced, and cleaned daily. While much of the technology and many of the procedures used to perform these functions also remain unchanged, there have been advancements in certain areas. Advances in data acquisition, revenue transfer and security, waste water recycling, exterior washing equipment, and others have affected the manner in which some servicing and cleaning tasks are performed.

While new products and procedures have assisted maintenance personnel with improving the efficiency of certain service line and cleaning functions, other circumstances have hindered the process. For example, wheelchair lifts, which are commonplace on transit buses today, can add considerably to service and cleaning tasks. In addition, the incidence of graffiti and vandalism, which have grown to epidemic proportions in some cities today, require vast sums of money and labor to combat.

PURPOSE AND METHODOLOGY

Although they occur simultaneously at most transit agencies, mechanical servicing and inspections, cleaning, and graffiti/vandalism are addressed as separate service line functions in this synthesis. By isolating these functions into separate chapters, a more comprehensive review can be made of each.

For the purposes of this synthesis, service and inspection functions include:

- Fueling,
- Checking and replenishing other consumables,
- Safety and accident inspections,
- Mechanical inspections,
- Tire checks,
- Revenue removal,
- Data collection, and
- Wheelchair lift cycling.

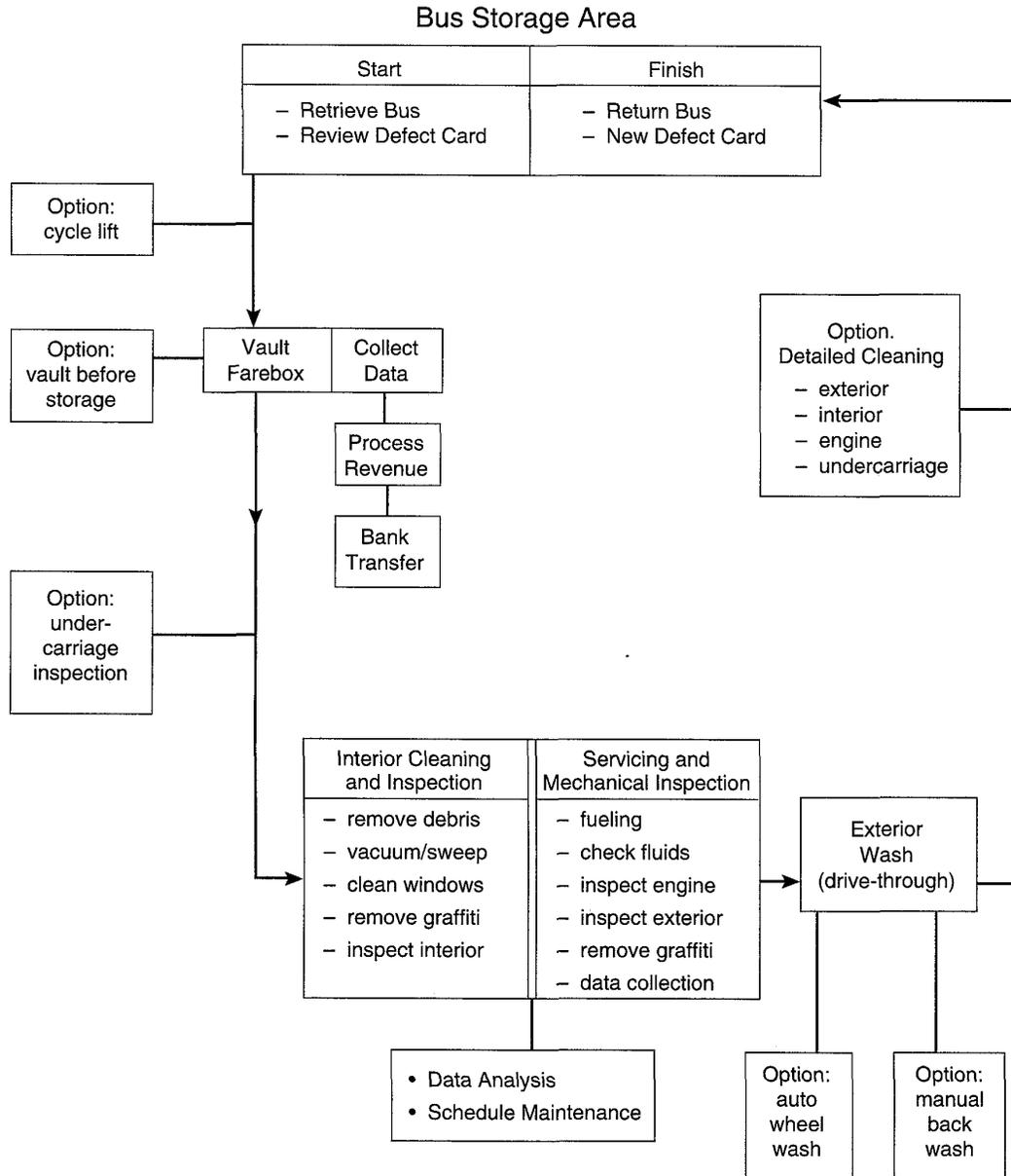


FIGURE 1 Typical sequence of service line and cleaning functions.

Cleaning functions include:

- Daily exterior washing,
- Daily interior cleaning, and
- Periodic detailed cleaning.

Graffiti and vandalism functions include:

- Prevention programs,
- Special products and materials, and
- Cleaning procedures and removal

A group of bus transit agencies of various sizes with differing operating characteristics in North America was selected to report on their individual servicing and cleaning functions. A group of 120 geographically diverse agencies was surveyed, and 52 bus transit agencies responded with information about their cleaning and servicing practices. A copy of the survey questionnaire, along with a list of agencies responding, is contained in Appendix B. In addition to the survey, a thorough investigation was made of three transit agencies.

Although transit agencies perform many of the same functions, each uses a combination of labor and equipment unique to its operation.

This synthesis does not attempt to define the "correct" combination of resources needed to carry out service line and cleaning functions. What may be appropriate for one agency may be not be for another. Developing the most efficient blend of resources is for each transit agency to establish on its own.

In many ways, finding the appropriate balance of labor and equipment is both art and science. Each transit agency must combine factual information and gut instinct to develop an overall approach that is both efficient and cost effective. Some of the elements used in developing the overall approach are the result of exhaustive research and testing, others are done through trial and error, and still others are simply the consequence of intuition or habit. This synthesis provides a variety of approaches so transit agencies can evaluate the effectiveness of their own operations.

DEFINITION OF A CLEAN BUS

The word "clean" is arbitrary and subject to personal interpretation. As a result, many transit agencies have established written job standards that objectively define cleaning tasks. Of the 52 transit agencies responding to the survey, 44 percent have job standards for exterior cleaning and 65 percent have written standards for interior cleaning. Some of the standards are rather vague and ambiguous in scope. Others are extremely detailed and include the sequencing of tasks, concentrations of chemicals, and other details. In fact, the Regional Transportation District (RTD) in Denver ends its job standard with a final instruction for cleaners to "go home and *hit the sack!*" -- as if to imply cleaning personnel should be too tired to engage in anything else.

One of the most comprehensive definitions of a clean bus is provided by the Metropolitan Atlanta Rapid Transit Authority (MARTA). The definition is extremely detailed and may be unrealistic for most to achieve. Regardless, it is a level of cleanliness that all should certainly strive to attain. MARTA defines a clean **exterior** as having:

No dirt on the front, sides, or rear of the bus; no sticky or oily residue on the front, sides, or rear of the bus; no graffiti on the front, sides, or rear of the bus; no dirt, stickers, residue, or graffiti on the windshields or window glass of the bus; all outside mirrors clean; no soap streaking on the body or exterior glass of the bus; and all wheels painted.

MARTA defines a clean **interior** as having:

No dirt, dust, trash, stains, gum, or any kind of residue on seats, floors, side panels, walls, wheel wells, step wells, ledges, handrails, driver's area, driver's control, light panels, and ceiling; no graffiti on any interior surface; no dirt, stickers, residue, or graffiti on windshields or window glasses; inside mirror glass clean; no damaged advertising signs, no cut seats; and step wells and floors sealed

DEFINITION OF A PROPERLY SERVICED BUS

The first step in a successful preventive maintenance program is the early detection of mechanical defects before they escalate into major failures. The service line provides a daily opportunity to identify abnormal conditions and to ready the bus with all necessary fluids for the next day's run. Based on written procedures submitted by several survey respondents, a properly serviced bus can be defined as having:

A sufficient amount of fuel; oil, transmission, coolant, windshield washer, power steering and other fluids at the correct level; no unusual

leaks of the fluids listed above; tires are inflated with the appropriate amount of air, tire treads have sufficient depth and the tire is safe for operation; lug nuts are tight, all contact surfaces free of paint, and wheel seals are not leaking; the rear doors, interlock and sensitive edge components are all working properly; the wheelchair lift has been cycled and is in proper working condition; all equipment fitted to alternatively fueled buses is operational; all lights including signal lights, running lights, head lights, dome lights, step tread lights and others are functioning properly; the overall condition of bus body is free of safety-related damage such as loose inspection doors, panels, etc; the interior is free of cracked or cut seats and trim, broken or loose grab bars, broken stop request activators, and any other loose, bent or broken panels that may cause injury to driver and passengers; the brake, steering, suspension and drive systems of the bus are all functioning properly without any unusual noises, air leaks or excessive free play; the fare box is probed and vaulted; and the destination signs, driver's seat and controls, HVAC (heating, ventilation and air conditioning) system and all instruments and warning lamps are functioning properly

LABOR AND COST

Service line personnel appear to be adequately paid for their work, which requires relatively low levels of skill and educational requirements. Of those transit agencies responding to the survey, most pay their service line employees between \$10.00 and \$15.00 per hour. Although each transit agency has its own wage scale, the salary paid to service line personnel appears to be consistent with wages paid to transit bus operators and represents about 75 percent of the wage paid to top bus maintenance employees (3).

Determining the time and cost for each service line and cleaning function is difficult because of the many variables involved. Each transit agency has its own unique operating environment, allocation of labor, frequency interval, equipment, facility layout, wage scale, and quality standards. Regardless of the differences, it is appropriate to include a general analysis concerning the time and cost for specific tasks. Table 1 includes the time and cost for all service line and cleaning functions included in the survey.

Because each transit agency supplements its daily interior cleaning with detailed cleaning, it is necessary to take a closer look at the costs involved. From the survey results it is difficult to determine how much total time is spent cleaning interiors because of the many variables involved. As noted in Table 1, the majority of survey responses indicate that transit agencies spend about 5 minutes cleaning each bus interior as part of the daily service line function. However, the time does not reflect detailed cleaning because it is typically performed on a periodic basis separate from the service line.

One indication of time and cost spent on interior cleaning involves an examination of the three transit agencies used as case studies in this synthesis. At NJ Transit's Hilton Garage, it takes approximately 12 minutes to clean each bus interior on a daily basis. The hostler, who drives buses to the service line, spends an average of 5 minutes cleaning each bus as part of the regular service line function. Another 7 minutes per bus on average is spent removing graffiti and stains and cleaning other areas that the hostler did not have time for on the service line. In addition to daily cleaning, NJ Transit spends 3.5 staff hours on detailed interior cleaning on each bus monthly. The average hourly wage for cleaners at NJ Transit is \$13.20 per hour.

Phoenix Transit also spends an average of 5 minutes cleaning each bus interior on the service line. Each bus also receives a midlevel cleaning every two weeks involving six people, each working

TABLE 1
PER BUS LABOR & COST ANALYSIS OF SERVICE
LINE/CLEANING FUNCTIONS

Function	Staff Minutes	Labor Cost (based on \$12.00 per hour)
Fueling *	0.25	0.05
Consumables	2.0	0.4
Defect Inspection	3.0	0.6
Farebox	2.0	0.4
Wheelchair lift	2.0	0.4
Interior clean	5.0	1.0
Exterior wash	1.0	0.2
Service line	15.25	\$3.05

* Estimated time includes nozzle attachment and detachment only. Other activities are taking place during the actual fueling process. Note: the table reflects the most popular response received from each survey question, as opposed to averaging all responses. Times included in the table are for specific tasks and do not account for idle time between tasks, nor does it include transportation time from one bus to another. Because some tasks are done simultaneously by different workers, it would be inappropriate to estimate the time of the overall service line function by simply adding all times together. However, the most popular response to the survey question regarding total service line time for each bus was 15-16 minutes, which coincidentally represents the total of all times included in Table 1. The labor cost of \$12.00 is based on the most popular response to survey questions concerning wages paid to service line and cleaning personnel, and does not include fringe benefits.

about 20 minutes per bus. In addition to the mid-level cleaning, each bus receives a detailed cleaning annually. This cleaning involves two people each working about six hours. The average wage for cleaners at Phoenix Transit is \$10.81 per hour.

Santa Monica spends 6 to 7 minutes cleaning bus interiors as part of the daily service line function. Five additional minutes are spent on each bus daily to clean graffiti and other items the hostler did not have time for on the service line. The average wage for cleaners at Santa Monica Municipal Bus Lines is \$13.00 per hour. Unlike the other case study examples, detailed cleaning is contracted to an independent cleaning company. Each bus is detailed once every 3 months at a cost of \$167.40 per bus. The contractor spends about 8 staff hours to detail one bus and is responsible for providing any fringe benefits supplied to workers along with all cleaning materials.

CHAPTER TWO

SERVICING AND INSPECTIONS**SEQUENCE AND RESPONSIBILITIES**

Part of the service line function is to examine the overall mechanical condition of the bus and replenish it with fuel and other consumables. The service line also provides an opportunity to check for accident damage and to record mechanical defects before they result in more serious failures. Depending on the number of buses to be serviced, transit agencies typically perform these functions throughout the day with the majority taking place during evening hours. Regardless of when inspections take place, virtually all transit agencies service and inspect their active bus fleets on a daily basis.

Each transit agency has its own list of tasks to be performed when servicing and inspecting buses on the service line, along with a sequence and staffing requirements for performing each task. Although the overall approach varies from one agency to another, service functions are generally performed by several two-worker teams. The member of the team responsible for shuttling buses to the service line and cleaning interiors is typically called a "hostler." The other worker, typically called a service person or "fueler," is stationed on the service line. In addition to fueling the bus, the fueler usually checks and replenishes vital fluids, performs mechanical inspections, and records all pertinent data. The sequence for a typical service line operation is as follows:

- Retrieve bus from storage area and drive to service lane,
- Record bus number and miles traveled,
- Replenish fuel,
- Check and replenish consumables as needed (i.e., engine oil, automatic transmission fluid (ATF), power steering fluid, windshield washer fluid, etc.),
 - Record the amount of fuel and other fluids consumed,
 - Conduct an inspection of entire bus including mechanical operation and accident damage,
 - Inspect tires, wheels, and lug nuts, paying particular attention to tire tread depth, air pressure, loose lug nuts and any signs of overheated brakes,
 - Remove revenue from farebox and record data,
 - Check wheelchair lift operation and record defects,
 - Inspect undercarriage for brakes and other components,
 - Clean interior,
 - Wash exterior,
 - Perform detailed cleaning and graffiti removal, and
 - Return bus to storage area.

Some of these functions, for example inspections of tires, brakes, and wheelchair lifts; and farebox collection, may be performed by off-site contractors or during other scheduled phases of operation, and are not considered part of the service line function. Although cleaning functions and graffiti removal are integral parts of the service line activity, they will be addressed in separate chapters.

Bus Retrieval From Storage Area

After returning from revenue service, buses typically are placed in a storage area until retrieved by hostlers and driven to the service line, although in some transit agencies, operators drive buses through the service line. Transit agencies with outdoor storage generally assign buses to individual parking spaces, depending on space allocation and availability. Those with indoor storage do not have this luxury as buses are parked bumper to bumper in parallel lanes. Transit agencies with a mixed fleet of wheelchair lift-equipped buses must also arrange their parking so these buses can be easily retrieved for use on accessible routes. Other agencies use parking spaces to assign buses to specific drivers. The so-called "Bus-to-Block" system is an attempt to have drivers take an active interest in the bus they will drive on a continuous basis.

Regardless of the parking assignments, it is essential that the flow of buses to and from the storage area is done with minimal labor. Time spent shuttling buses is not productive and could be better spent on more constructive activities. The most efficient system of bus retrieval is one where the next bus to be serviced is in close proximity to the bus being returned.

To improve productivity, some transit agencies require hostlers to begin work while the bus is parked in the storage area. In this case, hostlers inspect the interior for damage and graffiti, clean windows, and perform other duties to reduce the amount of cleaning time required in the service line.

In a novel departure from the traditional routine of transporting buses to and from the service line, Ben Franklin Transit in Richland, Washington, services a fleet of 54 buses while they remain parked in the storage area (4). Fuel is made available via a series of underground pipes and aboveground fueling stations. A small, motorized fuel cart containing quick-connect hoses delivers fuel to each parked bus. The cart also contains an air compressor, electricity hookups, tanks, and fluid dispensers. The cart is also used to vault the farebox and transport revenue.

Ben Franklin Transit cleaning crews use a separate cart to vacuum the interior and clean all windows on a daily basis. Buses are driven through the exterior washer by the operator before being parked in the storage area. The servicing-in-place system has allowed Ben Franklin Transit to reduce the number of service personnel and deadhead miles as a result of not having to shuttle buses to and from the service line.

Servicing-in-place is a rare exception. Most transit agencies shuttle buses to and from the service line. While some have designed new facilities to optimize traffic flow, others must conform to the limitations of an existing facility. One agency actually uses an electric cart to shuttle hostlers between buses and the service line to improve the efficiency of their existing facility layout.

Refueling

Although transit agency use of alternative fuels is increasing,

this synthesis focuses on the dispensing of diesel fuel, the predominate fuel used in most standard-sized transit buses today. The use of alternative fuels requires special handling and safety precautions on the service line, which are addressed in the TRB publication, *TCRP Synthesis 1: Safe Operating Procedures for Alternative-Fuel Buses*, published in 1993 (5).

Virtually every transit agency fuels its active bus fleet daily. Of the 52 survey respondents, all include refueling as a service line function. Because of increased concerns over groundwater contamination, poor lighting at the service island, and potential safety hazards caused by fuel spills, most transit agencies have adopted a dry-break fueling system. Popular in auto racing, the dry-break system allows fuel to flow only when the nozzle has been installed, rotated, and locked into a special fill receptacle located on the vehicle. Of the transit agencies responding to the survey, 81 percent claim to use a dry-break fueling system.

Another method of dispensing fuel that has potential for transit bus applications involves the use of robotics. Robotic fuel dispensing has been installed at a transit bus facility in Bayonne, France, with some success (6). This experience has prompted the Metropolitan Transit Authority of Harris County (Houston Metro) to investigate the feasibility of using robots for its liquified natural gas (LNG) dispensing operation. Because LNG is dispensed at or below -260°F (-162°C), inadvertent skin contact with leaked LNG or dispensing hardware can freeze human tissue and cause serious cryogenic burns (5). To prevent these burns, Houston Metro requires LNG fuelers to wear protective gear consisting of a full face shield, tight-fitting goggles, full-length gloves and a full-length apron.

To isolate the LNG refueling process completely from human contact, Houston Metro is working with Sandia National Laboratories in Albuquerque, New Mexico, to develop a robotic LNG dispensing system. The robotic action of getting the fuel nozzle to the inlet port on the bus is relatively straight forward. In Bayonne, a robot fitted with a fueling nozzle moves on a parallel track, locates the fueling port and automatically dispenses the fuel. In Houston's case, it is the cryogenic nature of LNG fuel that presents the greatest challenge. Because of the extremely cold temperatures, obtaining an air-tight and leak-free seal at the connection to the bus must first be established before robotic fueling can be applied. Lack of funding is also hampering Houston's robotic fueling program.

It is too early to tell if robotics will play a significant role in bus refueling. Costs, at least initially, will be high and the benefits of a robotic fueling system have not been fully identified. Diesel is a relatively safe and familiar fuel, requiring minimal precautions especially when dry-break dispensing equipment is used. However, because alternative fuels such as liquified natural gas (LNG), liquified petroleum gas (LPG), compressed natural gas (CNG), and the fuels used in fuel cells require more rigorous safety precautions, there may be an enticement to use robots in the future.

Check and Replenish Fluid Levels

Checking fluid levels is critical to every service line operation. To ensure the longevity of critical drive components, fluids must be maintained at levels established by the original equipment manufacturer (OEM). In addition to maintaining correct levels, it is equally important to use the correct fluid type as different manufacturers recommend specific fluids with their products. These fluids include engine oil, ATF, power steering fluid, and coolant. Wind-

shield washer fluid is also checked in some cases, especially by those operating in environments with snow and slush.

Of the transit agencies responding to the survey, virtually all include the daily inspection of engine oil and coolant levels, 81 percent check ATF levels, 54 percent check power steering fluid levels, and 46 percent check windshield washer fluid levels on the service line.

Engine Oil

Checking and replenishing engine oil on the service line is universally accepted. The diesel combustion process is such that oil is consumed by the engine. Diesel engines also have a tendency to leak oil as gaskets and seals become worn. Traditionally, however, it has been difficult to obtain accurate engine oil level readings in a service line environment. Engines need to be shut down for a sufficient amount of time to allow oil to settle in the crankcase. Due to the high oil capacity of heavy-duty diesel engines and the lack of time available on the service line, a significant amount of oil is still contained in the engine when levels are checked. Many agencies instruct service personnel to take this into consideration. Despite the training, however, there is a general tendency among service line workers to overfill fluid levels, believing "too much is better than too little."

Houston Metro has a different approach to obtaining oil level readings. Hostlers are required to check oil levels in the storage area before starting the bus and driving to the service line. Low levels are reported to the fueler, who adds the appropriate amount of oil on the service line based on information obtained when the engine was cold.

