U.S. Department
of Transportation
**Federal Railroad
Administration**

Railroad Passenger Car Waste Retention Systems

A Report to Congress

**Office of Research
and Development**

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Preface

The Fiscal Year 1989 House Appropriations Committee (H.R. 3015) directed the Federal Railroad Administration (FRA) to undertake an analysis of suitable toilet and waste retention technologies for use on future passenger cars. Specifically, the Conference Report stated:

> "Of the funds made available to the Federal Railroad Administration under the head "Railroad Research and Development," $500,000 shall be available to identify suitable toilet and waste retention technologies that do not discharge onto tracks to be included as part of future year passenger car acquisitions. The Federal Railroad Administration shall report its findings to the appropriate committees within nine months after passage of this Act."

This report addresses the conclusions of the study to identify suitable toilet and waste retention technologies.

This report is divided into the following sections:

- Introduction and Background
- Review and Analysis of Waste Retention Systems
- Identification and Description of Waste Retention Technology
- Existing Practices and Experience
- Evaluation of Waste Retention Systems
- Capital, Maintenance, and Operating Costs
- Waste Disposal, Health, and Environmental Issues
- Waste Retention System Evaluation Programs
- Conclusions

Executive Summary

Amtrak presently is permitted to dump untreated waste from passenger train toilets and washing facilities directly onto the track. Older cars (predating Amtrak's formation in 1970) have no capability to retain waste. Recently constructed cars are fitted with either full-retention, or short-term retention systems which dump waste on the track at speeds over 25 mph.

This practice is being questioned by several state and local governments, and legislation has been introduced in Congress that would require Amtrak to fit full-waste-retention systems to all cars. As part of this process, Congress has requested that a study be made to identify and evaluate waste disposal technologies suitable for application in future Amtrak passenger cars. This report summarizes the results of the study.

The study includes the following:

- A review of existing waste retention practices on rail services in North America, Europe and Japan. The purpose is to determine what technologies are available, what systems are in use, and the nature and extent of service experience with them.

- A full description and evaluation of waste retention technologies currently offered in the United States by the supply industry. This evaluation covers various aspects of the performance and reliability of the systems, as well as capital and operating cost estimates for different types of cars.

- A review of waste disposal issues, including acceptability of the chemical or highly concentrated waste produced by transportation waste retention systems to waste treatment facilities, and associated costs.

- A review of the requirements for a test and evaluation program to confirm that retention systems fully meet Amtrak performance requirements for 72-hour retention capability.

The principal findings of this study are as follows:

- There are a number of railroad toilet waste retention systems developed by the supply industry which can potentially meet the performance requirements for Amtrak's coach and sleeping cars. However, some of these systems are only at the prototype stage of development and none have had sufficient service experience in an environment similar to Amtrak, where a 72-hour retention capability is required.

- It is reasonable to include a toilet system with retention capability on all future passenger cars.

- Amtrak's past experience with retention toilet systems on existing passenger coaches has not been good. The retention and retention-dump systems have been fitted to all cars purchased since Amtrak's formation in 1970. Some of these systems have been unreliable and Amtrak has been forced to adopt costly preventive maintenance procedures to keep them working satisfactorily. Passenger surveys have shown that good restroom facilities are of high importance to passengers. A high level of passenger dissatisfaction exists with the condition of restrooms, as seen by the number of customer complaints.

- A carefully structured evaluation program for waste retention systems is essential if Amtrak is to avoid the kinds of reliability and performance problems that have plagued toilet systems in the past. This program should include:

  - Establishment of system performance criteria
  - "Desk" evaluation of system performance
  - Bench tests of critical components or complete systems, especially "abuse" tests
  - Service evaluation of systems that have "passed" desk evaluations and bench tests. These should include surveys of passenger response.

- The bench test should include an abuse test. Passenger abuse is a major cause of toilet malfunction, and vulnerability to damage from this cause should be an important evaluation criterion.