To obtain more accurate oil level readings, newer diesel engines are available with "running level dipsticks." The dipstick tube is positioned in the crankcase in such a way as to allow oil to be checked while the engine is running and oil circulates. Another method of maintaining correct engine oil levels involves the use of an automatic oil level regulator. These onboard systems typically maintain the correct level by withdrawing oil from a reserve tank as the engine needs it.

Coolant

Checking and replenishing coolant, whether it be water with a conditioning agent or water with a mixture of antifreeze, is also universally accepted as a service line function. Pressure relief caps are provided on most cooling system fill tanks to reduce the potential for burns during the replenishment process. In addition, fill tanks can be equipped with a sight glass inspection tube, which allows a simple visual inspection to determine the correct level. Scania, a Swedish-designed transit bus sold in North America during the 1980s, had an innovative design. Its sight glass was mounted on an exterior body panel for convenient visual inspections.

Automatic Transmission Fluid

While adding engine oil and coolant are universally accepted as service line functions, replenishing other fluids is not so common. As mentioned above, 81 percent of those responding to the survey

check ATF levels on the service line. Unlike engine oil, ATF is not consumed and the need for replenishment is generally an indication of a leak. Additionally, automatic transmissions are more sensitive to correct fluid levels. Serious (and expensive) damage can result from overfilling. As a result, 19 percent of those responding to the survey do not check ATF on the service line. The feeling is that the task should be performed by more qualified maintenance personnel.

AC Transit in Oakland, California, for example, elects to check ATF levels during regularly scheduled service intervals. The Capital District Transportation Authority (CDTA) in Albany, New York, is one of the two agencies responding to the survey that checks ATF levels on the service line but elects to replenish it in the maintenance shop. If a low-level condition is identified on the service line, the bus is scheduled for repair. Before adopting this policy, CDTA service line personnel continually added ATF until a gradual leak resulted in serious transmission damage.

Defect Inspections

Performing a thorough inspection of the bus is another important service line function. The inspection may identify malfunctioning equipment, accident and body damage, graffiti, vandalism, and other damage. Hostlers are typically responsible for interior inspections, while fuelers are primarily assigned to exterior inspections. The defect identification process actually begins with the bus operator, who is required by the Commercial Drivers License (CDL) law to conduct a pretrip inspection and note any defects before boarding passengers. A "defect card" is typically left on each bus, which must be completed, signed, and returned by the operator after each bus run. (See Data Collection below for additional information)

Unlike the operator who is trained primarily to drive the bus, fuelers and hostlers are trained to look more closely for mechanical defects and damage. On retrieving the bus from the storage area, the hostler reviews the defect card left by the operator and notes all comments. The trip from the storage area to the service line serves as a test drive of sorts, giving hostlers an opportunity to check the mechanical condition of the driveline and braking systems. All interior and exterior lights and flashers are illuminated so they can be easily checked.

Once the bus is parked in the service line, the hostler is generally responsible for interior cleaning and visual inspections. The inspections include all aspects of the interior including the operation of lights, electrical equipment, doors, farebox equipment and checks for graffiti and vandalism. While the hostler inspects the interior, the fueller inspects the exterior of the bus for faulty conditions and pays particular attention to the engine compartment for leaks, loose belts, and other mechanical defects.

Tire Inspections

Only 65 percent of the survey respondents include tire inspections as part of their service line duties. The remaining 35 percent either check tires off the service line or contract with a tire supplier to perform the inspections. Transit agencies that check tires on the service line typically have the fueller make a visual inspection. A bar or pipe is often used to "bump" inside tires at the rear axle. The thumping sound generated from the strike is sufficient to tell if the tire is flat.

Revenue Removal and Transfer

Nearly 77 percent of those responding to the survey consider revenue removal to be part of the service line function. The hostler is usually responsible for transferring revenue from the bus, which generally occurs as the first service line function. Some transit agencies use a separate location to transfer revenue, which often adds a person or two to the overall service line function. Often, the allocation of staff and the procedures used to transfer revenue depend on the physical setup of the facility. Regardless of where, when, or how revenue is transferred, security is the primary concern.

Recently, transit agencies have increased efforts to promote noncash payment of fares by encouraging the use of passes, tokens, stored value cards, and other forms of payment where security can be more tightly controlled. Although the use of noncash fares is expected to increase, especially among daily commuters, transit agencies continue to handle large sums of cash. Several procedures have been tried throughout the years to transfer revenue quickly and with a high degree of security. The most common for an urban transit agency is the exact fare system where passengers deposit the exact fare (i.e., cash, ticket, token, etc.) and the bus operator is not exposed to carrying large amounts of cash. Farebox manufacturers have invested a great deal of effort developing revenue handling systems to accurately record and secure the revenue from exact fare systems.

A modern exact fare revenue transfer system consists of a farebox with a removable cashbox and receiver vaults to which revenue is transferred (7). All components are made of steel and incorporate tamper-resistant and interlock security designs. Access to the cashbox is through a hand-held electronic key, often called a probe. The electronic probe downloads revenue and passenger data from the farebox to a central computer. After data have been transferred, the probe uses a security code to unlock the farebox door and provide access to the removable cashbox inside. The cashbox contains two separate compartments, one for coins/tokens and one for bills/tickets.

The cashbox is removed from the farebox during the vaulting procedure and placed in a cashbox receiver, typically located adjacent to the service line. A heavy-duty door on the cashbox remains locked until the revenue transfer has been completed. While the contents of the cashbox are transferred to the mobile safe (revenue bin) located inside the receiver, the serial number of the cashbox is constantly being monitored. A time and date stamp for each revenue transfer is also reported to a central data system. All data generated by the farebox and receiver can be used to audit revenue and identify variances.

Despite manufacturer's design efforts, exposed revenue is an inherent by-product of the fare collection process. Exposed revenue can occur as a result of farebox jams, cashbox vaulting jams or during maintenance actions. To minimize revenue exposure and loss, transit agencies must continually monitor and manage the revenue transfer process.

The three case studies included in this synthesis provide three different approaches for transferring revenue from the bus to the receivers. Instead of the service line, Phoenix Transit's South Facility uses a separate area and dedicated revenue personnel to transfer revenue. At New Jersey Transit's Hilton Garage, revenue bins are removed from the receivers and secured in a vault room adjacent to the service line. An armored car service transports the revenue bins directly to a bank for processing. At Santa Monica

Municipal Bus Lines, the receivers are located directly on the fuel island and the hostler completes the revenue transfer while the bus is being fueled. An overhead hoist is used to help lift cashboxes to the cash receivers. All revenue is processed at a separate location within the facility. (See individual case studies for additional information).

Wheelchair Lift Cycling

Shortly after wheelchair lifts were introduced to transit buses, it was discovered that continuous cycling of the lift mechanism was an effective way to identify faulty conditions and to maintain the lift's operational integrity. In addition, the Americans with Disabilities Act (ADA) requires transit agencies to establish a system of regular and frequent maintenance checks of lifts sufficient to determine if they are operative (8). As a result, transit agencies set aside a period during which wheelchair lifts are cycled. Of those responding to the survey, 90 percent claim to have programs in place to cycle wheelchair lifts on a regular basis. Over 80 percent cycle lifts daily. Most (67 percent) cycle their lifts in the storage area before the bus pulls out for revenue service. Of those responding to the survey, 46 percent have bus operators perform the lift cycling, 33 percent assign the task to operations/maintenance personnel, and the remainder use hostlers/service line personnel or did not indicate.

Brake and Undercarriage Inspections

Some transit agencies include an over-the-pit inspection of the brakes and undercarriage as part of their service line function. Others perform the inspections as part of their PM inspection program. Those who include undercarriage inspections as a service line function typically perform them on a weekly basis. Of the three case studies, Phoenix and Santa Monica perform undercarriage inspections weekly as part of their service line functions. NJ Transit conducts the inspections as part of its regularly scheduled preventive maintenance program.

On days when the undercarriage inspections are scheduled, a mechanic is stationed in a pit and visually checks for leaks and other mechanical defects. A typical inspection includes a check for oil, coolant, and hydraulic leaks, air system leaks, brake slack adjuster travel, universal joints, excessive steering system travel, wheel seal leaks, and other mechanical conditions visible from under the bus. All defects are noted and reported. During this time the hostler is usually available for interior inspections and cleaning.

To automate the brake and undercarriage inspection process, testing dynamometers are available and used on a limited basis to provide an assessment of brake and suspension components (6). The advanced testing equipment can be installed in an existing pit to complement other service line functions or replace on-road test drives. The equipment is designed to identify unusual wheel bearing or brake drag, brake force, wheel and axle load, and pedal forces. Additionally, the testing equipment can be used to evaluate pneumatic pressures in the entire braking system and to identify excessive free-play in the suspension and steering systems. A side-slip tester also detects incorrect toe adjustments (tire alignment) to prevent premature tire wear.

Testing results obtained from the brake dynamometer are analyzed by microprocessors, printed out as reports, and sent to a

central data bank for maintenance scheduling and future reference. The modular design of this equipment can be expanded to include other test functions such as drive line performance, exhaust emissions testing, headlight testing, and more advanced wheel and suspension alignment. Brake and suspension testing dynamometers are used by The Hamilton Street Railway Company in Ontario, Canada, and MTA Long Island Bus, New York.

Other Service Line Inspections

The transit agency questionnaire provided space for "other" functions performed as part of the service line function. Some transit agencies indicated that replenishing public information material and advertising are part of their service line routines. Checking the operation of emergency escape hatches, rear door safety mechanisms, and reprogramming destination signs were also listed in the "other" category on a limited basis.

DATA COLLECTION

In addition to checking the overall mechanical condition of the bus, the service line provides a daily opportunity to collect important data. This includes information about mechanical defects, fuel and fluid consumption, graffiti and vandalism, and several other bus conditions. The collection and recording of this vital information is traditionally done as a collective effort by the hostler, the fueler, and the bus operator. With the advent of electronic controls and equipment, monitoring and reporting of certain bus functions can be done automatically. Most importantly, automated systems minimize the possibility of human error while the data are being entered.

Electronic data collection and condition monitoring systems are not new to the automotive industry. Many automobile manufacturers began installing onboard diagnostic systems more than a decade ago, and most light and heavy rail vehicles incorporate these systems today. Despite the widespread use, electronic "health monitoring" systems have been slow to make their way into transit bus applications. The majority of transit agencies continue to use the eyes, ears, and hands of service personnel to collect data. A clear exception lies with revenue data, as 75 percent of those responding to the survey claim to collect this information electronically. Automated collection of fuel and engine oil dispensing data was next in popularity with a 42 percent response rate for each.

Data collected at the service line typically consist of the following:

- Bus identification number,
- Odometer (mileage) reading,
- Fuel and fluid consumption,
- Revenue and passenger information, and
- Mechanical defects

Bus Identification Number

The identification number of the bus is critical because it serves as the common point to which all other information is assigned. A portion of that number is often used to denote a specific bus make and model delivered to the transit agency as one order built to the

same specification. This numbering system easily identifies buses in need of a service campaign or that require special servicing procedures (e.g., a different weight or type of engine oil, a separate check to a newly installed component, etc.)

Recording the bus identification number is usually done by the fueler as the bus enters the service line. A popular system is one where all bus numbers are preprinted on a sheet of paper located near the fuel dispenser, as shown in Figure 2. Space is provided to enter pertinent data such as mileage, fuel consumption, and other fluid usage. In other systems, the bus number is entered on a key pad linked to an automated fluid dispensing system. The major problem with these systems is that data, especially numbers, can be entered incorrectly. Manual identification and recording of bus numbers is being replaced on a limited basis by sophisticated systems that use wireless, radio frequency (RF) signaling. These systems automatically identify the bus as it enters the service line and do not require service line personnel to make manual entries. Once identified, the bus itself becomes the authorizing agent for fuel and fluid dispensing. The systems eliminate unauthorized dispensing of fuel and other fluids, while improving the accuracy of vehicle identification.

In one automatic bus identification system, a radio transmitter mounted under the bus sends a radio signal containing an identification code to an inductive loop embedded in the service lane (9). The bus identification number is automatically transmitted to a host computer, which confirms the number and activates the fuel and fluid dispensing nozzles.

Mileage

Maintenance intervals are triggered by a variety of methods that includes time, miles traveled, fuel usage, and others. For those who

base maintenance intervals on accumulated miles traveled, obtaining accurate bus mileage is absolutely essential to an effective maintenance management information system. Accumulated bus mileage can be obtained manually or through the use of electronic equipment. Manual recording of mileage is typically done in one of two ways. One method involves the use of a wheel-mounted odometer called hubodometers. Mounted on the fuel-fill side of the bus, the mileage reading is visually taken from the hubodometer by the fueler who manually enters the numbers into the particular data collection system being used. The other method involves the accumulation of route miles to determine total miles traveled. Because buses are assigned to specific routes, the mileage for each route can be added together.

To improve the accuracy of bus mileage, electronic hubodometers using RF signaling have been developed (10). The electronic device automatically counts and records each revolution of the wheel and uses the diameter of the tire to calculate the distance the bus has traveled. Once the bus is stopped at a predetermined location in the service line, mileage data are transmitted automatically via radio signal to a receiver unit. Electronic hubodometers can be used with data collected from automated fuel and fluid dispensing equipment to generate mileage and consumption reports. They can also be used to transmit the bus identification number.

Fuel and Fluid Consumption

The accurate recording of fuel and other fluid consumption by each bus is important for several reasons. Maintenance managers typically use excessive fluid consumption data to identify faulty mechanical conditions. Additionally, accurate recording of fuel dispensing can be used as one method to monitor underground

DAILY MILEAGE REPORT

Diesel Meter #1 _____ Oil Meter #1 _____ Date _____
 Reading #2 _____ Reading #2 _____ Day _____

Bus #	Hub Reading	Fuel	Oil	Odometer	Mech.	Bus #	Hub Reading	Fuel	Oil	Odometer	Mech.
4402						4448					
4407						4449					
4408						4450					
4409						4451					
4410						4452					
4411						4453					
4412						4454					
4413						4455					
4414						4456					
4415						4457					
4416						4458					

FIGURE 2 Sample portion of Daily Mileage Report sheet requiring manual data entry. (Courtesy Long Beach Transit)

storage tanks for leaks Transit agencies record fluid consumption manually, or with an automated fuel and fluid management system. Of those responding to the survey, 58 percent use a manual system to record fluid consumption, and 42 percent use some type of automated system

In a typical automated fluid management system, the fueler enters the bus number on a key pad which activates the appropriate dispensing nozzles. All fluids dispensed are assigned to that bus number and consumption information is transferred to a central data source for future analysis.

Revenue and Passenger Information

The extent to which revenue and passenger information is available to transit agencies depends on the type of farebox being used. Many transit agencies now use electronically registering fareboxes capable of generating a variety of accurate reports. Data obtained from the fareboxes are used for the financial accounting of revenue and to analyze ridership patterns. Transfer of data to a central computer is done automatically with an electronic probing device. Of those responding to the survey, 75 percent capture revenue data automatically. Those without electronically registering fareboxes record and extrapolate data manually. Some combine the manual collection of data with electronically registering fareboxes to provide a backup and to ensure tighter security.

Mechanical Defects

The Vehicle Condition Report, commonly referred to as the "defect card," is probably the oldest and most effective data collection device used in bus transit. Bus operators are required by the U.S. Department of Transportation's CDL law to inspect their vehicles before transporting passengers. In addition to noting mechanical defects, it provides an appropriate check list on which to conduct this mandatory pretrip inspection. Information contained on the defect card is combined with other data collected on the service line to obtain an accurate account of the overall bus condition.

Each transit agency has its own design for the defect card, which is usually left on the bus by the operator for the hostler to review before driving to the service line. Serious problems are reported immediately to supervisory personnel and result in the bus being taken to a holding area after daily service line functions have been completed. Otherwise, the card is returned to a specified area and a new one placed in the bus for the next operator. At some transit agencies, supervisory personnel review the defect cards manually and schedule maintenance events accordingly. Others enter information into a computerized data base for more sophisticated analysis and reporting. A sample defect card is included in Appendix C.

INTEGRATED DATA COLLECTION SYSTEMS

Transit agencies can upgrade and integrate their data collection systems for increased speed and accuracy. Community Transit in Everett, Washington, for example, has installed a fully integrated and automated system for vehicle identification, mileage, and fuel and fluids dispensing. When a bus pulls into the service line, a receiver mounted on the fuel island interrogates the electronic

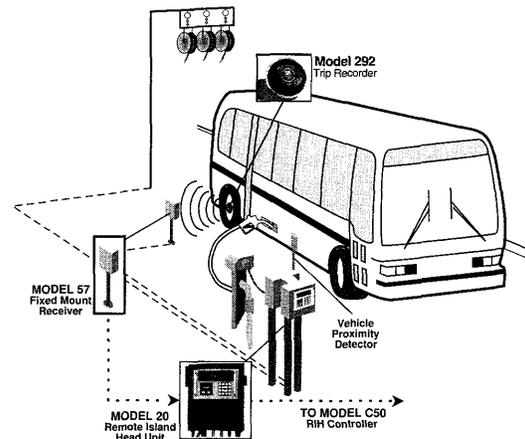


FIGURE 3 Fully automatic bus identification, mileage, fuel, and fluids tracking system (Courtesy of S&A Systems, Inc.)

hubodometer. The bus number and life-to-date accumulated mileage are transferred via radio signal to a central control unit. The control unit then activates the diesel fuel dispensing pump, as well as the appropriate oil, coolant, ATF, and power steering fluid dispensers. The quantities of the fluids dispensed are automatically recorded and assigned to each bus without manual entry by service line personnel. Figure 3 identifies the features of such a system.

CONDITION MONITORING AND ADVANCED DATA SYSTEMS

The concept of condition monitoring is not new. For years, automobiles have been equipped with diagnostic ports that allow technicians to plug in an electrical connector to obtain information on several vehicle operating conditions. Early in the 1980s, UMTA provided a grant to equip several buses with an onboard diagnostic system developed by Hamilton Test Systems. Although funding for the project was terminated, 52 buses with onboard diagnostic equipment continue to operate at the Mass Transit Authority (MTA) in Flint, Michigan. Pleased with the overall concept, MTA is seeking to upgrade its existing system and install more modem onboard diagnostic equipment on upcoming bus orders (Hayward Seymore, MTA, personal communication, March 1995).

Despite the positive implications for improving service line functions, condition monitoring systems have been slow to make their way into transit bus applications. If fluid levels and other mechanical conditions of the bus were known in advance, dwell time spent in the service line could be significantly reduced. In addition, vehicle condition monitoring allows maintenance personnel to identify problems as they begin to develop. Identifying problems in the early stages can prevent them from escalating into more serious failures that usually require more time and money to correct. Vehicle condition monitoring also allows management to schedule maintenance based on need, thereby saving unnecessary expenditures of labor and parts.

Many of the electronic components installed on late model buses already have condition monitoring and self-diagnostic capabilities. This equipment includes electronically controlled fareboxes, destination

signs, wheelchair lifts, engines, and transmissions. The condition monitoring capabilities of these components can greatly assist technicians with troubleshooting, and provide a nonintrusive method of quickly determining the overall condition of vital components. Before this equipment can be joined into a collective condition monitoring system, the communication protocol (language used to "speak" to each other) must be standardized.

A significant amount of effort has been made in recent years to standardize the communication protocol of the electronic equipment used for heavy-duty vehicles. The Society of Automotive Engineers (SAE) has an overall standard for data communication protocol known as J1708. Working with the American Trucking Association (ATA), SAE has developed a specific protocol for the trucking industry known as J1587. Specific bus functions such as fare collection, door controls, silent alarms, driver identification, annunciator voice message equipment, and others have been incorporated into the SAE J1587 standard to facilitate the equipment communication process (11). Standardized communication protocols are also required to integrate automatic vehicle location (AVL) systems with Intelligent Transportation Systems (ITS) functions.

To help establish a standardized communication protocol among electronic equipment, integrated wiring systems have been developed for transit buses (12). In addition to standardizing data transmission, the advanced wiring systems reduce the amount of onboard wiring and vehicle weight, and help to establish a priority-based condition monitoring and reporting system for electronic components. They are being developed together with proposed industry standards such as SAE J1708 and SAE J1587 to ensure that all electronic components will interface with the wiring system.

Integrated wiring systems typically use shared power, control, and data circuits to connect all electrical modules. Each module is a complete, highly miniaturized computer that uses a common communication protocol to "speak" with other components and the central data network. The modules can monitor and record various bus functions, perform self-diagnostics, and send warning signals when a malfunction occurs or is about to occur. Depending on the severity of the malfunction, the system can warn the driver, store the information until downloaded on the service line, or send a signal immediately to the central maintenance facility. Future systems will interface with AVL systems to monitor vital bus functions "on-line" while operating in service.

Engine Data Communication Systems

Unlike the sophisticated system described above, more basic data transfer systems are available for many of today's electronically controlled diesel engines. These engines are factory equipped with engine control modules (ECMs) that can be used to adjust idle, fuel delivery, and timing functions. Additionally, ECMs have enough memory to store a variety of operational data including excessive idle time, engine RPM data, engine error codes, miles traveled, and other information.

A variety of data recording products is available to provide transit agencies with different levels of engine performance, diagnostic, and maintenance information. Software packages are also available to analyze the information and produce a variety of reports. Information is extracted from the engine via a physical cable

connection, which can be made during service line inspections, preventive maintenance inspections, or when troubleshooting specific engine conditions.

In addition to physical connections, wireless technology using RF signaling is also being developed to extract engine data for transit bus applications (13). The wireless, RF signaling technology will use a type of RF modem to permit on-line communication between the engine's ECM and a computer terminal. The RF signaling device is expected to be a more convenient method of extracting engine information and analyzing it on a regular basis. While the bus is being attended to in the service line, a wayside receiver polls a small RF device wired directly to the ECM. The flow of information can be two-way, allowing service personnel to adjust the ECM (set idle, adjust horsepower, governor, etc.) directly on the service line without a physical cable connection.

Wireless Tire Data Communication

Tire manufacturers have also developed systems that use built-in sensors and receivers to store and transmit information via radio signal to a wayside receiver (14). Memory chips embedded in the tires are capable of storing a variety of information including the manufacturing date, plant location, and tread style. The so-called "smart tires" are also capable of monitoring conditions such as air pressures and temperatures. Integrated with the chip is a radio transponder that broadcasts data to a receiver unit. The receiver can be embedded into the service line or used as a portable, handheld device. Information transmitted from the tire is stored in a central data base where various reports can be produced. Maintenance managers can use the information to decide on when to retread or replace tires.

Another automated tire system is used to monitor air pressures only (15). Wheel sensors, called "electronic valve caps," are located on each wheel. The sensors continuously monitor the air pressure at each tire and warn the driver via wireless remote radio transmission when tire pressure falls below normal operating levels. An instrument display mounted near the driver identifies which tire is losing air pressure. A portable hand-held monitor can also be used to check for low tire pressures on the service line.

Future Bus Designs

The Federal Transit Administration (FTA) has provided grants to Houston Metro and the Los Angeles County Metropolitan Transportation Authority (LACMTA) to develop new designs for transit buses. The Houston project is called "The Next Generation Bus," and the LACMTA calls its project the "Advanced Technology Transit Bus" (ATTB). It appears that the new bus designs will feature lighter weight construction, lower floors, wider doors, and low exhaust emission characteristics. In addition, both projects are attempting to incorporate advanced wiring systems with integrated condition monitoring capabilities, data storage, and wireless data transmission, which could be used to improve data transfer on the service line. The new projects will also allow design teams to address service line and cleaning issues that older designs failed to meet.

CHAPTER THREE

EXTERIOR WASHING**OVERVIEW**

The automated brush washer continues as the most popular piece of equipment to wash the exterior of transit buses. Buses are driven through the washer at slow speed while a combination of water, soap, and moving brushes remove dirt. Other bus washing equipment, including automated pressure washers and gantry washers, are used on a limited basis. Automated pressure washers rely on high-pressure water and soap spray to remove dirt, while gantry washers move brushes around a stationary bus. Each automated washing system has its advantages.

This chapter will address the frequency of bus washing, the different types of bus washing equipment available, issues associated with automated washing equipment, water recovery and recycling systems, and detailed exterior cleaning.

FREQUENCY

Most transit agencies wash their active bus fleets daily. Of those responding to the survey, 65 percent wash buses daily during the summer months and 81 percent wash daily during the winter. Those without a daily sequence either do their exterior bus washing two to three times per week or as needed. Clean buses tend to promote a good public image and help to attract and maintain ridership. However, the need to conserve water and reduce the problems associated with the mechanical scrubbing process have caused some agencies to review the frequency of bus washing.

For example, Santa Monica Municipal Bus Lines once had a

policy of washing buses every day. When a water shortage in Southern California forced them to wash every other day, they noticed that overall cleanliness was not drastically affected. As a result, Santa Monica has changed to a Monday-Wednesday-Friday schedule, which has reduced its use of labor, water, soap, and washing equipment. Brush contact with exterior body panels has also been reduced.

WASHING EQUIPMENT**Automated Brush Washers**

The automated brush washer is the most common washer used in bus transit today (see Figure 4). More than 87 percent of those responding to the survey claim to use some form of automated brush washer. Of those, 66 percent use equipment with four brushes. Automated brush washers with two, three, five, six, seven, and eight brushes were reported on a limited basis. Brush washers typically use a combination of rotating brushes and water/soap spray to clean the bus exterior. Some washers include additional brushes or oscillating or stationary wet mops to clean the roof and front and rear bus sections.

Brush washers generally begin with an application of soap and water to lubricate the brushes, reduce abrasion, and prevent excessive wear on paint and plastic windows. This is followed by the application of more soap and the mechanical scrubbing action of the brushes. A series of electronic actuators provides automatic control of the various wash functions as the bus travels through the

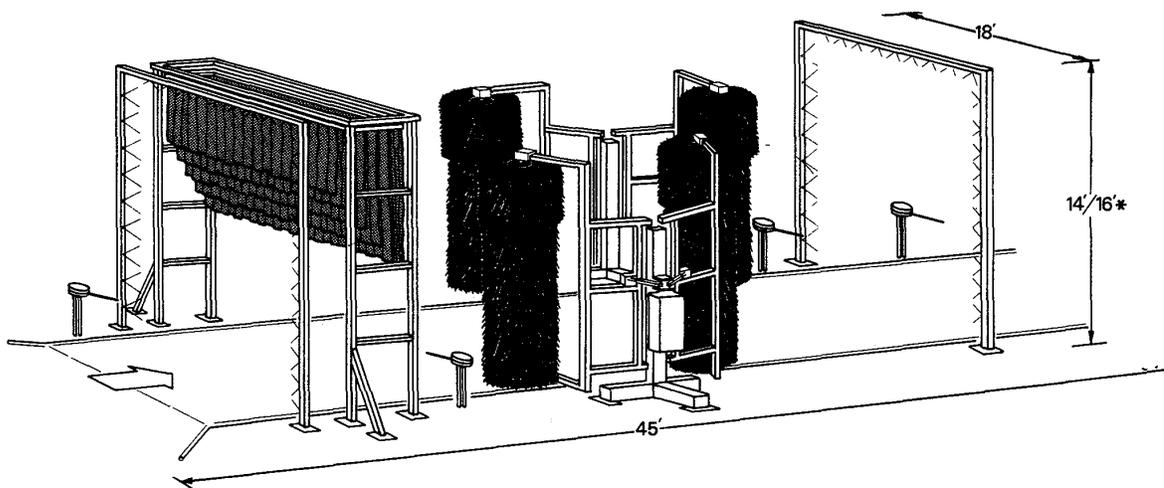


FIGURE 4 Schematic diagram of a typical automated 4-brush washer. (Courtesy of SSI Corp.)

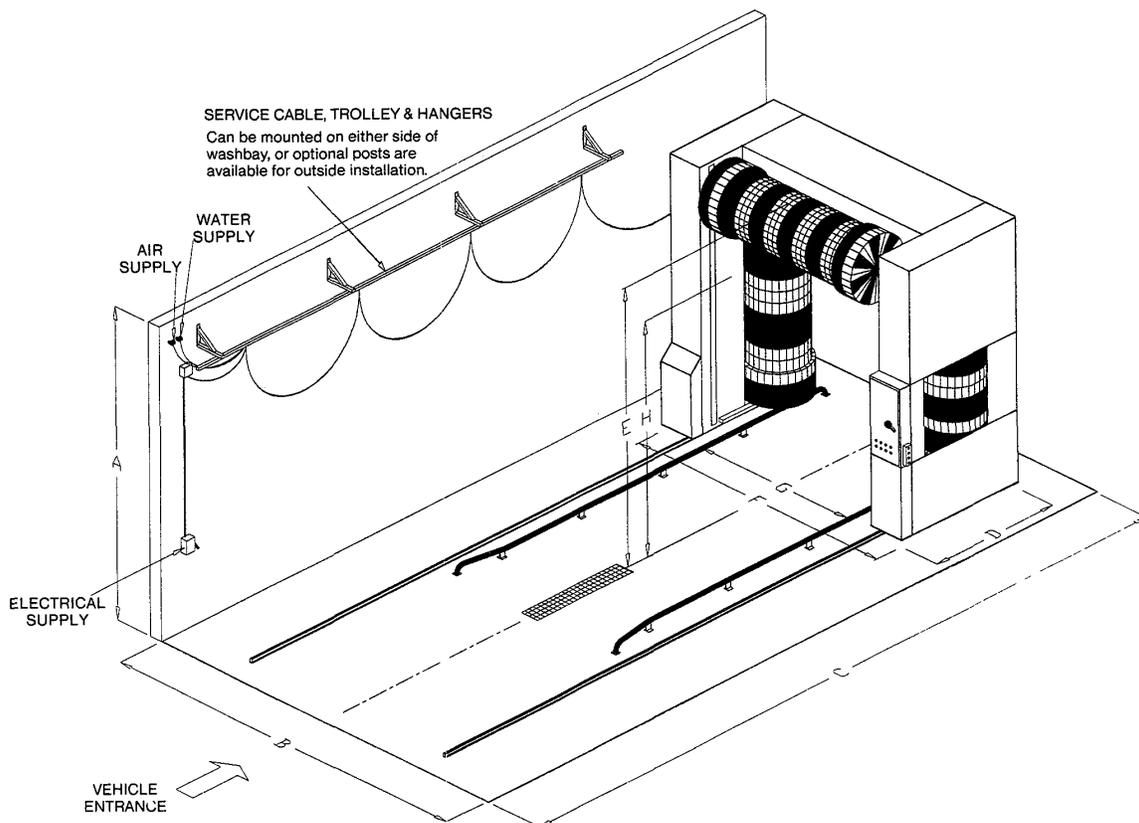


FIGURE 5 Schematic drawing of a typical gantry washing system. (Courtesy of SSI Corp.)

washer. Brush arm movement against the bus is controlled by air pressure. Hydraulic or electric power is used to agitate roof mops and to rotate the brushes. A rinse cycle of fresh water removes dirt suspended in the soap. Most transit agencies allow the buses to drip dry in the storage area.

Automated Pressure Washers

Another type of bus washing equipment involves a pressurized system without brushes, commonly referred to as "brushless" or "touchless" washers (16). The 1982 TRB study on bus cleaning stated that pressure washing systems "appear to be the state of the art in exterior washing systems" (1). Despite this claim, pressure washers are used on a limited basis for transit buses. In fact, none of the 52 transit agencies responding to the survey indicated the use of automated pressure washers.

Automated pressure washers are more common in the trucking and school bus industries. They typically consist of three or four self-supporting, drive-through application arches. Each arch is fitted with several rotating spinners from which water and soap are dispensed under pressure. Each stainless steel spinner has several fully adjustable nozzles, each with a zero-degree spray pattern for maximum cleaning pressure. A high-pressure pump is used to

produce up to 400 psi of pressure through the nozzles, causing the spinners to rotate in a circular fashion.

Depending on the operating environment, pressure washing systems may require cleaning assistance from a chemical reaction involving a hydrofluoric acid solution and an alkaline based chemical to dislodge all dirt and leave a film-free finish. Otherwise, pressure washers essentially use the same type of detergent as automated brush washers. Because of the contactless nature of the washing, they do not require the lubricity agents normally required with brush systems. The high-pressure spinners are sometimes used independently with brush washing systems to clean wheels (see Wheel Cleaning).

Automated Gantry Washers

Another type of automated washer involves a gantry system where the bus is driven into the washer and remains stationary while it is being cleaned (see Figure 5). Gantry washers can be used as the primary piece of washing equipment or to supplement traditional brush washers to obtain a more thorough cleaning. Once parked inside the washer, the brushes move around the bus. These washers are said to use less water and detergent because the cleaning process is much more controlled than drive-through systems.

Speed through the washer is not an issue because the bus remains stationary while the brushes move around it at a predetermined speed. Because the bus remains stationary, gantry washers are also capable of doing a more complete job of cleaning front and rear sections. Disadvantages reported with the gantry washers include more time needed to complete the wash cycle and to maintain the washing equipment.

The Southwest Ohio Regional Transit Authority (SORTA) in Cincinnati has replaced its automated brush washers with automated gantry washers. It is one of the largest fleets in North America using such a system. SORTA uses three gantry washers, each cleaning about 70 buses per day (Mike Collins, SORTA, personal communication, January 1995). To compensate for the extra time needed for gantry washing, SORTA made changes to its cleaning procedures. While the bus is being washed, the hostler uses the extra time to clean interiors. By making better use of time, SORTA can clean the same number of buses within the allotted time period.

SORTA decided to purchase the gantry washing system because it was unable to control bus speed through the brush washer to obtain an acceptable level of exterior cleanliness. SORTA reports a 50 percent reduction in detergent and water consumption compared with the brush washers previously used. Gantry washers can also be used to clean smaller, nonrevenue vehicles by simply pressing a switch on the operating console. Despite the extra time required for washing and maintenance, SORTA believes the wash quality obtained with the gantry system outweighs the disadvantages.

Mobile Brush Washers

A portable vehicle washing system developed for the trucking industry has potential applications for transit buses. The unique system consists of a self-contained and self-propelled mobile brush washer that is driven around the bus while it remains parked in the storage area (17). The mobile washer features water tanks and a large rotating brush that scrubs and rinses the bus after being driven around it. The mobile washer uses about 20 gallons of water and one quart of cleaning solution per bus. A collection basin option allows waste water to be collected, filtered, and reused. The mobile brush washer is relatively compact in size and can be transported from one location to another on a trailer.

The Southeastern Pennsylvania Transportation Authority (SEPTA) has two mobile brush washers in use. The washers were purchased to fill a short-term need for bus washing equipment while an existing maintenance facility was being refurbished. Queens Surface Bus Company, which operates in New York City, also has two mobile brush washers in use. The washers are used on a permanent basis for spot cleaning its fleet of 267 transit buses.

ISSUES ASSOCIATED WITH WASHING EQUIPMENT

Automated Brush Washers

Controlling Speed Through the Washers

Controlling bus speed through the automated brush washer is essential to the cleaning process and to reducing bus damage. The problem lies with excessive speed as hostlers rush to complete their work. Of those with automated brush washers responding to the

survey, 76 percent rely solely on the hostler to control bus speed. The others use a myriad of speed-control devices including red and green lights, speed bumps, video cameras, audible alarms and electronic devices that shut down the washer if the bus is traveling too fast. In Europe, some agencies incline the floor slightly as a method to control bus speed through the washer (Vladas Eikinas, Stone & Webster Engineering, Inc, personal communication, February 1995).

The majority of survey respondents instruct hostlers to drive between 1 and 3 miles per hour (mph) (0.6 to 4.8 km/h) through brush washers. Buses that come to a complete stop in a washer can cause excessive window crazing and paint wear as the scrubbing action of the brushes becomes highly concentrated in certain areas (see "Window Crazing and Spotting" below).

Driving too fast through the washer is the major issue because it does not give the cleaning equipment enough time to do its job. Despite the variety of speed-control devices available, it appears that strict discipline and proper training are the most effective ways to control speed through brush washers. One manufacturer suggested that a short video be made to instruct hostlers on how to drive through the washer and the consequences of driving too fast (Olli Lamminen, InterClean Equipment, Inc., personal communication, December 1994).

To assist the hostler in keeping buses centered in the washer, Houston Metro has installed a lighting system similar to the approach lights used at airports. Lights embedded in the washer floor line up directly under the driver and provide a visual reference through the washer. The lighting system is especially helpful when water spray reduces visibility and causes inexperienced hostlers to drive off course. The lights are used to supplement the standard guard rails supplied with the washer to keep tires centered in the wash bay.

Maintenance

Maintenance is required of any complex machinery containing many moving parts. Automated brush washers are no exception, especially when they combine electric, hydraulic, and pneumatic operation in a damp environment with extreme temperature shifts. Just how much maintenance is required is somewhat difficult to ascertain because it depends on many factors including operating environment, frequency of washing, size of fleet, make and age of the washing equipment, and the skill level of the personnel using and maintaining the equipment. Although improved over the years, maintenance of automated brush washing equipment continues to be an issue in bus transit.

Typical maintenance and repair items required of automated brush washers include periodic greasing of the bearings, nozzle cleaning (especially with processed water), leaking pump seals, leaking air lines, hydraulic leaks, electronic repairs, brush replacements, brush pressure adjustments, sludge removal and treatment of drains, and occasional damage caused by buses jumping over the guide rail.

To assist maintenance personnel, built-in diagnostic systems are available for automated brush washers. The systems are capable of monitoring the complete operation of washing equipment and can be configured to include the monitoring of water reclamation and cyclone vacuum systems as well. Included in the monitoring functions are the total number of buses washed per day, low hydraulic oil level, high hydraulic oil temperature, excessive bus

speed through the washer, low detergent level, low water level in the water reclamation system, total number of buses cleaned with the cyclone vacuum, and other bus cleaning functions. The monitoring systems automatically detect malfunctions as they occur and display them on a screen or in printed reports. They can also display or print routine maintenance instructions.

Window Cracking and Spotting

Another problem commonly associated with automated brush washers involves the so-called crazing of plastic windows. During the 1980s, plastic windows were specified instead of laminated safety glass by many transit agencies with acute vandalism problems. Daily trips through the brush washer eventually wear off the protective coating on the plastic. Constant sun and weather exposure combined with the abrasive nature of the washer brushes results in a maze of fine lines commonly referred to as crazing. The plastic windows eventually become so scratched that passengers can no longer see through them. One alternative involves replacing the plastic windows with new ones. Doing so, however, can be expensive. Another alternative involves removing the plastic windows and sending them to a processing company on an exchange basis. The plastic windows are milled to remove surface damage and an abrasion-resistant hard coating is applied (18).

Another solution to damaged plastic windows involves replacing them with laminated safety glass. Many transit agencies have returned to glass windows to avoid the costly process of constantly replacing plastic windows or having them reprocessed. When asked what they were doing to prevent window scratching, 12 survey respondents indicated they had replaced their plastic windows with glass. Although the brush washer will not scratch or haze the glass surface, another problem is created by the washing process.

A problem commonly associated with glass windows involves spotting, created by the drops of water deposited on the window by the washer. When dry, calcium deposits contained in the water actually stain the glass and can be difficult to remove. The severity of the spotting depends on the mineral content of the water. Several transit agencies treat their water with softening agents for the final rinse stage to mitigate this problem. Others use water additives designed to bead rinse water so it rolls off bus surfaces easier. The advanced water reclamation system used at NJ Transit's Hilton Garage is said to eliminate the glass window spotting problem (see "Water Recovery and Recycling" below for additional information).

Glass window spotting is not easily removed and requires a great deal of manual labor. After researching several products, Orange County Transportation Authority (OCTA) found a product that removes spotting without scratching the glass surface (Jerry Farrar, OCTA, personal communication, December 1994). The polish is packaged in a tube and applied to the window much like car wax. OCTA sprays a water mist on the window while applying the polish to dilute it and extend its use. Once dry, the polish is removed with an air/electric buffer. Material cost to do all exterior windows on one bus is about \$20 and takes about four hours. The process is applied to each bus annually.

In addition to replacing windows, either with glass or plastic, precautions can be taken to reduce the damage caused by scrubbing action of the brush washer. The most basic precaution is to ensure adequate lubricity on the brushes before they come in contact with the bus. Several survey respondents indicated they use a lubricity additive to the detergent to prevent exterior surface scratching,

especially to plastic windows. Another basic precaution involves maintaining a slow enough speed through the pre-rinse cycle to allow adequate water and detergent flow over the entire bus surface before the brushes make contact.

Another method to minimize the scratching of plastic windows and painted surfaces is to ensure that brush pressure against the bus is adjusted properly and that the brush itself is designed to reduce scratching. Because each bus surface is different (i.e., glass, paint, mirrors, etc.) some transit agencies are specifying washer brushes with individual brush sections. Each brush section is specifically designed to clean specific areas of the bus.

One brush manufacturer offers up to seven individually designed brush sections to reduce damage to a variety of bus surface areas (19). The areas include destination signs, windshield wiper blade assemblies, mirrors, antennas, and decals. The type of filament, configuration, and density in each brush section is matched to the particular surface to be cleaned so as not to scratch or craze plastic windows or cause premature wear of painted surfaces and decals.

In addition to the precautions already cited, two types of barrier coating products are available to isolate the actual window surface from the washer brush. One involves a clear plastic film with a self-adhesive backing that is applied to exterior window surfaces. The other involves a thicker plastic laminate that is placed over the window and affixed to the exterior window frame. Both serve as sacrificial barriers that are easily replaced after being damaged by the brushes, leaving the actual window and coating surfaces intact. In addition to preventing brush damage, the barrier products also reduce vandalism and graffiti damage. Polyurethane paints that offer greater resistance to abrasion and prevent damage caused by brush washers are also available. (See Chapter 5 for additional information)

Brush Life

Over time, brushes used in automated brush washers become worn and need replacing. Overall brush life depends on several factors including equipment maintenance, frequency of washing, climate, and other conditions. Of all factors affecting brush life, proper maintenance of the washing equipment is the most essential (Boyd Lofton, AIB Brush, personal communication, March 1995). Three maintenance factors that have the greatest impact on brush life include the proper exhausting of air cylinder pressure, brush cleanliness, and sufficient water/soap flow through the nozzles. If not maintained or adjusted properly, all three will cause excessive brush contact against the bus. The abrasion resulting from excessive contact eventually causes the brushes to wear prematurely and contributes to the scratching of paint, decals, windows, and other surfaces. Brush and washer manufacturers have recommended maintenance practices for their equipment that must be followed to ensure maximum brush life.

Issues With Pressure Washers

Pressure washers have not had extensive experience in the transit industry. Manufacturers claim that because they have fewer moving parts, pressure washers require less maintenance. These washers do, however, contain high-pressure pumps, O-ring seals, spinners, nozzles, gear mechanisms, and other items that can be

damaged and require maintenance or repair. The many nozzles used in pressure washers are susceptible to clogging, especially if the water (fresh or reclaimed) contains particles greater than 50 microns in size (a micron is one millionth of a meter).

Houston Metro has investigated a number of automated high-pressure washing systems for buses, including some designs of their own. After trying several high-pressure washing systems, they have decided to abandon the concept (George Herman, Houston Metro, personal communication, December 1994). Although the pressure washers did an adequate job of cleaning buses, they removed paint and forced water past the doors and windows causing an unacceptable accumulation of water inside the bus. Houston Metro has now incorporated the application arches of the pressure washing system into a traditional brush washing system.

Issues With Gantry Washers

Gantry washers can take twice as long to clean a bus as do automated brush washers because buses must enter the washer and come to a complete stop before the washing cycle begins. In addition, gantry washers are often programmed to make two complete passes around the bus. Whereas an automated brush washer takes about two minutes to clean an average transit bus, gantry washers require about five minutes. Depending on the transit agency, an additional number of gantry washers may be required to clean the same number of buses as traditional brush washers. Gantry washers are said to require additional maintenance compared with traditional brush washers.

WATER RECOVERY AND RECYCLING

Many transit agencies are becoming increasingly concerned over the amount of water and hazardous waste generated from bus washing systems. State and local governments are also concerned and have imposed strict requirements for some transit agencies to follow. Of those responding to the survey, 75 percent collect and treat water from their bus washing equipment. Some water reclamation systems are basic in nature while others are more complex. All of these systems are designed to collect water and filter out the solids so water can be reused by the washer without clogging spray nozzles. In general, most reclamation systems reuse water for the pre-rinse and soap cycles only. Because processed water leaves a residue on the bus when dry, fresh water is often used for the final rinse cycle.

In a typical reclamation system, water discharged by the washer collects in drainage pits located below the floor level and is transferred by gravity into an underground oil separator. Water is pumped from the separator to a series of sediment tanks, where heavier solids fall to the bottom. From the sediment tanks, water is pumped to a series of filtration devices. Depending on the sophistication of the system, each has its own method of removing small particles from the water. In general, water is sent through a stainless steel mesh screen and then through a cyclone particulate separator, which uses centrifugal force to further detach solids. Basic systems are effective at removing solids suspended in the water down to the 40- to 50-micron range. Some water reclamation systems are equipped to remove odor caused by bacteria, viruses, and algae. Odor is typically treated by injecting the water with chlorine or ozone.

In addition to basic systems, sophisticated systems are available with advanced filtration technologies capable of removing solids down to the 4- to 5-micron range. What is said to be the most advanced water reclamation system has been installed at NJ Transit's Hilton Garage. (See New Jersey Transit Case Study for additional information) This is a completely closed water reclamation system in that all nonseptic water used at the facility is processed and reused. Water for bus washing, floor washing, engine degreasing, and building degreasing is reused and kept out of city sewers. The system has substantially reduced water and soap consumption, and has eliminated potential violations caused by the disposing of hazardous waste into city sewers.

The advanced water reclamation system uses a diatomaceous earth filter system, granular activated carbon absorption, ozonation, and reverse osmosis (20). The last two filtration stages, ozonation and reverse osmosis, make it possible for the reclamation system to produce drinking-quality water. This absolutely clear water is used for the rinse cycle of NJ Transit's automated brush washer and for its steam cleaning equipment. Water that bypasses the last two filtration stages, commonly referred to as "grey" water, is clean enough for use in the pre-rinse and soap cycles of the washer and for floor scrubbing.

DETAILED EXTERIOR CLEANING

Despite the improvements made to automated brush washers, transit agencies still need to follow up their exterior bus washing with detailed cleaning. This concentrated cleaning process involves attention to those areas that daily washing does not sufficiently address. Bus areas that require the most attention include wheels, back ends, undercarriages, and engine compartments. How often the detailed cleaning occurs depends on many factors including the thoroughness of the regular (i.e., daily) cleaning process and the environment in which buses operate. Detailed cleaning functions are typically scheduled during off-peak hours such as midday or late evenings. Some transit agencies use salaried cleaning personnel while others contract with independent service companies.

Undercarriage Cleaning

Of those responding to the survey, 79 percent perform some type of undercarriage cleaning. Bus undercarriages are cleaned using two different methods. One involves either low- or high-pressure water/soap spray jets installed directly in the service line. The other process is more thorough and involves high-pressure steam cleaning, which requires the bus to be over a pit or on a lift. Undercarriage water cleaners, sometimes called chassis jet cleaners, typically are used to remove the accumulation of dirt and salt on a regular basis, while heavy-duty steam cleaning typically occurs before scheduled service inspections. Steam cleaning is used to remove heavy debris and grease buildup, to keep mechanical components clean, and to assist with visual inspections.

A debate exists in the transit industry concerning the effectiveness of undercarriage washing systems that use water pressure to remove road dirt and salt. Those who favor the process claim it reduces corrosion caused by road salt and provides service technicians with a better work environment. Others claim that undercarriage washers cause problems with electrical and engine components. Edmonton Transit in Alberta, Canada, has an alternative to

undercarriage washing They perform an annual inspection of the undercarriage and follow it up with a mechanical cleaning process such as sand blasting and the application of fresh undercoating.

Engine Cleaning

All survey respondents clean their engines on a regular basis as part of their regularly scheduled service inspections. A clean engine helps with the visual inspection process and allows mechanics to access components more easily (and cleanly) Pressurized steam is the preferred engine cleaning method.

Innovative Degreasing Equipment

NJ Transit is using an innovative degreasing process that uses sodium bicarbonate (baking soda) to clean engines, undercarriages, and maintenance facilities (21). (See New Jersey Transit Case Study for additional information). The nontoxic, noncorrosive baking soda is used in NJ Transit's high-pressure washer to eliminate virtually all worker and environmental hazards associated with solvents, soaps, detergents, caustic chemicals, and toxic fumes. The portable degreasing equipment can be wheeled from one location to another and requires a source of compressed air, clean water, and drainage to operate. The equipment can also be used to remove paint and graffiti by adjusting the delivery pressure.

Another water-based technology that has potential for transit bus applications to remove paint, graffiti, grease, and other coatings involves the use of small ice pellets (22). The ice-impact equipment requires compressed air, clean water, and a power source (220-volt, 3-Phase) to operate. Upon impact, the ice particles displace

surface contaminants with a simple "blast force." As the ice changes from solid to liquid, ice particles deform laterally to exert a shearing force which begins as mechanical scrubbing and ends as liquid flushing. This "scrubbing and flushing" action provides cleaning action sufficient to remove grease, surface rust, paint and graffiti.

Wheel Cleaning

Wheels can be difficult to clean for several reasons. Many transit agencies paint bus wheels white, which easily shows brake dust, grease and road dirt that gets "baked" onto the wheel by brake and road heat. Some have painted bus wheels black or other colors to make the accumulation of dirt less noticeable. Others have changed to aluminum wheels. In addition to reducing weight and dissipating brake heat, those who use aluminum wheels claim they are easier to keep clean.

Transit agencies have experimented with several types of automated wheel cleaning equipment. The most popular is a high-pressure spinner mounted at specific locations in the wash lane (see Figure 6). As the bus wheel arrives at a certain location, a switch activates water pressure and causes the nozzles to spin in a circular fashion. Water and soap are directed into the wheel at high pressure to dislodge dirt. Because there is no direct physical contact with the wheel surface, this type of washer usually requires additional cleaning during detailed cleaning operations Another type of wheel washer involves a rotating brush that moves into the wheel when the bus stops at a predetermined location.

Despite efforts to clean wheels automatically, most transit agencies continue to clean wheels manually during scheduled detailed

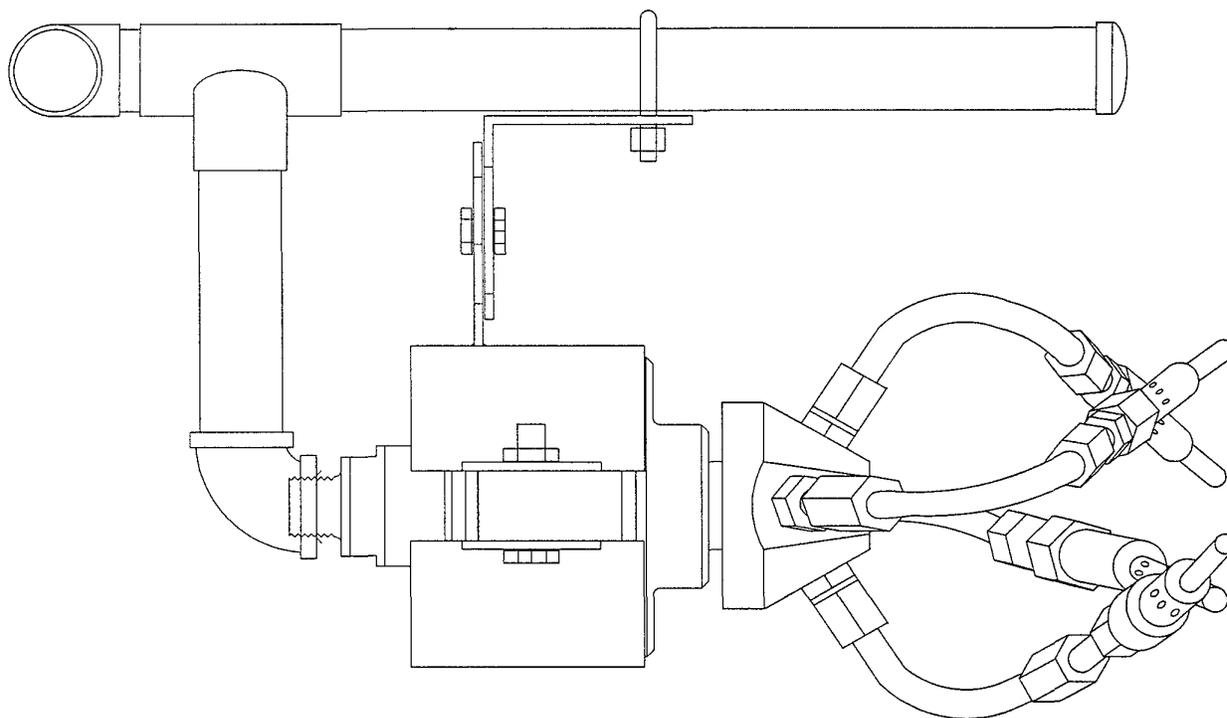


FIGURE 6 Schematic drawing of a high-pressure spinner wheel washer. (Courtesy of SSI Corp.)

cleaning operations. The most popular methods involve brush scrubbing and portable high-pressure steam washers. Others send their steel wheels out to be stripped (i.e., sand blasted) and painted with polyurethane-based paints to ensure their appearance. Those who constantly paint bus wheels to maintain a clean appearance should be aware that a buildup of paint on the wheels can cause lug nuts to come loose.

Back End Cleaning

The back end of the bus is difficult to keep clean because of the diesel exhaust drawn into that area as the bus moves forward. Although automated brush washers wrap around the back of the bus,

it is difficult to clean the exhaust soot that accumulates there. Additionally, the bus is constantly moving away from the brush as it is driven through the washer, making it more difficult to keep back ends clean.

The problem is made worse when bus speed through the washer is excessive. As a result, many transit agencies pre-wash the back ends manually, either before the bus enters the washer, or separately during detailed cleaning operations. Of those responding to the survey, 87 percent wash difficult areas such as back ends manually. Gantry washers reduce the need for manual washing of back ends because the bus is stationary and the brush typically makes two passes to clean the back end. As noted earlier, one transit agency uses a portable brush cleaner to wash the back ends of buses as they remain parked in the storage area.

CHAPTER FOUR

INTERIOR CLEANING**OVERVIEW**

In many ways, there has been no substantial improvement in the productivity of interior cleaning since the cyclone cleaner was first introduced more than 30 years ago. Interior cleaning remains very labor intensive and does not easily lend itself to automation. Newly introduced central vacuum systems with retractable hose mechanisms represent one potential area of improvement. Although some European transit agencies are experimenting with robotics to clean interiors, their widespread application is a long way off. For the average transit agency, interior cleaning involves a great deal of time-consuming manual effort. Efficiencies lie primarily with the allocation of labor.

In a typical transit operation, the hostler is responsible for interior cleaning and is assisted by a vacuum device, usually a cyclone cleaner. However, the large-capacity cyclone vacuum continues to draw negative criticism because of the need to manually wipe down interior surfaces as a result of airborne dust and because of the noise generated by the vacuum. As a result, many transit agencies have discontinued using cyclone cleaners and have reverted to manual (hand) removal of debris and broom sweeping.

Manual cleaning of bus interiors has caused concern among service line workers who report an increase in the amount of biohazard material (i.e., potentially infectious hypodermic needles, germ-soaked paper tissues, etc.) left onboard buses by passengers. This material often is left between seat cushions and in wheelchair lift equipment where it is not always visible, increasing the risk of inadvertent contact. Additionally, hostlers continue to face growing incidents of graffiti and vandalism, which adds more time and labor to an already labor-intensive job. (Graffiti is addressed separately in Chapter 5)

This chapter begins with the frequency of interior cleaning (daily versus detailed) and then examines the various types of equipment available to clean bus interiors, human safety issues associated with interior cleaning, and specific ways in which to clean bus flooring. The chapter concludes with a review of bus design considerations that affect interior cleaning.

FREQUENCY**Daily Versus Detailed Interior Cleaning**

Virtually every transit agency cleans bus interiors on a daily basis, even if only to remove coarse refuse such as bottles and newspapers. In addition to daily cleaning, transit agencies typically perform periodic detailed cleaning of the entire bus, which includes the interior. Depending on the agency, detailed cleaning is performed monthly, quarterly, or annually when additional time is set aside to address hard-to-reach and more difficult areas of the interior. The level of detailed cleaning depends on how much of it is done daily as part of the service line function. Some transit

agencies elect to do most of the interior cleaning daily and schedule detailed cleaning on a limited basis (e.g., annually). Others perform cursory interior cleaning on the service line and schedule detailed cleaning more frequently (e.g., monthly).

The overall approach to interior cleaning depends on the number of buses to be cleaned and how the work force is allocated. Agencies that perform the bulk of the interior cleaning as part of the service line function usually employ additional workers to clean difficult areas that hostlers did not have time for. Due to the limited amount of time available in the service line, some transit agencies also require hostlers to begin cleaning interiors before the bus arrives at the service line, when undercarriage inspections are being performed, when the bus exterior is being washed (in the case of gantry type washers), or after the bus has returned to the storage area. To minimize the cleaning effort, 81 percent of the survey respondents equip their buses with wastepaper baskets.

INTERIOR CLEANING EQUIPMENT

To clean bus interiors, transit agencies use a combination of equipment and procedures consisting of hand sweeping, cyclone cleaners, flexible hose vacuums, portable vacuums, and others. Of those responding to the survey, 64 percent incorporate hand sweeping into the interior cleaning procedure, 56 percent use cyclone vacuums, 19 percent use some type of flexible hose vacuum, and 21 percent use portable vacuums.

Cyclone Cleaners

Along with hand sweeping, the cyclone vacuum cleaner is a common way of supplementing the interior cleaning process. This large-capacity vacuum features a main orifice bellows that extends from the service line and fits over the entire front door of the bus (see Figure 7). The hostler opens the rear door or a rear window to allow air drawn into the cyclone to be replaced with outside air. A compressed-air wand is then used to dislodge debris from hard-to-reach areas and direct it to the front door and eventually into the cyclone. The hostler typically starts at the back of the bus and works forward.

Many transit managers are not pleased with the cyclone cleaner because of the excessive noise (up to 100 dBA) and airborne dust it generates. Continuous exposure to noise and dust may create respiratory and hearing loss problems for workers. Additionally, airborne dust created by the cyclone eventually settles on interior surfaces and requires a manual wipe-down to remove. Airborne dust also has become a major concern with sophisticated electronics used in today's transit buses. Electronic systems that operate fareboxes, destination signs, radio communications, wheelchair lifts, and other equipment are much more sensitive to dust compared

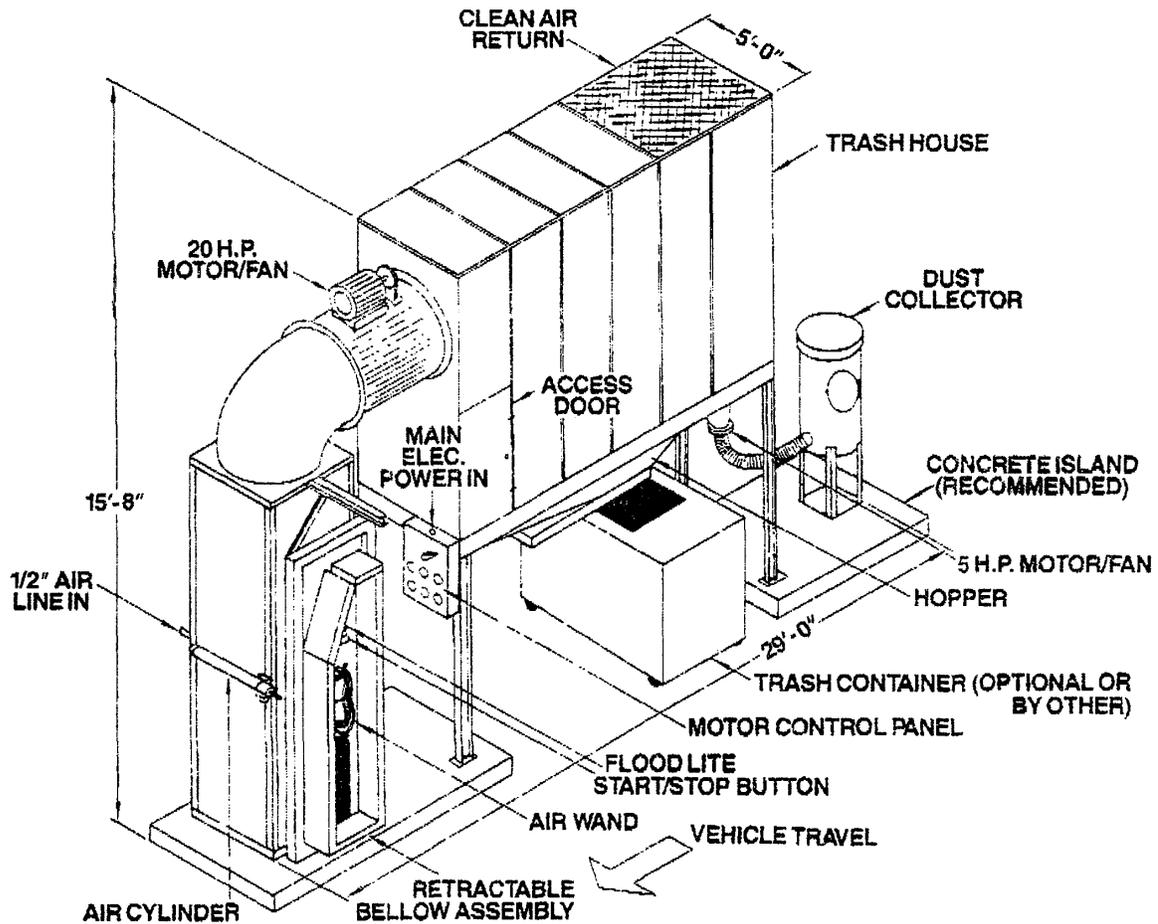


FIGURE 7 Schematic drawing of a typical cyclone vacuum system. (Courtesy of SSI Corp.)

with the mechanical systems used when cyclones were first introduced.

To reduce the negative effects of airborne dust, many transit agencies require the hostler to install a special cover or towel over the farebox when operating the cyclone. Transit agencies also require workers to wear dusk masks and ear protection when operating cyclone cleaners.

Other Vacuum Systems

The dissatisfaction with cyclone vacuum systems is evident by the large number (64 percent) of transit agencies responding to the survey that still use a manual sweep to clean interiors. In addition to the cyclone, other forms of vacuum systems are used as well. Some sweep or use compressed-air wands to "blow" dirt and debris to the step wells and then use a vacuum to transport it to a storage container.

Another cleaning method involves the use of portable vacuums. One in particular is a backpack-type vacuum cleaner, which can be carried by cleaning personnel on their backs to clean bus

interiors (23). The backpack-style vacuum cleaner weighs about 8 pounds and operates on 110 volts AC via a 50-ft electrical cord. Features include a unique cleaning head to reach behind or under obstructions, and a recessed magnet located in the cleaning head to collect any metal debris on the floor.

Another type of portable vacuum cleaner is designed specifically for bus upholstery (24). The portable wet-vac type cleaner, mounted on four casters, is rolled down the bus aisle between the seats. A mild cleaner is first sprayed on the upholstery, and the portable vacuum draws out the dirt and solution. The vacuum can also be equipped to clean carpets.

Central Vacuum Systems

The Santa Monica Approach

The concept of a central vacuum system for buses has been around for some time. However, getting hoses in and out of the bus easily has been the major obstacle preventing its acceptance in a

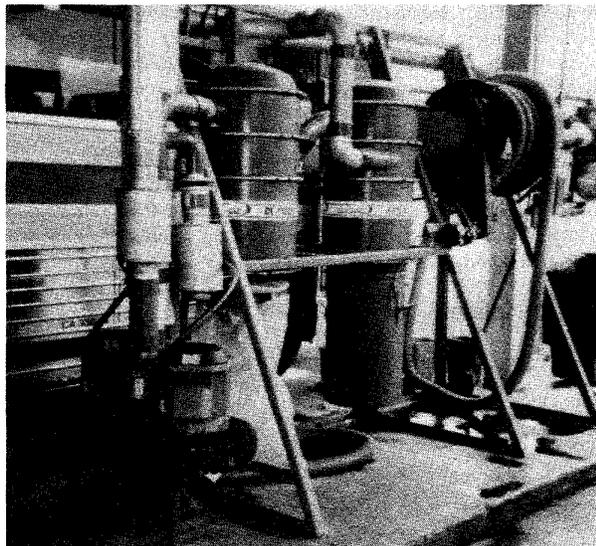


FIGURE 8 Central vacuum system in use at Santa Monica Municipal Bus Lines.

transit environment. One company that specializes in dust control has developed a central vacuum system with a retractable hose mechanism (25).

One version of the central vacuum system has been installed on the service lines at Santa Monica Municipal Bus Lines (See Santa Monica Case Study for additional information and initial experience

results). The system being used by Santa Monica has the entire central vacuum system with vacuum generator, fine filter, piping, and retractable reel mounted directly on the service line as a self-contained unit (see Figure 8). Other versions of the system are available with the vacuum generator mounted in a separate area with hoses installed on the service line (see Figure 9).

The central vacuum system can be configured in a variety of ways to suit individual transit system's needs. In one configuration, coarse refuse containers with vacuum suction devices are mounted directly in the service line and vacuum pressure transports the refuse into a central container. Where newspapers, cans, and bottles are recycled, individual containers are dedicated for each recyclable item. After the coarse refuse is collected and deposited manually, the hostler then takes a flexible vacuum hose into the bus to clean the remaining dirt and debris from the floor, seats, and other interior surfaces.

The central vacuum system used by Santa Monica does not use a pneumatic transport system for coarse refuse. Newspapers and recyclable items are removed manually from the bus and placed in ordinary containers on the service line. Except for clean recyclable objects, Santa Monica is concerned about protecting workers from physically touching the refuse left on buses. As a result, a system with larger diameter (3-in.) hoses and more suction power has been specified.

The system is capable of picking up coarse refuse and finer dirt in one operation. Santa Monica was especially concerned with debris lodged between seat cushions and wanted a vacuum system strong enough to pull out any material that workers would normally use their hands to remove. The system also features an automatic-feed hose assembly, making it easy to get the vacuum hose into the bus. When finished, the cleaner leaves the entire length of hose on the bus and pushes a switch on the service line to retract and recoil the hose automatically.

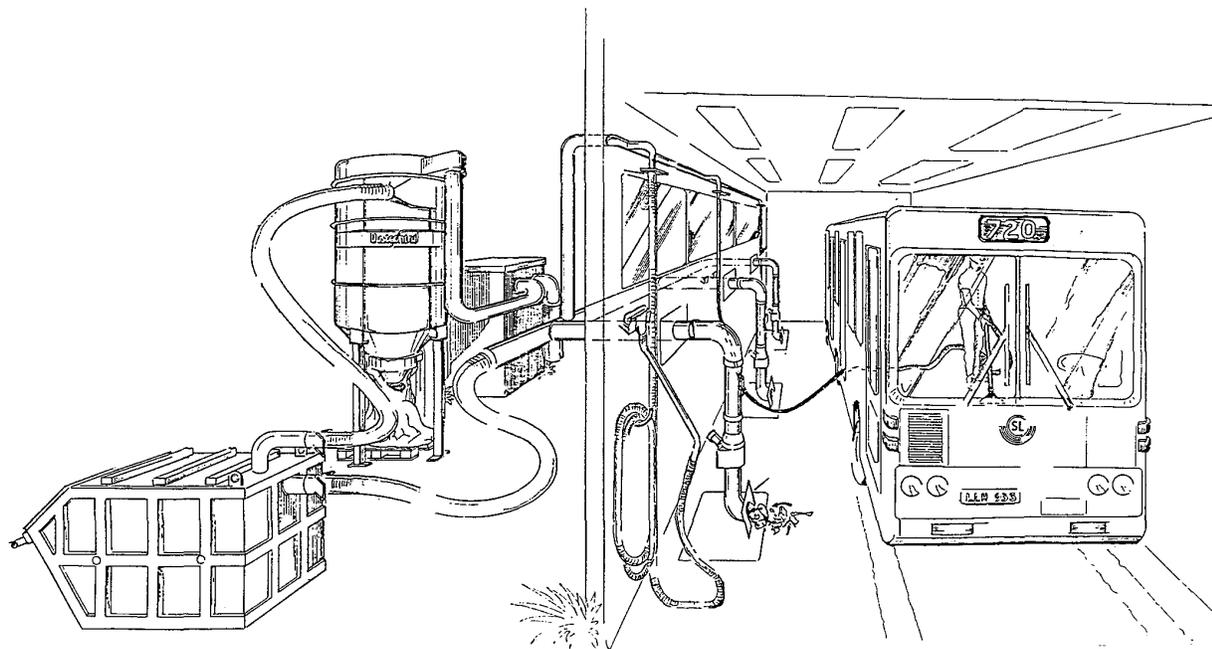


FIGURE 9 Schematic drawing of one example of a central vacuum system for bus interiors. (Courtesy of Transmatic, Inc.)

The Toronto Experiment

Another type of central vacuum system is under development at the Toronto Transit Commission (TTC), which became dissatisfied with cyclone cleaners. The prototype vacuum system being evaluated consists of four pull-down, overhead vacuum hoses and two curb-mounted vacuum collectors (see Figure 10). As the bus stops at a predetermined location at the fuel island, one 2-in. hose is located above the driver's window, while three others are suspended above the front and rear doors.

The approach being evaluated by TTC begins with the hostler removing large debris and sweeping dirt into the step wells before arriving at the service line. Once in the service line, the hostler sits in the driver's seat, opens the side window and pulls in an overhead vacuum hose. While sitting in the driver's seat, the hostler uses the hose to clean difficult-to-reach areas of the driver's compartment.

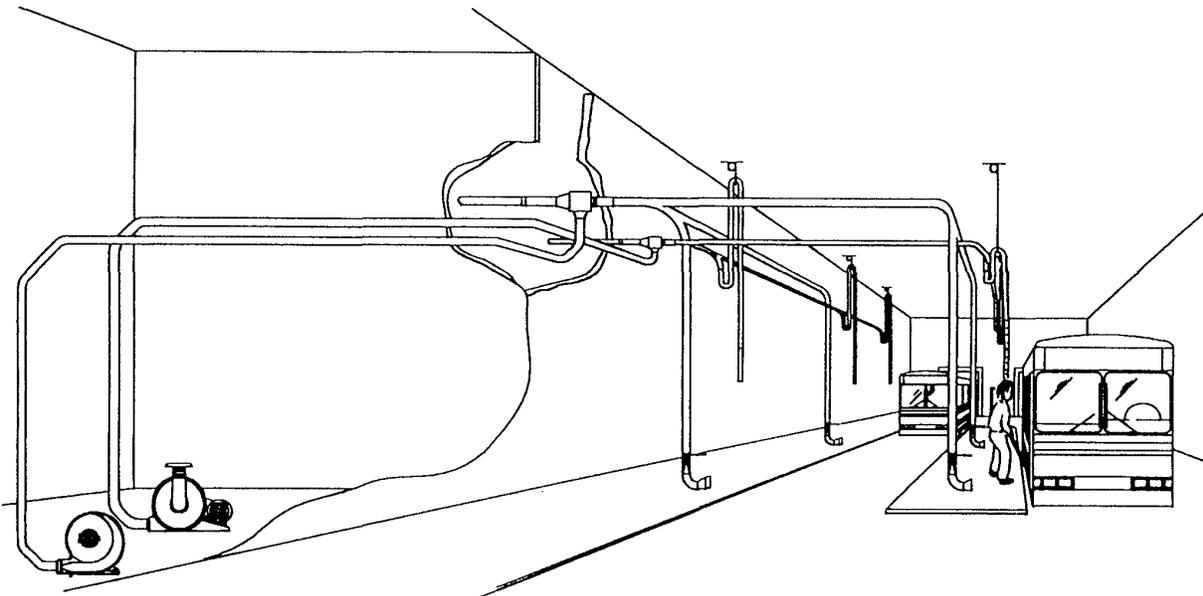


FIGURE 10 Central vacuum system being evaluated by the Toronto Transit Commission. (Courtesy of Eurovac)

When finished, the hose is retracted back into the spring-loaded tool retractor. The hostler then uses a broom to sweep dirt and debris from the step wells into the curb-mounted vacuum receptacles. Larger 6-in hoses attached to the curb receptacles are used to transport dirt and debris to a central container.

Although TTC is optimistic that the prototype interior vacuum system will be optimized, it is clear that full operation will not be realized soon (Douglas Kennedy, TTC, personal communication, March 1995). TTC intends to use the interior vacuum system on days *without* snow and ice accumulation. During inclement weather, TTC plans to use another procedure involving built-in plumbing to wash slush and dirt from bus flooring (see "Floor Cleaning" below for additional information).

In the TTC system, vacuum hoses are relatively short in length and are only intended to transport dirt from three specific locations

inside the bus. Because the hoses are suspended from above, they do not create a tripping hazard inside the bus. This particular system does not address the handling of refuse that may present health hazards and still requires manual broom sweeping.

The two central vacuum systems described above represent earnest attempts at developing a more efficient and productive method of cleaning bus interiors. Based on the negative experiences with cyclone cleaners, many transit agencies are eagerly awaiting longterm experience results from Santa Monica and TTC. Until more efficient vacuum systems are developed, the interior cleaning process will continue to be labor intensive.

HEALTH ISSUES

An increasing number of transit agencies are becoming concerned with potentially infectious bio-hazard material left onboard

buses. Phoenix Transit displays a large poster to instruct service line workers on ways to reduce exposure to AIDS and other infectious diseases (26). The poster is displayed in the supervisor's office where service line workers meet daily. It is strongly recommended that cleaners wear protective rubber gloves when cleaning bus interiors.

Airborne dust and noise generated from cyclone cleaners represent other health and safety concerns. A dusty environment can reduce worker productivity and strain the respiratory tract, affecting the nose, eyes, throat, and lungs (27). While many interior bus cleaners wear protective masks to filter some of the dust, many do not. In fact, of the two case studies featured in this synthesis that use cyclone cleaners, only one worker was observed wearing a mask while "blowing down" the interior with a compressed-air wand.

FLOOR CLEANING AND GUM REMOVAL

Floor Cleaning

The debate on whether or not to use pressurized water systems to clean bus floors continues, although the majority of transit systems surveyed elect not to use pressurized water systems. Of those responding to the survey, only 17 percent use water pressure to clean bus floors. The remainder use a damp mop to avoid the accumulation of excess water inside the bus. With the addition of many electronically controlled devices inside buses, transit agencies are reluctant to use water spray to clean and rinse interiors. Additionally, excessive water can penetrate the subfloor where it can cause substantial corrosion problems over time.

After the floor has been washed, a variety of techniques are used to drain off excessive water and dry the floor. Most transit agencies simply let the process happen naturally by parking buses on an incline and using the kneeling feature to help direct excess water out of the bus. Others use hydraulic lifts or blocks to create the incline. To speed the drying process, some agencies use the heating system of the bus, while others use towels, portable fans, and auxiliary heaters.

One agency reported the use of a portable wet-vacuum to remove water from the floor. Several transit agencies drive the left rear wheel of the bus on a ramp so water can drain out of the doors easily. To solve the problem of water collecting behind the right rear wheel well, some have drilled a hole in the bus floors. After the water has drained, a plug is installed to seal the opening.

The Toronto Transit Commission (TTC) is in the process of retrofitting its buses with an innovative system that quickly washes bus floors while the bus is in the service line (see Figure 11). The system, designed by TTC, is used only on days with significant ice/snow accumulation. A 1.5-in. plastic pipe, with small holes drilled about 6 in. apart, runs along the flooring below the rear seat. The plastic pipe is connected to a receptacle mounted to the outside of the bus.

When weather conditions warrant its use, a water hose with a 1.5 minute timing mechanism is inserted into the bus-mounted receptacle by the fueler. The hostler (wearing rubber boots) uses a narrow, hard-bristle brush to scrub the floor and direct water that flows onto the bus flooring out of the doors. Because so much sand accumulates at the front door area, TTC has found it necessary to use a second station in the service line to hose down the sand.

To assist the flow of water, an 8-in. incline is built into the left side of service line, tilting the bus to the right. Water flows from the small pipe openings across the floor taking mud, salt, and other debris dislodged by the scrubbing action of the brush out the doors. After water stops flowing across the floor, the hostler uses a squeegee fitted to the back side of the brush to push out the remaining water. Smooth bus flooring allows the squeegee to work effectively.

TTC has specified this system on its next order of low-floor buses, which will incorporate two additional water outlets at the front of each rear wheel well. The buses will feature a special grade of water-resistant subflooring material to prevent rotting.

Gum Removal

One of the most annoying and difficult substances to remove from bus flooring is chewing gum, especially when it gets into ribbed surfaces. The problem is more prevalent on buses that carry school-age passengers. Nearly every transit agency uses some type



FIGURE 11 Innovative floor washing system developed by the Toronto Transit Commission. (Courtesy of TTC)

of scraper (i.e., putty knife) to remove gum from floor surfaces. The process is made easier with several commercial solvents that reduce the gum's adhesion strength.

Cooling or freezing the gum is another popular method of removal. The most basic technique involves the use of cold water. Freon, the material used in air conditioning systems, had been a popular method to freeze gum. However, environmental concerns with the release of chlorofluorocarbons (CFCs) into the atmosphere forbids its use for gum removal. Several non-CFC alternatives to freezing gum are being used by transit agencies. One in particular involves the use of a high-pressure, nonflammable chlorodifluoromethane spray to freeze the gum, making it brittle and easy to remove (28). In addition to solvents and sprays, NJ Transit has found a portable steam cleaning device that has been effective at "lifting" gum from floors and seating materials (29).

BUS DESIGN CONSIDERATIONS

Over 15 years ago, the Urban Mass Transportation Administration (UMTA) published *Baseline Advanced Design Transit Coach*

Specifications, commonly referred to as the "White Book." The White Book was an attempt to standardize the design of buses around one advanced design bus (ADB) specification, collectively established by bus manufacturers and transit agencies. Cantilevered seats, which extend outward from the side walls and require no seat-to-floor pedestal supports, were specifically included in the ADB specification to facilitate interior cleaning. With an unobstructed floor, cleaners could sweep, wash, vacuum, or mop the floor without "going around" the many seat pedestals that were common on earlier buses.

Although no longer required for federally assisted procurements, transit agencies continue to use portions of the White Book specification today. In fact, 11 transit agencies responding to the survey listed cantilevered seating as a bus design feature they use to improve interior cleaning. Other interior design features adopted by transit agencies to improve cleaning include the use of sealed floor seams, a clear coat floor finish, nonribbed flooring, rot-resistant subflooring material, dark interior colors, modesty panels with 1-in clearance above the floor, new European-designed nonslip floor material to eliminate the need for sand in the winter, and holes drilled into plastic seat bottoms to allow water drainage.

Some bus designs today incorporate the use of low floors, originally introduced in Europe to improve passenger boarding. In the

United States, the enactment of the Americans with Disabilities Act (ADA) has been a major force in the growing interest of low-floor buses (30). Several provinces in Canada are also encouraging the use of low-floor buses. Although most transit bus manufacturers in North America have low-floor programs underway, only a few are in actual production. Despite their limited use, transit agencies have raised some valid issues about cleaning low-floor buses.

BC Transit, Victoria, British Columbia, which operates several low-floor buses, has identified four bus design issues relating to interior cleaning (A. Little, BC Transit, personal communication, January 1995). The issues raised by BC Transit include:

- The increased ceiling height on low-floor buses has made it more difficult for cleaners to reach upper areas.
- An unusual amount of dust settles on interior surfaces. Although they are not completely certain, officials think the problem may be created by the different air-flow characteristics within the bus.
- Because they are closer to the splash areas of the road, exterior window surfaces are more difficult to keep clean.
- The cavity from which the wheelchair ramp extends collects dirt and can be difficult to keep clean.

CHAPTER FIVE

GRAFFITI PREVENTION AND REMOVAL**OVERVIEW**

Many cities are experiencing dramatic increases in graffiti and vandalism, which accounts for a significant portion of the time and money spent cleaning buses. Transit agencies with severe problems are taking steps to minimize the damage, but vandals seem intent on finding ways to circumvent these efforts. Although this synthesis is not charged with determining the reasons why vandalism occurs, transit agencies must attempt to deal with this question as part of their overall graffiti prevention program. An official with the Phoenix Transit System, speaking to a local newspaper, highlights the confusion about why vandalism occurs: "We don't understand it all, and we don't get much of an opportunity to talk with those people. It just seems like all of a sudden, buses have become real popular with them" (31).

Transit officials have noticed that the types of graffiti experienced on buses have changed in recent years. In the past, a limited amount of graffiti was placed on buses by adolescents who wanted others to know about their sweetheart or a profanity that they recently learned how to spell. Today, that type of graffiti has given way to gang insignias as members attempt to mark their territory or gain prominence in a particular neighborhood. Whatever the reason, graffiti and vandalism have grown to epidemic proportions in some cities today. In Phoenix for example, reports of graffiti have grown from an average of only nine per month in 1993, to more than 750 per month in 1994.

This chapter will address specific precautions that transit agencies have adopted to prevent graffiti and vandalism from occurring, followed by a review of how graffiti are removed from bus surfaces.

GRAFFITI/VANDALISM PREVENTION**Basic Methods**

Transit agencies have discovered that quick removal of graffiti is the best way to deter future occurrences. Once perpetrators realize that their "art work" will not last more than a few hours, there is little incentive for putting it there in the first place. In addition, the longer a stain is allowed to set, the more difficult it will be to remove. Of those responding to the survey, over 90 percent remove graffiti daily or as soon as they are noticed. Traditional types of graffiti reported by transit agencies include pens, felt-tip markers, paint, lipstick, and shoe polish. Some agencies report that vandals are using self-adhesive stickers with symbols and other preprinted messages as a form of "instant graffiti."

Despite the diligent efforts made by transit agencies to remove graffiti quickly, vandals have responded with alternative methods of destruction. To leave a more permanent marking of their work, vandals have resorted to more sophisticated paints and markers that are more difficult to remove. Even more problematic are sharp instruments capable of scratching or "etching" graffiti into objects.

The most troubling aspect of etching is that it thwarts the primary graffiti countermeasure—its immediate cleanup. Once windows, seats, and other objects are etched, they are permanently damaged and require costly and time-consuming replacements. Over 35 percent of those responding to the survey have experienced graffiti and vandalism caused by sharp etching tools.

More Aggressive Methods

In addition to removing graffiti quickly, many transit agencies are taking more aggressive measures to prevent vandals from putting it there in the first place. Some agencies conduct awareness seminars to help students and others understand the importance of bus cleanliness and to warn them of the financial and legal consequences of destroying public property. Some use public messages to discourage graffiti, while others offer financial rewards to those who report the perpetrators. One transit agency sees to it that vandals are arrested, convicted, and made to pay for their destruction. Yet other agencies install video surveillance cameras randomly on buses to help catch and punish vandals. Several transit agencies have special call buttons on their buses to alert local police. Others park their buses in secured lots with security guards to keep vandals away. Some agencies have reduced the tinting of their windows so vandals are more visible from the outside and passengers inside feel safer.

Polyurethane Paints and Topical Finishes

A growing number of transit agencies are equipping their buses with specially designed products that make graffiti harder to apply and easier to remove. Polyurethane paints, both clear-coat and base-coat, are specially formulated to provide excellent resistance to many of the harsh solvents needed to remove graffiti. The paints are also formulated to reduce the cohesion of graffiti, thereby making them easier to remove. LACMTA applies wax to exterior surfaces painted with polyurethane paints, making graffiti easier to remove. Polyurethane paints can be applied to exterior as well as interior bus surfaces. When coated with a clear topical finish, textured interior plastic trim surfaces become smoother and easier to clean. Despite the hardness and excellent chip-resistant characteristics of these topical finishes, they do little to prevent the damaging effects of etching.

Interior Seat and Trim Protection

Interior seating and trim panels are popular targets for graffiti "artists." Several products and procedures are used by transit agencies to minimize the effects of graffiti on interior seating and trim. One procedure reported by a few agencies involves the application

of liquid-based automotive product to protect plastic, rubber, and vinyl surfaces. Once applied, the silicone-based formula penetrates and bonds to surfaces, interfering with adhesion of paint, markers, etc. These products are readily available in automotive stores and must be applied frequently to be effective.

Agencies with more persistent problems have a variety of graffiti and vandal resistant seating and trim alternatives to choose from. Fiberglass seat shells and thermoplastic seat grab rails are naturally graffiti resistant because the material hardness makes it difficult to absorb graffiti. When these products are finished with a topical clear coat, graffiti removal is made easier. Another alternative for transit agencies with severe vandalism problems involves the use of stainless steel seat frames and backs (32). The dieformed stainless steel construction is more resistant to vandalism, graffiti, and stains, and is gaining attention among the larger cities with severe vandalism problems.

In addition to seat frames and backs made from graffiti and vandal resistant materials, the seat itself is available with several material alternatives. The most basic seat is a one-piece design made entirely of fiberglass. Seat inserts are molded directly into the shell, and feature completely smooth surfaces for easy cleaning and graffiti removal. For transit agencies requiring additional comfort for their passengers, seat inserts (vinyl and upholstered) made of graffiti and vandal resistant materials are also available.

Seat inserts made from vinyl can be ordered with a protective finish designed to be cleaned with active solvents such as nail polish remover (acetone/water) without damaging the finish (34). Available in an assortment of colors, the coated vinyl material resists stain penetration making graffiti easier to remove.

Seats upholstered in a fabric material make it more difficult to apply graffiti because the fabric is not smooth and does not lend itself to graffiti, especially when the pattern is multicolored. However, vandalism caused by sharp knives or other instruments does pose a serious problem with this type of upholstered seating because it is traditionally more expensive to replace. One alternative involves the use of upholstered inserts made from a vandal-resistant fabric, which offers some degree of comfort while discouraging graffiti and vandalism. The upholstered insert consists of a molded plastic substrate to which a vandal resistant fabric is bonded (34). Vandals attempting to cut the fabric with a sharp knife quickly discover that the knife has no effect—the fabric is not penetrated, nor can it be separated from the molded substrate.

Plastic Laminates

Another form of protective coating involves the use of special laminates made from advanced plastic materials. The advanced plastics have exceptional mechanical strength and inertness toward a wide variety of chemicals, solvents, and other staining agents (35). The plastic laminates are available in thicknesses from 0.5 to 2.0 mils and can be permanently bonded to steel, aluminum, vinyl, fabric, and many other substrates to form a strong and durable finish. These laminates can be used in several bus applications to protect interior and exterior surfaces against graffiti and vandalism. Additionally, the anti-stick properties of the laminates facilitate cleaning. They are available in clear or pigmented forms, and can be painted if necessary.

The plastic laminates can be applied to a variety of interior panels including trim and seat backs. Their strong physical properties resist vandalism, while the chemical inertness permits the use

of solvent-based cleaners to remove graffiti without causing discoloration of the substrate material. When applied to exterior surfaces, plastic laminates can provide similar protection against graffiti and vandalism. Bonding of the plastic laminates to the substrate is applied by the manufacturer. Application by maintenance personnel is also being investigated.

Window Protection

Sacrificial panels made from advanced plastic materials are becoming increasingly popular with many transit agencies that have become frustrated with replacing windows damaged by etching. These thin-sheet panels are made of clear plastic and are held in place with retaining tracks. The interior panels essentially isolate bus passengers from the windows and serve as protective barriers. When the panels are vandalized with a sharp instrument or etching tool, they can be easily replaced for a fraction of the cost of a new window. Despite their obvious advantage, some transit agencies report that the panels make a rattling noise as they vibrate in their retention tracks. One service line worker believes the plastic panels actually promote etching because they serve no other purpose.

GRAFFITI AND STAIN REMOVAL

Depending on the precautions taken in advance, removing graffiti and stains can be an extremely labor-intensive task. Once paint, markers, and other substances penetrate the surface and dry, removal becomes more difficult. As described below, each combination of material (i.e., windows, painted surfaces, plastic, etc.) and stain (i.e., ink, paint, lipstick, etc.) requires a different solvent and procedure to remove, which exacerbates the cleaning process.

It is difficult to draw any conclusions concerning the effectiveness of specific products because of the wide variety of chemical/ solvents used by transit agencies to remove graffiti. As with bus washing soap, each transit agency appears to prefer a particular brand of graffiti removal product.

Because transit agencies use such a wide variety of products to remove graffiti from their buses, it would be difficult to make a determination as to which products perform better than others. Despite the product variation, there are some general procedures that have been found effective for the removal of specific stains on interior plastic and vinyl surfaces (36).

Level One stains listed below can be cleaned with nonabrasive household cleaners and a soft cloth or damp sponge:

- Coffee/tea, hair oil tonic, blood, urine, grape juice, motor oil, chocolate, and ketchup.

Level Two stains can be cleaned with solvent-type cleaners such as rubbing alcohol, naphtha, mineral spirits, turpentine, etc. to be liberally applied with a soft cloth or damp sponge:

- Nicotine, eye shadow, crayons, and grease.

Level Three stains require strong, active solvent cleaners such as nail polish remover (acetone/water) to be applied with a soft cloth or damp sponge. The stain should be removed with less than six rubs. If the stain persists after six rubs, the stain has set and removal is unlikely. Rinse cleaned area with fresh water and dry with a clean cloth.

- Spray paint, permanent felt-tip marker, ballpoint pen, lipstick, and yellow mustard.

CHAPTER SIX

CASE STUDIES

Three transit agencies were investigated in greater detail as case studies for this synthesis report. Each of the three agencies chosen has unique service line and cleaning conditions. The Hilton Garage operated by NJ Transit is a good example of a northeastern transit bus facility with limited indoor bus storage capacity. The Hilton Garage is also equipped with an advanced water reclamation system, an area that is gaining widespread attention as the transit industry attempts to contain hazardous waste and conserve resources.

The Phoenix Transit System was chosen primarily because of its innovative team approach to service line functions. The team concept has greatly improved work quality and serves as a good example to other transit agencies trying to improve productivity. Santa Monica Municipal Bus Lines uses a central vacuum system for interior bus cleaning. The innovative cleaning equipment represents an alternative to the cyclone cleaner, which has not changed over the last 30 years. Profiles of the three case study agencies are shown in Table 2.

NEW JERSEY TRANSIT

HILTON GARAGE

Overview

NJ Transit serves the entire state of New Jersey with 1,918 buses operating from 16 facilities. NJ Transit's Hilton Garage, located in Maplewood, is a transit bus operating facility that houses 147 40-ft buses and 21 articulated buses. The service line operates on one daily shift from 6:00 pm to 3:00 am. All buses are serviced daily during this one shift.

Originally constructed in 1910, extensive modifications were made to the Hilton facility in 1988 to make use of the limited amount of space available there. Because of its residential location, no land was available for expansion and the Hilton Garage can barely accommodate the 168 buses assigned there with indoor storage. Consequently, maneuvering buses inside the facility is somewhat difficult.

Service Line and Cleaning Sequence

Service line and cleaning functions at NJ Transit's Hilton facility are performed in the following sequence:

- Buses are retrieved from the storage area by hostlers.
- Revenue is removed by hostlers.
- Refueling, fluid checks, fluid replenishment, and exterior mechanical inspections are performed by the service person (fueler).
- Interior inspections and cleaning are performed by the hostler.
- The hostler also drives the bus through the automated brush washer and returns it to the storage area.

TABLE 2
PROFILES OF THE THREE CASE STUDY AGENCIES

New Jersey Transit, Hilton Garage

Location: Maplewood, NJ
Service Area in Sq. Miles: 288 (749 km²)
Number of Staff: 393
Annual Miles: 5,438,571 (8,752,292 km)
Annual Ridership: 18,834,000
Total No. Buses: 168
Total No. of Service Line Shifts: 1

Phoenix Transit System, South Facility

Location: Phoenix, AZ
Service Area in Sq. Miles: 465 (1,204 km²)
Number of Staff: 518
Annual Miles: 12,576,272 (20,238,994 km)
Annual Ridership: 17,637,358
Total No. Buses: 205
Total No. of Service Line Shifts: 2

Santa Monica Municipal Bus Lines

Location: Santa Monica, CA
Service Area in Sq. Miles: 40 (104 km²)
Number of Staff: 207
Annual Miles: 3,965,000 (6,380,874 km)
Annual Ridership: 17,602,352
Total No. Buses: 139
Total Number of Service Line Shifts: 1
(Detailed Cleaning is contracted out)

Retrieval From Parking Area

Buses are taken from the storage area by a hostler and driven to one of two service lines. Before moving the bus, the hostler inspects the defect card left by the operator. If the operator has reported any defects concerning the brake or suspension system, the bus is returned to a repair bay after all other servicing has been performed. While driving to the service line, the hostler turns on all interior and exterior lights including the emergency flashers.

To optimize the use of indoor space, the flow of buses within the Hilton facility has been reorganized for efficient use. Instead of randomly parking buses in the storage area, in assigned spaces, or "stacking" buses in the service lines, NJ Transit has developed a traffic pattern to improve the efficiency of its work force and to reduce engine exhaust buildup.

With five bus storage bays available at the Hilton facility, the first group of buses returning from revenue service is directed into the second bay, leaving the first bay open. Hostlers take buses from the second bay, drive them through the service line and return them to the first storage lane, where they are ready for the next day's service. As the first bay begins to fill, buses returning from

revenue service are directed to the third storage bay, leaving the second bay free. This process continues throughout the evening until all bays are full

Revenue Removal

The first area of the service line consists of revenue removal where the hostler engages the parking brake, removes the cashbox from the farebox and empties it into the cashbox receiver located near the front door of the bus. During the revenue transfer process, contents of the cashbox are isolated from the hostler. After the revenue has been deposited into the steel-encased receivers, it is transported directly to the bank by an armored car service. Revenue is not routinely handled by NJ Transit personnel at all. If the dollar bill module in the farebox becomes inoperable while in service, passengers are asked to pay in coin or are allowed to travel free of charge. This continues until the end of the trip or until the bus can be replaced.

While the hostler vaults the farebox, the fueler, who is positioned directly ahead, visually inspects the front of the bus for operation of the headlamps, running lamps, emergency flasher lamps, and for signs of visual damage. After the cashbox has been emptied and returned to the farebox, the hostler moves the bus ahead to the fueling station and activates the parking brake. During the driving maneuvers, the hostler pays particular attention to any abnormalities in the brake, suspension, and drive systems.

Service Line Duties and Interior Cleaning

As the hostler begins to inspect and clean the bus interior, the fueler activates the fluid management system by entering data on a keyboard. Data entered into the system consist of the bus number, the identification numbers of the fueler and hostler, and the mileage reading listed on the hubodometer. Once the system is activated, the fueler installs the dry-break nozzle and activates the flow of diesel fuel into the bus.

As the bus is being fueled, the fueler checks and replenishes other fluids including oil, coolant, and transmission fluid. All consumables dispensed are recorded by the fluid management system (see Data Acquisition below for additional information). The fueler also inspects the exterior for damage and mechanical defects, inspects the tires for loose lug nuts, and "bumps" the inside dual rear tires with a steel bar to check for flat tires. To aid in the inspection of loose lug nuts, NJ Transit applies a "torque seal" on each lug nut after it has been properly torqued (tightened to a uniform force). The red seal material is applied from a tube, much like silicone sealer. Torque seal material is applied over the top of each lug nut, bridging the wheel stud in the center. The sealer dries to a solid and when a lug nut becomes loose and starts to rotate on the stud, the seal is broken and becomes easily visible.

While the fueler is working around the outside of the bus, the hostler inspects the interior for damage and mechanical defects, and removes coarse refuse such as bottles and newspapers. The hostler then cleans the interior with assistance from a cyclone cleaner and a compressed-air wand.

After all duties have been completed, the fueler removes the fuel nozzle and records the amount of fuel dispensed into the fluids management terminal. The fueler signals to the hostler by tapping two times on the side of the bus indicating that it is safe to move ahead.

Exterior Washing

NJ Transit's Hilton Garage uses an automated brush washer with four brushes to clean each bus on a daily basis, summer, and winter. Speed through the washer is controlled by the hostler at approximately 2 to 3 mph. Driving the bus too quickly through the washer results in road dirt being left on the back side of the bus. When the unwashed dirt becomes visible to supervisory personnel, hostlers are reprimanded and told to control bus speed more accurately.

To maximize cleaning and minimize scratching, each of the four brushes used in the automated bus washer consists of five different sections (19). Each brush section is designed with individual characteristics to react with the particular bus surface to be washed and each brush section is color-coded to ensure proper installation in the overall brush assembly.

Despite the softer brush design, the scrubbing action of the brush washer scratches the plastic windows over time. Daily contact with the brushes causes the window coating to break down, resulting in many fine scratches commonly referred to as crazing. Because of the expense involved in replacing the plastic windows (about \$1,000 each), NJ Transit sends them out to be resurfaced (18).

Data Acquisition

NJ Transit's Hilton Garage uses three independent data acquisition systems, consisting of fluid management, revenue collection, and a manual defect card. The fluid management system records the consumption of diesel fuel, engine oil, transmission fluid, and coolant. Fluid consumption is tracked by mileage. Supervisory personnel review the computer printouts generated by the system on a regular basis and schedule maintenance events based on excessive consumption levels.

In addition to the fluid management system, NJ Transit uses a manual defect card to identify mechanical abnormalities. At the start of each run, the bus operator takes what is called an "Operator's Bus Condition Report." The 8-1/2 x 11-in. card consists of two copies. Defects noted throughout the day by the operator are listed on the card. One copy remains with the bus, while the other is submitted by the operator. Maintenance supervisory personnel review the defect cards and schedule maintenance events accordingly.

The acquisition of revenue data is part of the entire revenue collection system. The system consists of an electronic farebox, a removable cashbox, and a cash receiver, in which revenue collected from the farebox is transferred. The cash receiver is located in a secured room adjacent to the service lane. The hostler uses an electronic device to unlock the cash box from the farebox. Passenger and revenue data are downloaded to a central computer where they are used to account for revenue and to identify ridership trends (37).

Water Reclamation System

An innovative feature of the Hilton Garage is the use of an advanced water reclamation system (20). Except for septic water, all water generated by the facility is reclaimed in a completely closed system. The system is capable of processing about 60 gallons of water per minute (gpm) and uses a series of holding tanks and pumps to process, store, and deliver water. The reclamation

system is designed to remove contaminants in accordance with both federal and state hazardous waste disposal regulations.

Water at NJ Transit's Hilton facility is treated as follows:

1. The settling of solids and the gravity separation of oil is done in a 10,000-gallon tank.
2. An ozonation process sanitizes the water, removes odors, and separates trace metals so they can be easily removed.
3. Micro-filtration (diatomaceous earth filter) removes large particles.
4. Ultra-filtration removes fine particles, oils, emulsions, and metals
5. Reverse osmosis (RO) removes ionized metals and salts, and produces clear, distilled water

The distilled water generated through the RO process is completely clean. In fact, NJ Transit had this water tested against bottled drinking water and the two were virtually identical in purity. NJ Transit uses the distilled water to supply the steam boiler for engine degreasing and for the final rinse cycle of bus washing. Distilled water dries with virtually no spotting on the bus windows and allows the engine-degreasing steam gun to operate without clogging. All other water processed by the system, referred to as "grey" water, has much of the soap, dirt, and other solids filtered from it. Grey water is reused in the washer for the pre-rinse and soap cycles, and is also used in the floor scrubbers.

Soap consumption at NJ Transit's Hilton Garage has been reduced from about 300 gallons per month to about 500 gallons per year. Additionally, the absence of large particles in the water has allowed NJ Transit to use low-flow washer nozzles (from 3 gpm to 0.5 gpm), which has greatly contributed to the reduction of water and soap. NJ Transit estimates that it is saving about 3,000 gallons of water per day by recycling.

NJ Transit has spent about \$37,000 to purchase and install the advanced water reclamation system. Maintenance for the first 14 months of operation totaled approximately 20 staff hours per week. Now that the initial problems have been addressed, NJ Transit is expecting routine maintenance to consist of 10 minutes per day inspecting the system and another two hours per month cleaning the reverse osmosis filter and installing new diatomaceous earth filters. The diatomaceous earth filters add approximately 20 cubic yards of hazardous waste (i.e., sludge) that must be removed annually by an independent hauler.

CFC-Free Chewing Gum Removers

Removing chewing gum from bus floors is an ongoing process at the Hilton facility because of the many school-age children using the bus system. After trying several methods to remove gum from bus flooring, NJ Transit settled on two methods. One involves a CFC-free spray (28). The high-pressure, nonflammable spray uses chlorodifluoromethane to freeze the gum, which makes it brittle and easy to remove from several surfaces including carpeting, wood, and flooring. NJ Transit also uses a portable steam-type device, which they claim is very effective in removing gum from flooring and seating material (29).

Baking Soda Based Degreaser

Another innovative cleaning process used at NJ Transit's Hilton facility involves a baking soda based degreaser (21). The baking

soda cleaner is used in a portable pressure washer to degrease engines and undercarriages and in the service bay where the degreasing takes place. The nontoxic, noncorrosive baking soda is water-soluble and free from virtually all worker and environmental hazards commonly associated with solvents, caustic chemicals, and toxic fumes. The residue of baking soda and water left behind is said to inhibit rust for several weeks. Prior to painting, the residue must be removed by flushing it with fresh water.

Equipment Under Consideration

To improve the efficiency of its service line and cleaning operation, NJ Transit continually investigates new equipment. NJ Transit is currently exploring the following equipment for use at its Hilton facility: an overhead door system that reduces the amount of heat loss during winter months, an evaporative cooling system for the service lane to reduce heat loading and to improve worker comfort, and an automated bus wheel washing system.

PHOENIX TRANSIT SYSTEM

SOUTH FACILITY

Overview

The Phoenix Transit System maintains 205 transit buses from its South Facility. About 40 of the buses are serviced during the day shift, and the remainder are serviced during the evening. The day shift is also used to perform detailed cleaning on all buses on a two-week rotation basis. Because of the warm temperatures, all bus storage at Phoenix is outdoors with steel canopies overhead to provide shelter from the sun. The facility has dual service lines and a bus washer, also located outdoors with canopy-type shelters. An overhead water misting system built into the canopies overhead is used on extremely warm days to improve the comfort of service line personnel. Overhead electric heaters also provide warmth during cooler temperatures. The revenue removal area is located in its own separate area, away from the service lines.

An inspection pit, located adjacent to the service lines, is used for brake and undercarriage inspections that take place weekly. A small electric vehicle, similar to a golf cart, is used to shuttle bus operators and maintenance personnel to and from the parked buses.

Service Line and Cleaning Sequence

The service line and cleaning sequence at Phoenix Transit is as follows:

- Buses returning from service are taken by the operator to a revenue vaulting area independent of the service line.
- After the revenue has been removed, the bus is parked by the operator in an assigned and numbered storage location.
- A hostler retrieves the bus from the storage area and drives it to the service line.
- After interior cleaning and mechanical service functions have been completed, the bus is driven through the wash bay by the hostler and returned to its assigned parking spot.
- Once per week the bus is driven over the brake inspection pit

for a detailed undercarriage inspection before being returned to its assigned parking spot.

- Every two weeks buses receive a detailed cleaning during the day shift.

Revenue Removal

On returning from revenue service, the operator drives the bus directly to one of two lines that make up the revenue vaulting area. The revenue area is located near the storage area and is independent of the service line. The fare collection system uses an infrared probe, which downloads revenue and passenger data from the farebox and unlocks the removable cash box (7). The cash box is taken to a steel-encased receiver where funds are transferred. The transfer process is such that revenue is isolated from human contact. Once emptied, the cash box is reinstalled into the farebox and the bus is returned to its assigned parking spot by the operator. If available, a small electric vehicle transports the operator from the parking area.

Phoenix Transit's revenue counting room is located adjacent to the vaulting area. A wall common to both areas contains the cash receivers. Revenue transferred from the cashbox goes directly into the secured room for counting and processing. Video surveillance cameras are used to monitor all activities associated with revenue transfer and counting.

Retrieval From Parking Area

After revenue has been removed and buses returned to their assigned parking spaces, they are taken to the service line by a hostler. As the bus enters the service line, a red lamp illuminates to indicate that the bus is in the correct orientation for fueling.

Service Line Duties and Interior Cleaning

After engaging the parking brake, the hostler removes any coarse refuse and opens the rear door. A cyclone cleaner and compressed-air wand are used to remove the remaining debris. A cover is placed over the farebox to prevent dust infiltration. While cleaning the interior, the hostler also makes a visual inspection for vandalism, graffiti, and mechanical defects. Gum and easily removed graffiti are eliminated by the hostler. Hard to remove graffiti, more serious vandalism, and other defects are noted and addressed later.

While the interior is being cleaned, the fueler checks all engine fluid levels and inspects the exterior for graffiti and mechanical defects while the bus is being fueled. ATF is checked every third Wednesday to prevent unnecessary overfilling. Exterior graffiti are also removed while the bus is being fueled. Fuel and fluid consumption are noted manually on a sheet of paper containing all bus numbers. An automated fuel and fluid dispensing system will be installed soon to replace the manual reporting system. Bus mileage is also recorded manually from the hubodometer.

After interior cleaning and mechanical servicing duties have been completed, the fueler pulls a cord suspended from above. The cord turns off the red lamp located just ahead of the bus and activates a green lamp, indicating to the hostler that the fuel nozzle has been removed and it is safe to drive forward. In the past, service

personnel would give a verbal command that was sometimes misinterpreted by a hostler in the adjacent service line. A similar green-red lamp signaling system controls bus movement over the brake inspection pit.

Exterior Washing

After the bus has been fueled and serviced, the hostler drives directly ahead to the wash bay consisting of an automated fourbrush washer. A sign directly in front of the wash bay instructs the hostler to "turn off AC (air conditioner) before entering." Speed through the washer is maintained by the hostler at approximately 2 mph. Once through the washer, the hostler returns the bus to its assigned storage spot and retrieves another bus in need of service. This process continues until all buses scheduled to be serviced in that particular shift have been completed.

Water generated from the automated brush washer is reclaimed. The water treatment system consists of collection pits, large settling tanks, and oil/water separators. Reclaimed water is used for the pre-rinse and wash cycles. Fresh city water is used for the final rinse.

Detailed Cleaning

Phoenix Transit performs a mid-level cleaning on each bus about once every two weeks, and a complete detailed cleaning annually. Both take place during the day shift when more time is available. During mid-level cleanings, buses are pulled to one side after receiving their daily servicing. Mid-level detailed cleanings are accomplished by three teams of two workers. Each team member has specific responsibilities, which are decided on in advance. The teams are responsible for specific functions including a complete cleaning of exterior body panels, windows, tires, and wheels. Interior responsibilities include removing gum from the floor, scrubbing and rinsing the floor, and a comprehensive cleaning of all interior surfaces including seats, driver's area, and windows. In addition to the mid-level cleaning, a more thorough detailed cleaning is administered to each bus annually.

Graffiti Protection and Removal

Phoenix, like most transit agencies, has a policy of quickly removing graffiti from its buses. Phoenix found that quick removal offers the greatest deterrent to more graffiti. Once vandals realize that their graffiti "art" will not reach a large audience, there is little incentive to put it there in the first place. To add a degree of permanency to their markings, however, vandals have turned to etching glass and other interior panels. Unlike paint and other surface-marking devices such as lipstick and ink pens, the etchings cannot be removed with solvents. To remove the etchings, the window or interior panel itself must be replaced at great expense.

Graffiti has increased to epidemic proportions at Phoenix Transit. Last year, only nine graffiti incidents were reported on average each month. During 1994 that number grew to more than 750, resulting in an additional \$7,000 in cleanup and repair costs needed on average each month.

To combat graffiti, Phoenix has hired off-duty police officers dressed as regular passengers to ride bus routes on which vandalism

reports have been particularly high. To date, 14 people have been arrested. As more arrests are made and the presence of police officers on buses becomes known, Phoenix is hoping that the number of graffiti incidents will decline.

To supplement undercover police patrols, Phoenix has specified plexiglass shields that cover the inside passenger windows on its new order of buses. The plexiglass shields protect the actual window from damage and are less costly and easier to replace. Once damaged, the plexiglass panels simply slide out from their tracks and new ones are inserted.

Team Approach to Servicing and Cleaning

An innovative approach to service line and cleaning functions involves the team approach adopted by Phoenix Transit. Service line workers are given more responsibility in deciding how to approach and accomplish their work. By giving these workers greater responsibilities, their job outlook and overall performance have greatly improved.

Each weekday the entire service line staff meets with the supervisor to conduct informal discussions concerning a variety of topics. The meetings last about 15 minutes. Workers plan their schedules, decide on who will work together as teams, and address issues in an open forum. If someone has a problem with the quality of another worker's performance, the meeting provides an opportunity to address the issue in a relaxed environment. Instead of harboring animosity, issues are resolved quickly to prevent worker dissatisfaction.

The daily meetings have created an esprit de corps among service line and cleaning personnel at Phoenix Transit. During one meeting, the teams decided that workers responsible for washing wheels would rotate on a daily basis during the summer months instead of weekly due to the extreme heat generated by brakes and tires. In another meeting, one worker was asked by team members in a supportive way to help solve a particular problem concerning poor work habits. In the past, the poor workmanship was allowed to continue with an occasional sarcastic remark made by fellow workers. By addressing sensitive issues in an open and constructive forum, workers can resolve potential conflicts before they escalate into serious problems. Team members openly praise the team concept and their work environment.

SANTA MONICA MUNICIPAL BUS LINES

Overview

Santa Monica Bus Lines operates 139 buses from one facility with all daily servicing and cleaning functions performed during one evening shift. A small crew of mechanics is used to execute basic repairs noted during the service line inspections. An additional worker is employed during the early morning hours to remove graffiti that the evening crew did not have time for. A supervisor makes random bus inspections throughout the evening, which serves as a quality control measure to ensure that all service line/ cleaning work was done properly.

The California climate allows all buses to be parked outside in assigned parking spots. An undercarriage inspection pit and two service lanes are also located outdoors, sheltered by overhead steel canopies. The four-brush automated bus washer is located out-

doors as well. The flow of buses through the service/cleaning lines is done in a circular fashion to optimize traffic flow. Buses taken from their assigned parking spots are first driven to the undercarriage inspection pit (on Tuesdays only). They then turn left and enter one of two fuel/service lines, turn left again through the washer, and return directly ahead to the parking area. All buses are fitted with glass windows. Wheels are painted blue to match the color of the side panels, making it easier to keep them looking clean (as opposed to white paint).

The more innovative approaches to service line and cleaning functions at Santa Monica involve the use of radio frequency (RF) signaling to activate the fuel pumps and fluid dispensers, and a centralized vacuum system for interior cleaning. After thoroughly investigating all service line and cleaning functions, Santa Monica has settled on what it believes is the most efficient use of labor and equipment. This includes the contracting out of detailed cleaning, as well as scheduling some activities traditionally done on a daily basis to a less frequent basis.

Service Line and Cleaning Sequence

After completing revenue service, buses are parked in their assigned spaces. The service line and cleaning sequence at Santa Monica is as follows:

- Buses are retrieved from their assigned parking spots by hostlers. Each hostler is responsible for cleaning and servicing 28 to 32 buses per night. The average time per bus is typically 13 to 15 minutes.
- On Tuesday evenings, each bus receives a more thorough inspection. Hostlers begin the detailed inspection while the bus is parked in the storage area. They pay particular attention to the brakes and other mechanical systems while the bus is being driven to the inspection pit. Once over the inspection pit, a mechanic makes a thorough investigation of the bus undercarriage.
- On all other evenings, buses are taken directly to one of two service lines.
- On Mondays, Wednesdays, and Fridays, revenue is removed from the fareboxes and deposited into cash receivers located directly on the service island.
- After vaulting the farebox, the bus is moved ahead so the fueler can refuel the bus, check fluid levels, and make an inspection of the bus exterior. Meanwhile, the hostler removes newspapers, bottles and cans for recycling and uses a centralized vacuum system with a self-extracting flexible hose to vacuum the floor and seats.
- On Mondays, Wednesdays, and Fridays, buses are taken through the washer before being returned to the storage area.

Retrieval From Parking Area

Each bus is assigned its own parking space. Buses are returned to that space following revenue service and after being serviced. Hostlers begin to wash interior windows before driving to the service line. They continue to wash windows while the bus is awaiting its turn in the service line, or after being returned to its assigned parking space. On Tuesdays when detailed inspections are conducted, hostlers begin by closely examining all mechanical components while the bus remains in its assigned parking space. The

inspection includes the operation of all lamps (inside and outside), steering, brakes, damaged components, graffiti, vandalism, windows, doors and other areas. On all other days, the walk-around inspections are cursory and limited to the visual inspection of lights, windows, body damage, etc.

Undercarriage Inspection

On Tuesdays, an additional service line function is added to the routine. Buses are driven over an undercarriage inspection pit where a mechanic checks for fluid leaks, air system leaks, brake slack adjuster travel, condition of universal joints, excessive steering system travel, wheel seal leaks, and other mechanical conditions visible from under the bus. Mechanical defects are noted, while the hostler uses this time to inspect the interior and clean windows.

Revenue Removal

Free standing, steel-encased cash receivers are located directly on the fuel island. Fareboxes are vaulted on Mondays, Wednesdays, and Fridays only. To assist with the lifting and transfer of heavy cash boxes from the farebox to the receiver, Santa Monica has installed electrically operated overhead hoist mechanisms. The hoisting equipment is intended to help reduce back injuries caused by manual lifting of cash boxes that are especially heavy. An infrared probe downloads revenue, passenger and bus identification data from the farebox and also unlocks the access door to the cash box.

The management at Santa Monica decided against daily revenue removal because of the time involved. On Tuesdays and Thursdays when buses are not vaulted, revenue remains secured in the farebox. Theft has not been a problem. Closed circuit cameras are used on the service line to monitor the revenue transfer process. Steel vaults located inside the island cash receivers are removed and transported by forklift to a money counting room where the revenue is processed.

Service Line Duties and Interior Cleaning

After revenue has been vaulted (on Mondays, Wednesdays, and Fridays), the bus is pulled ahead by the hostler to the fueling station. Santa Monica has installed an automated vehicle identification control system to activate the fuel and fluid dispensing pumps, to monitor fuel and fluid consumption, and to provide an added measure of security to the dispensing operation (9). As the bus passes over an inductive loop embedded in the service line, the identification number of that bus is transmitted automatically via a low-frequency radio signal to a host computer. Once the bus has been identified, the system activates the fuel pump and fluid dispensing nozzles. By using the vehicle itself as the authorizing agent, fuel and fluid dispensing is more accurately controlled, monitored, and recorded. The vehicle identification tag requires no batteries or wires to install, and no periodic maintenance.

The automatic vehicle identification and fluid dispensing system have been installed at both the diesel and gasoline fuel pumps. Because the pumps are also shared by the Santa Monica Police Department, the accounting for fuel, oil, and water is greatly simplified. Additionally, unauthorized use is eliminated.

After the fuel nozzle has been removed from the pump, a red lamp on the service line ahead of the bus is activated. This serves as a visual signal to the hostler that fuel is being dispensed and it is not safe to move the bus ahead. Once the fuel nozzle is returned to the pump, the light changes to green signaling that it is safe to move the bus ahead.

While fuel is being dispensed, the fueler checks all critical fluid levels including engine oil, ATF, and coolant. Any fluids dispensed to a particular bus are recorded by the computer-controlled vehicle identification and fluid management system. This system also records the date and time. Santa Monica does not use hubometers or other onboard mileage tracking equipment to establish distance traveled. Instead, they use daily route miles traveled adjusted by the dispatcher whenever exceptions occur. Total accumulated mileage is maintained by computer and used to schedule maintenance and to calculate fuel and fluid consumption. According to their estimates, mileage accuracy is within two percent.

Central Vacuum Interior Cleaning

While the bus is being fueled, the hostler is responsible for cleaning the interior. To assist the process, towel washers and dryers similar to those used at car washes are located directly on the service island.

During the past several years, the maintenance manager at Santa Monica had become dissatisfied with the efficiency and safety of the cyclone cleaner. As a result, the transit agency decided to install a central vacuum system. The decision to purchase the system was made for several reasons. Noise levels generated by the cyclone were approaching maximum levels established by the Occupational Safety and Health Administration (OSHA). An excessive amount of dust was also settling inside the bus after the cyclone had been turned off, requiring an additional wipe down of all interior surfaces.

In addition, paper and other debris trapped in tight areas were difficult to remove with the cyclone cleaning. Often, cleaners had to reach in between the seat cushions and other areas where visibility is limited. Although they wear gloves, bio-hazard materials such as germ-soaked paper tissues and a rare hypodermic needle still present potentially dangerous conditions for the workers. Also, dust generated by the cyclone can cause some respiratory concern, especially given the constant daily exposure.

While many transit agencies are contemplating the use of a heavy-duty central vacuum to help resolve the issues described above, Santa Monica is among the first with one in daily operation. The central vacuum system consists of a vacuum generator, fine filter, electrically operated hose reel, and a 3-in. diameter reinforced flexible hose equipped with handle and remote reel feed switch (25). (See Chapter 4 for additional information on the Central Vacuum System).

Before operating the vacuum, the hostler walks through the bus to remove newspapers and bottles and deposits them in refuse containers on the fuel island for recycling. The hostler then takes the vacuum hose, which is coiled on a reel just opposite the front door of the bus. A wireless remote switch, similar to those used to operate automatic garage door openers, is fitted on the hose handle. The switch operates a motorized hose reel, which uncoils the flexible plastic hose and feeds it into the bus. The automatic feed makes it easier for the hostler to position the hose inside the bus.

The hostler starts at the back of the bus and works forward using

the flexible vacuum hose to clean the floors, seats, and driver's compartment. Vacuum pressure generated through the 3-in. inside diameter hose is strong enough to pick up coarse refuse such as cans, bottles, and papers. Once finished, the hostler leaves the full length of hose inside the bus and activates a recoil switch mounted on the side of the hose reel. The motorized reel automatically recoils the hose and removes it from the bus.

Short-Term Experience With Central Vacuum System

Overall, Santa Monica is pleased with its central vacuum system after only 6 months of operational experience. The system is compact and contained entirely on the service line. Santa Monica's maintenance manager is convinced that this type of interior vacuum system will eventually replace cyclone cleaners in the future. Short hose life remains as one of the two issues that need resolving. After about 8 weeks of use, the plastic hose becomes fatigued, cracked and must be replaced. The manufacturer is working to solve this problem with a search for hoses made from a stronger plastic material. The other problem area is the wireless remote switch that feeds the hose into the bus. The switch, which is mounted on the hose itself, is not strong enough to withstand constant use by cleaning personnel. The manufacturer has located a heavy-duty switch that is expected to solve this problem.

The time it takes to operate the central vacuum system is comparable to using the cyclone. Santa Monica reports that the average cleaning time using the central vacuum system is about 3 minutes. Except for recycled cans, bottles, and newspapers, workers do not have to touch any debris. Cleaners reportedly do a better job with the more difficult to clean areas such as wheelchair lifts, wheelchair restraint areas, driver's compartment and wheel wells. A planned modification to the central vacuum system will exhaust air above the steel canopy. Although the vacuum has a fine filter element to trap small particles, a small amount of dust is occasionally noticed in the air that exhausts from the vacuum. The overhead exhaust location is expected to eliminate this problem.

The automatic hose feed and retraction system, developed in close cooperation with Santa Monica, is working satisfactorily. Noise has been reduced from over 100 dBA for the cyclone cleaner

to about 70 dBA. Santa Monica also reports that hostlers use less sick time. With the central vacuum system, workers are not exposed to wind chill caused by the massive amounts of cold damp ocean air passing by them to the cyclone. Additionally, workers are not exposed to airborne dust and dirt and no longer need to wear protective dust masks.

Exterior Washing

After the bus has been fueled and the nozzle placed back on the pump, a green light mounted in front of the bus is activated indicating that it is safe to drive away. On Mondays, Wednesdays, and Fridays, buses are driven through the four-brush automated washer. During a water shortage in Southern California, Santa Monica reduced its bus washing frequency to conserve water. When the water shortage ended, the agency decided to continue the every-other-day washing schedule because the buses continued to appear clean.

The wash bay has a water softening system for the rinse water. The same system will also be used soon to soften water for the pre-rinse cycle, as well as for water used in the cooling system of each bus. Except for high-pressure, centri-spinner wheel washers (see Figure 6) and a water reclamation system added by Santa Monica, the automated four-brush washer is the standard type used in the transit industry.

Detailed Cleaning

Detailed cleaning is done by an outside service. The company is contracted to clean 10 buses per week at Santa Monica's facility. The detailed cleaning includes a complete scrubbing of the floors and all interior surfaces. All graffiti are removed, as is gum and other hard-to-remove substances. Santa Monica is pleased with the outside contracting of its detailed cleaning. Managers feel they have more control over the quality of the detailed cleaning work. The bus interiors look exceptionally clean when the contractor is finished. Cost per bus is \$167.40, and the contractor spends about 8 staff hours per bus.

CHAPTER SEVEN

CONCLUSIONS

Service line and cleaning functions are two important elements of a transit bus operation that have not experienced much in the way of productivity gains. Most gains have come in the areas of data collection, servicing, mechanical inspections, exterior cleaning, and water reclamation. Interior cleaning tasks, however, do not easily lend themselves to automation and continue to be very labor intensive. In fact, the cyclone cleaner introduced to transit over 30 years ago continues as the primary piece of mechanized interior cleaning equipment in use today. Displeased with the cyclone's performance and the lack of alternatives to choose from, many transit agencies have reverted to the age-old process of hand sweeping.

Exterior cleaning, servicing, and mechanical inspections have proven much more adaptable to automation and offer the greatest potential for productivity improvements. Systems that electronically store and download revenue and passenger data are already used extensively, with fluid management systems not far behind. Integrated systems that collect, store, and extrapolate data for several service line functions are slowly making their way into the transit bus industry. These advanced systems are capable of automatically identifying the bus as it enters the service line, obtaining accurate mileage information, activating fuel and other fluid dispensers, and extrapolating data to track bus performance and schedule maintenance activities.

Additional systems are being developed with the potential of significantly improving the accuracy and efficiency of service line functions. Integrated bus wiring systems operating on a standard communication protocol can monitor the mechanical performance of several bus components. By linking the self-diagnostic capabilities of several bus functions, a central source can be used to store data and communicate failures. Depending on the severity of the failure, the transfer of information could occur as the bus enters the service line or immediately while the bus continues to operate in revenue service.

Unlike other service line functions, productivity improvements made to interior cleaning have been slow and are expected to remain that way for some time. Growing dissatisfaction with the cyclone vacuum is causing some to investigate central vacuum systems with flexible hoses. In use on a very limited basis, central vacuum systems have the potential of improving the quality, safety, and productivity of interior cleaning. If proved successful, however, the widespread use of central vacuum systems is a long way off. Until additional equipment is developed, productivity improvements made to interior cleaning will be achieved primarily through the efficient allocation of labor, job training and supervision.

Several factors actually hamper efforts to improve service line and cleaning productivity. The harsh working environment makes it difficult to attract and keep qualified workers. Graffiti and vandalism continue to increase, especially in the larger cities where gang members use transit buses as moving billboards for their stylized insignias. Graffiti removal is extremely labor intensive and adds significantly to limited budgets. Because the transit bus market is relatively small, it does not tend to promote the development of new products designed to improve the productivity of service line and cleaning tasks.

Despite the many drawbacks, transit agencies are diligent in their efforts to service and clean buses on a daily basis. They realize that bus fleets represent a significant investment and protecting that investment is their primary objective. Transit agencies that encourage a team approach to service line and cleaning functions are to be commended for their efforts. By varying the job assignments and giving workers direct responsibility for their tasks, morale is greatly improved resulting in increased productivity and a better work environment.

Because service line and cleaning productivity have not improved significantly over the years, research directed in specific areas is needed. Too often, maintenance personnel ignore new approaches and solutions because information is lacking or inconclusive. As a result, they tend to continue with a particular approach even though it may not be effective. Additional research in the following areas may assist transit managers to identify productivity improvements to service line and cleaning functions:

- Develop a standard definition for a "clean bus" that the entire transit industry can adhere to.
- Evaluate the effectiveness of automated fuel delivery systems.
- Ensure that future bus designs will incorporate features that address service line and cleaning productivity.
- Show how enhanced data acquisition systems can be applied to assist service line functions.
- Identify alternative surface coating materials to make graffiti easier to remove.
- Identify additional products and procedures that enhance labor productivity.
- Identify specific procedures and equipment designed to improve the safety of work environments.
- Determine how alternative fuels impact the service line.
- Conduct an industrial process analysis of service line and cleaning functions.

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GLOSSARY

AC Transit	Alameda Contra-Costa Transit District	LACMTA	Los Angeles County Metropolitan Transportation Authority
ADA	Americans with Disabilities Act	LNG	Liquefied natural gas
ADB	Advanced Design Bus	LPG	Liquefied petroleum gas
APTA	American Public Transit Association	MARTA	Metropolitan Atlanta Rapid Transit Authority
ATA	American Trucking Association	Mph	Miles Per Hour
ATF	Automatic Transmission Fluid	MTA	Mass Transit Administration (Flint, Michigan)
ATTB	Advanced Technology Transit Bus	NJ Transit	New Jersey Transit
AVL	Automatic Vehicle Location	OCTA	Orange County Transportation Authority
CFCs	Chlorofluorocarbons	OSHA	Occupational Safety and Health Administration
CNG	Compressed Natural Gas	OEM	Original Equipment Manufacturer
DOT	Department of Transportation	PC	Personal Computer
CDL	Commercial Drivers License	PM	Preventive Maintenance
CDTA	Capital District Transportation Authority (Albany, NY)	PMI	Preventive Maintenance Inspection
ECM	Electronic Control Module	RF	Radio Frequency
FTA	Federal Transit Administration	rpm	Revolutions Per Minute
gpm	Gallons per minute	RTD	Regional Transportation District (Denver, CO)
HVAC	Heating, Ventilation and Air Conditioning (system)	SAE	Society of Automotive Engineers
ITS	Intelligent Transportation Systems (formerly IVHS)	SEPTA	Southeastern Pennsylvania Transportation Authority
IVHS	Intelligent Vehicle and Highway System	SORTA	Southwest Ohio Regional Transit Authority
k/hr	Kilometers per hour	TRB	Transportation Research Board
		TTC	Toronto Transit Commission

APPENDIX A

SUMMARY: *CLEANING TRANSIT BUSES: EQUIPMENT AND PROCEDURES (1)*

SUGGESTED CHANGES TO IMPROVE BUS CLEANING WITH BRUSH WASHERS

A summary of suggested equipment modifications and procedural changes to overcome problems associated with the use of brush washers and improve exterior cleaning is presented below.

Scratched Windows

Equipment Modifications

- Prewash arch can be added, ideally at 25 to 40 ft (8-12m), before wash bay; or two prewash arches, separated by 6 to 10 ft (2-3 m) can be used.
- Water should be free of solids and have a minimum flow of 150 to 200 gal (9-13 L/s) of water.
- Polypropylene or nylon filament brushes or Tampico brushes can be used.
- A soft roller wheel guide can be used to reduce brush pressure.
- A spray line at window area can be added to provide lubrication directly at brush/coach interface.
- Alternatively, a pressure washer can be used.

Procedural Changes

- Require slow but constant speed through washer [1 to 2 mph (0.6-1.2 km/h)].
- Use a solvent-based, dissolving type of detergent with prewash.
- Use a highly lubricating detergent with wash.
- Use warm water [90° to 110° F (30°-45° C)] with detergent.
- Adjust brushes so that only one set of brushes washes side of bus, and no more than 2 to 5 in. (50-125 mm) of filament overlaps the side.
- Ensure that pressure of brush does not exceed 1 to 2 psi (7-14 kPa).
- Use a rinse spray to clean grit from brushes.
- Use a high pressure/high volume final rinse with a minimum delivery of 150 to 200 gal/min (9-13 L/s).
- When soap is not used in washer, increase amount of water and adjust brushes to 20 psi (140 kPa).

Controlling Speed of Buses Through Washer

Equipment Modifications

- Traffic lights can be installed in wash system.
- An audible alarm can be set up in foreman's office to signal when buses are going through the system too quickly.
- Wands can be placed on overhead instead of at side to prevent tampering.

Procedural Changes

- Provide training for hostlers.
- Closely supervise hostler force.
- Establish a standard operating procedure to be used by employees.

Difficulty in Cleaning Rear of Bus

Equipment Modifications

- Wrap-around brushes or two overlapping brushes can be used.
- A special nozzle and soap activator triggered by left rear wheel wand can be added.
- Brush pressure of 25 psi (170 kPa) is recommended (greater pressure will cause brushes to wear out more quickly).

Procedural Changes

- Wash rear of bus by hand.
- Spray a mild degreaser on rear before bus enters wash rack.

Broken Equipment (e.g., Mirrors and Windshield Wipers)

Equipment Modification

- Softer brushes or tie-back, wrap-around brushes should be used.

Procedural Change

- Fold all mirrors into bus before washing.

Dirty Wheels

Equipment Modifications

- Wheel washers can be used; brushes should be replaced every 6 to 8 weeks and carriage length can be reduced.
- Wheels should be steam-cleaned during service cycle (requires steam jenny near service lane).
- Use of spray bar is recommended.

Procedural Changes

- Use Imron paint on wheels.
- Steam-clean wheels when tires are changed or bus painted.

Greasy Brushes

Procedural Change

- Install rubber grease shields over brushes.

Drainage

Equipment Modifications

- Floors can be grooved to direct runoff to catch basin.
- Roof blankets can be replaced with brushes.

Dull Paint Finish

Procedural Change

- Use Imron or polyurethane-based paint on exposed surfaces.
-

Electrical Problems

Equipment Modification

- Solid-state controls should be specified.

Bruised Rear Tires

Equipment Modification

- A stainless-steel plate can be installed at washer entry.

Striping on Rear of Bus

Equipment Modification

- Washer should be realigned, and pressure changed to prevent bouncing.

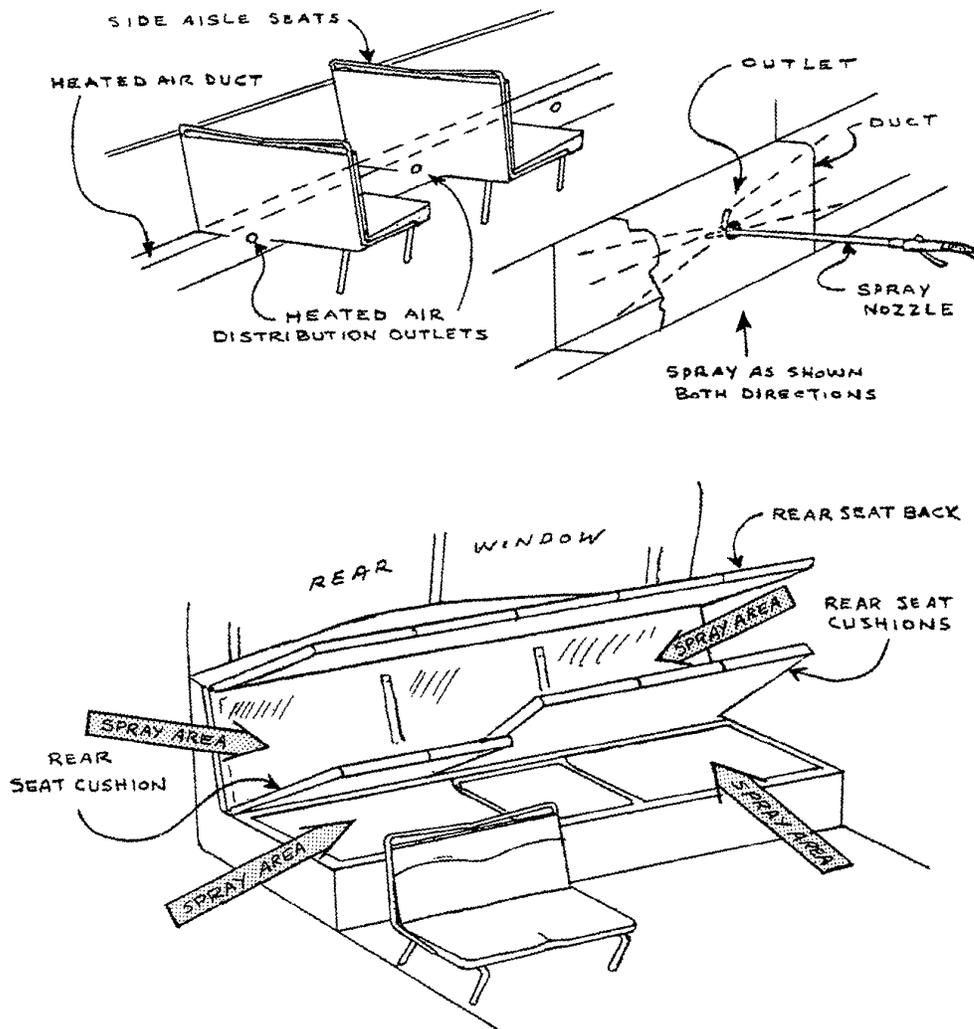


FIGURE 7 Partial illustrated instructions for fumigation procedure (Detroit Department of Transportation).

APPENDIX B

TRANSIT AGENCY QUESTIONNAIRE AND RESPONDENTS

TRANSIT COOPERATIVE RESEARCH PROGRAM (TCRP)
 SYNTHESIS TOPIC SE-1
 TRANSIT BUS SERVICE LINE AND CLEANING FUNCTIONS

1994 QUESTIONNAIRE

Providing the public with buses that are safe, clean and mechanically fit for service is essential to a successful transit operation. However, as buses become more complex, labor rates increase, and graffiti and vandalism become more prevalent, transit managers are faced with new challenges in providing efficient and cost effective service.

In 1982, a Synthesis of Transit Practice No. 1, "Cleaning Transit Buses: Equipment and Procedures" was published by the Transportation Research Board (TRB). This synthesis described several approaches to cleaning buses and served as a useful report. A synthesis of practice is now needed to update the material presented in this report. The revised synthesis will be expanded to include information on service line functions, an area that was not included in the original synthesis.

We are seeking your valued input to update and expand this important synthesis. In addition to documenting traditional approaches to service line and cleaning functions, the synthesis will also include innovative procedures and technologies used in public transit and other modes of transportation.

The questionnaire is detailed and provides additional space for narrative comment if you require it. Please take a moment and tell us about the approaches taken at your transit agency to facilitate service line and cleaning functions. We have a particular interest in procedures and technologies that are innovative and could prove beneficial to your peers.

John Schiavone may be calling you after you have returned the completed questionnaire for clarification or further information.

Please return the completed questionnaire by June 24, 1994 to:

John J. Schiavone
 32 State Street
 Guilford, CT 06437

Direct any inquiries to (or fax) John J. Schiavone at 203-453-2728, or telephone Donna L. Vlasak or Sally D. Liff at 800-424-9818 or 202-334-3242.

THANK YOU FOR YOUR COOPERATION AND ASSISTANCE!

TCRP PROJECT
 SE-1

TRANSIT BUS SERVICE LINE AND CLEANING FUNCTIONS

SURVEY

SERVICE LINE FUNCTIONS

- 1) Indicate the activities that are considered part of the service line functions at your transit agency.
 Fueling Fluid Check Exterior Washing
 Interior Cleaning Body & Light (Defect) Inspection
 Revenue Removal Data Acquisition Tire Check
 Others _____

- 2) Indicate which consumables are checked on a daily basis in the service lane? Indicate if the consumables are also replenished in the service lane. (Check all that apply)

CONSUMABLES CHECKED	REPLENISHED IN SERVICE LANE
<input type="checkbox"/> Oil	<input type="checkbox"/> YES <input type="checkbox"/> NO
<input type="checkbox"/> ATF	<input type="checkbox"/> YES <input type="checkbox"/> NO
<input type="checkbox"/> Coolant	<input type="checkbox"/> YES <input type="checkbox"/> NO
<input type="checkbox"/> Power Steering	<input type="checkbox"/> YES <input type="checkbox"/> NO
<input type="checkbox"/> Windshield Fluid	<input type="checkbox"/> YES <input type="checkbox"/> NO
<input type="checkbox"/> Tire Air	<input type="checkbox"/> YES <input type="checkbox"/> NO
<input type="checkbox"/> Other _____	<input type="checkbox"/> YES <input type="checkbox"/> NO

- 3) For the consumables replenished in the service lane, indicate the equipment or procedures used to:

- prevent leaks/spills _____

Is the diesel fuel dispenser equipped with a dry break nozzle?
 YES NO

- control overfill/underfill _____

- make the job easier for service personnel (ergonomics) _____

Last other procedures or equipment used at your agency that are innovative and efficient in checking and replenishing all consumables (including fuel) in the service lane (e.g., onboard oiling systems, sight glass inspections of coolant level, etc.)

- 4) How often are wheelchair lifts cycled? _____
 Where is this done? _____
 Who cycles the lifts? _____
- 5) Are there seasonal adjustments made to the service line functions (e.g., winter sand removal, summer insecticide treatment, etc.) YES NO
 If yes, indicate the type of seasonal adjustments made.

DATA COLLECTION/INFORMATION MANAGEMENT SYSTEMS

- 6) The collection of accurate data is essential to a successful preventive maintenance (PM) program. List the methods used to record the following:

Use the following symbols for each application: "N" for no entry of data, "M" for manual data entry, and "A" for automated data entry (i.e., hand-held computers, electronic probe etc.).

- Employee identification Bus identification
 Mileage reading Amount of fuel dispensed
 Amount of oil dispensed Other consumables dispensed
 Revenue data Tire press. Other data _____
 Defects noted on the service line

- 7) Does your transit agency upload data to the bus (e.g., patron displays, information regarding lost/stolen fare cards, etc.)? YES No
 If yes, indicated the data being uploaded. _____

- 8) What type of management information system (MIS) Is used to store and evaluate all of the data collected? _____

List the advantages of this system. _____

List the disadvantages. _____

How Is pertinent information extracted (exception reporting)?

- 9) Once the pertinent maintenance information has been extracted, how is data transferred to the maintenance department to schedule repairs and correct problems?

- 10) List other innovative equipment or procedures used to improve the collection and dissemination of vehicle maintenance data (e.g., onboard/online condition monitoring equipment, fluid management systems, tire pressure monitors etc.)

EXTERIOR CLEANING

- 11) How often are buses washed? Summer _____ Winter _____
- 12) Indicate the type(s) of bus washers used at your agency.
 Drive-Thru Brush Washer No. of Brushes _____ Manf. Gantry Brush Washer _____
 No. of Brushes _____ Manf.
 Drive-Thru Pressure (Brushless) Washer _____ Manf.
 Gantry Pressure Washer _____ Manf.
 Combination Brush/Pressure Washer _____ Manf.
 Hand Pressure Washer _____ Manf.
 Other _____ Manf.

- 13) Indicate the type of detergent used in the washer.
 Brand _____ Concentration _____ PH Level
- 14) Is the waste water collected and recycled? YES NO
 Describe the major problems encountered with the recycling system

- 15) How is bus speed controlled through the washer?
 Hostlers Automatically Speed (mph)

- 16) How do you prevent windows and lenses from scratching?

- 17) How are "difficult areas" cleaned (e.g., wheels, roofs, back ends)?

INTERIOR CLEANING

- 18) How often are bus interiors cleaned? _____
 Are waste baskets used on the buses? YES NO
- 19) What types of interior cleaning systems are used? Cyclone Flexible Hose Vacuum
 Hand Sweep
 Portable Vacuum Others _____

- 20) How often are bus floors washed? _____

- 21) What methods are used to wash bus floors?
 Water Pressure Mop Portable Wet Vacuum
 Other _____

- 22) How is water drained from bus interiors?

- 23) How are bus interiors dried?
 Naturally Bus Heating System Outside Heaters

24) How Is chewing gum removed from bus interiors/floors?

25) How often Is graffiti removed? _____
What types of graffiti are encountered? _____

26) Which chemicals/solvents work best to remove graffiti from: Plastic trim _____
Windows _____
Upholstery _____ Metal trim _____
Vinyl/Fabric _____ Other _____

27) List special materials, fabrics or coatings used to protect against graffiti and to facilitate Its removal. Include where these materials are used (e.g., seat backs).

28) List the procedures or precautions taken at your transit agency to protect against vandalism.

DETAILED CLEANING

29) How often are the following areas cleaned:
_____ Undercarriage _____ Method
_____ Driver's Area _____ Method
_____ Engine _____ Method
_____ Upholstery _____ Method
_____ Int. Windows _____ Method
_____ Destination Signs _____ Method
_____ Wheelchair Lift/Restraints _____ Method

30) List the innovative procedures or equipment used to facilitate detailed cleaning operations.

REVENUE COLLECTION

31) List the procedures and equipment used to:
extract revenue _____
collect revenue data _____
insure revenue security _____

BUS DESIGN AND FACILITY DESIGN CONSIDERATIONS

32) List the bus design features adopted at your transit agency to improve:

Service Line Functions _____

Data Collection/Management _____

Exterior Cleaning _____

Interior Cleaning _____

Others _____

33) List the facility design features adopted at your transit agency to improve:

Service Line Functions _____

Data Collection/Management _____

Exterior Cleaning _____

Interior Cleaning _____

Others _____

LABOR AND COSTS

34) How much time and number of employees are required to fuel the bus, check and replenish consumables, extract fares, and perform the safety/mechanical Inspections?
___ time In minutes ___ number of employees

35) Indicate the time In minutes required for each function:
___ Fueling ___ Check & Replenish Consumables ___ Cycle Lift ___ Defect/Safety Inspection ___
Extract Fares

36) How much time and number of employees are required to clean interiors?
___ time in minutes ___ number of employees

37) How much time and number of employees are required to wash each bus?
___ minutes ___ number of employees

38) What is the average hourly pay for the following:
\$ ___ Hostlers \$ ___ Fuelers/Service Line \$ ___ Cleaners

JOB STANDARDS

39) Indicate if your agency has written job standards and instructions for the following:

- service line functions interior cleaning
- exterior cleaning detailed cleaning
- extracting revenue other _____
- employee safety/protection

Would you be willing to share those standards and instructions? YES NO If so, please mail copies with this survey.

40) In addition to maintenance, which departments in your transit agency help set standards for vehicle cleaning?

41) List any areas related to the service line, data collection, cleaning functions, extracting fares, job standards and labor that you would like to learn more about through the synthesis.

Name: _____ Title: _____
 Transit Agency: _____
 Telephone: _____

Please return the completed questionnaire by June 24, 1994 to:

John J. Schiavone
 32 State Street
 Guilford, CT 06437
 (203) 453-2728 (FAX & Phone)

THANK YOU VERY MUCH FOR YOUR PARTICIPATION

ATTACHMENT TO APPENDIX B**Survey Respondents***Arizona*

Phoenix Transit System
Phoenix, AZ

California

AC Transit
Oakland, CA

Central Contra-Costa Transit Authority
Concord, CA

Long Beach Transit
Long Beach, CA

Los Angeles County Metropolitan Transportation Authority
Los Angeles, CA

Montebello Bus Lines
Montebello, CA

North San Diego County Transit District
Oceanside, CA

Orange County Transportation Authority
Orange, CA

Riverside Transit Agency
Riverside, CA

Sacramento Regional Transit District
Sacramento, CA

San Diego Transit
San Diego, CA

San Mateo County Transit District
San Carlos, CA

Santa Monica Municipal Bus Lines
Santa Monica, CA

Colorado

Regional Transportation District
Denver, CO

Delaware

Delaware Administration for Regional Transit
Wilmington, DE

District of Columbia

Washington Metropolitan Area Transit Authority
Washington, DC

Florida

Broward County Division of Mass Transit
Pompano Beach, FL

Metro-Dade Transit Agency
Miami, FL

Georgia

Metropolitan Atlanta Rapid Transit Authority
Atlanta, GA

Hawaii

Oahu Transit Service, Inc.
Honolulu, HI

Illinois

Chicago Transit Authority
Chicago, IL

Kentucky

Transit Authority of Northern Kentucky
Fort Wright, KY

Maryland

Mass Transit Administration of Maryland
Baltimore, MD

Montgomery County Transit Services
Rockville, MD

Michigan

Ann Arbor Transportation Authority
Ann Arbor, MI

Missouri

Bi-State Development Agency
St. Louis, MO

Kansas City Area Transportation Authority
Kansas City, MO

New Jersey

New Jersey Transit Corporation
Newark, NY

New York

Capital District Transportation Authority
Albany, NY

Liberty Lines
Yonkers, NY

Niagara Frontier Transportation Authority
Buffalo, NY

North Carolina

Charlotte Transit System
Charlotte, NC

Ohio

Central Ohio Transit Authority
Columbus, OH

METRO Regional Transit Authority
Akron, OH

LAKETRAN
Grand River, OH

Miami Valley Regional Transit Authority
Dayton, OH

Southwest Ohio Regional Transit Authority
Cincinnati, OH

Oklahoma

Central Oklahoma Transportation and Parking Authority
Oklahoma City, OK

Oregon

Tri-County Metropolitan Transportation District of Oregon
Portland, OR

Pennsylvania

Port Authority of Allegheny County
Pittsburgh, PA

Texas

Fort Worth Transportation Authority
Fort Worth, TX

Metropolitan Transit Authority of Harris County
Houston, TX

Utah

Utah Transit Authority
Salt Lake City, UT

Virginia

Greater Richmond Transit Company
Richmond, VA

Tidewater Regional Transit
Norfolk, VA

Washington

Pierce Transit
Tacoma, WA

Wisconsin

Madison Metro Transit System
Madison, WI

Milwaukee County Transit System
Milwaukee, WI

Canada

Calgary Transit
Calgary, Alberta

Edmonton Transit
Edmonton, Alberta

Toronto Transit Commission
Toronto, Ontario

Winnipeg Transit
Winnipeg, Manitoba

APPENDIX C

SAMPLE DEFECT CARD

LONG BEACH TRANSIT
DAILY BUS INSPECTION

Bus No _____ Date _____

Federal Regulations and State law state that no motor vehicle carrying passengers for hire shall be driven unless the driver has determined that the following parts and accessories are in good working order. Each driver is required to complete and sign this report daily.

Fill In Air Pressure Readings

Maximum Air Pressure _____ Static Pressure Loss _____

Air Governor cut-in _____ Low Air Warning _____

Applied Pressure Loss _____

Indicate with an (X) Defective Items ONLY

- | | |
|----------------------------|----------------------------|
| _____ Parking Brake | _____ Destination Signs |
| _____ Air System (Brakes) | _____ Emergency Reflectors |
| _____ Lights & Reflectors | _____ Windshield Wipers |
| _____ Tires | _____ Mirrors |
| _____ Horn | _____ Door Interlock |
| _____ Wheelchair Equipment | |

DEFECTS

Indicate with an (X) Defective Items ONLY - Explain below

BRAKES

- _____ Air Leaks
- _____ Soft
- _____ Pull to L/R
- _____ Dragging
- _____ Other (Explain Below)

TIRES/WHEELS

- Circle: LF RF RRI RRO LRI LRO
- _____ Flat
 - _____ Cut
 - _____ Smooth/Cord
 - _____ Loose Missing Lug
 - _____ Other (Explain Below)

ENTRANCE/EXIT DOORS

- _____ Slow
- _____ Inoperative
- _____ Leaks Air
- _____ Other (Explain Below)

BODY DAMAGE

- _____ Explain On Back

INTERIOR CONDITION

- _____ Dirty Floors
- _____ Dirty/Cut Seats
- _____ Dirty Windows
- _____ Other (Explain Below)

RADIO

- _____ Explain Below

A/C & HEATING

- _____ Off
- _____ Too Cold/Hot
- _____ Defroster Defect
- _____ Ventilation (Blowers)
- _____ Other (Explain Below)

DESTINATION SIGNS

- _____ Scrambled or Blank
- _____ Sticky Dots
- _____ Loose Access Door
- _____ Other (Explain Below)

COACH OPERATOR COMMENTS

Defects Noted _____ AM _____
Time _____ PM (1st Driver) ID No _____

Defects Noted _____ AM _____
Time _____ PM (2nd Driver) ID No _____

Defects Noted _____ AM _____
Time _____ PM (3rd Driver) ID No _____

LONG BEACH TRANSIT
MAINTENANCE DEPARTMENT
WORK ORDER

(For Farebox defects use Farebox Work Order)

Coach * _____ Date _____ W/O * _____ Mechanic _____

REPAIRS NEEDED _____

REPAIRS MADE _____

COMPONENTS CHANGED _____

Hub Reading _____

Time In _____

Mechanic's Signature _____ Time Out _____

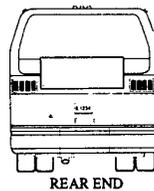
Total Time _____

Badge No. _____

Supervisor's Signature _____ Date _____

Job Completed Yes No

BODY DAMAGE COMMENTS
(Mark Damage to Bus Body)



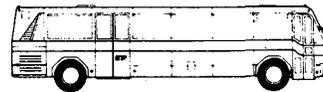
REAR END



FRONT END



LEFT SIDE



RIGHT SIDE

THE TRANSPORTATION RESEARCH BOARD is a unit of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. It evolved in 1974 from the Highway Research Board, which was established in 1920. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 270 committees, task forces, and panels composed of more than 3,300 administrators, engineers, social scientists, attorneys, educators, and others concerned with transportation; they serve without compensation. The program is supported by state transportation and highway departments, the modal administrations of the U.S. Department of Transportation, the Association of American Railroads, the National Highway Traffic Safety Administration, and other organizations and individuals interested in the development of transportation.

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce Alberts is president of the National Academy of Sciences.

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The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce Alberts and Dr. Robert M. White are chairman and vice chairman, respectively, of the National Research Council.