- Life cycle costs should be emphasized in evaluating the economics of alternative systems. Such evaluations should consider capital outlays for the toilets, installation of the toilets and other support facilities, as well as continuing operating and maintenance expenses.

- There are no systems or technologies on the market or in prototype form that provide for the retention of "grey" water (from washing or dining car activities). If Amtrak were required to fit such systems, it would have to start from scratch. Given that the technically more demanding problem of toilet waste retention has largely been solved, grey water retention systems are technically feasible. However, they will add complexity; therefore, capital and operating costs will increase. Waste disposal costs, in particular, will increase because disposal charges by waste treatment facilities are based on volume.

- There appear to be no significant environmental or engineering problems associated with toilet waste pumpout and disposal. Both chemically treated waste from recirculating toilets and concentrated waste from holding tanks are acceptable to local waste treatment plants.

Background

Since the earliest days of long distance rail passenger service, passenger cars have been provided with on-train toilets and washing facilities. Up until about 1970, toilets were simple water-flush units that discharged waste directly on the track. Use in stations and at a few environmentally sensitive locations was prohibited.

In the early 1970s, there was heightened concern that the dumping of waste from railroad equipment might represent a public health hazard. This led to legislation requiring railroad locomotives, cabooses and passenger cars to be fitted with systems to prevent discharge of untreated waste onto the track. New equipment constructed after March 31, 1971 had to comply with this regulation, and existing vehicles had to be retrofitted with such equipment by December 31, 1974.

As a result, the Amfleet I cars ordered by Amtrak for delivery in 1975 and 1976 were fitted with aircraft-style recirculating retention toilets. These cars are used on short-haul corridor-type services. Similar action was taken by commuter rail service operators such as the Long Island Railroad.

The regulation requiring retrofitting of waste retention systems to existing intercity cars was never implemented, primarily because there was no equipment available on the market that could meet reliability and performance requirements at an acceptable cost.

The legislative situation changed in 1976 by enactment of the Railroad Revitalization and Regulatory Reform Act of 1976, P.L. 94-210, as amended by the Rail Transportation Improvement Act of 1976, P.L. 94-535. These acts exempted intercity rail transportation services from Section 361 of the Public Health Service Act (42 U.S.C. 264). Commuter and freight railroad operations were not exempted, and equipment acquired for such operations have been fitted with retention toilets or on-board waste treatment systems. Retrofits to existing equipment were also carried out.

When Congress exempted intercity rail transportation equipment from the prohibition on dumping untreated waste, it also directed that a study be made of this issue. In response to this request, the Department of Health, Education and Welfare conducted a comprehensive study of the public health, environmental, financial and other aspects of the Federal regulations of waste discharge from railroad vehicles. The resulting report concluded that:

- There was no identifiable public health risk arising from the discharge of untreated waste from intercity rail passenger cars.
- New passenger cars should be fitted with systems that retained waste at speeds below 25 mph. This would reduce dumping in or near urban areas where dumping causes the greatest potential risk to health, and considerable aesthetic offense. A manual override should be provided to prevent discharge at other designated locations (such as drinking water watersheds).
- Retrofitting older passenger cars could not be justified in view of the low health risks, high costs, and limited future life of these vehicles.

Following these recommendations, all new cars put into service by Amtrak since 1978 have included systems providing for the automatic retention of waste at speeds below 25 mph. No changes have been made to cars manufactured prior to 1970. This policy is apparently voluntary rather than required by Federal regulation. Intercity railroad cars are exempt from the requirements of Section 361 of the Public Health Service Act that prohibits the dumping of untreated waste.

The dumping of untreated waste, or indeed any form of waste, is being questioned by several state and local governments. There have been several instances of people being hit by waste dumped from passenger cars and this has focused attention on the issue. As a result, the States of Oregon and Florida have filed suit against Amtrak to prevent this practice, relying on state environmental protection laws. Furthermore, bills have been introduced into Congress to repeal the exemption enjoyed by Amtrak, and to require waste retention systems to be fitted to all passenger cars within three years.

In response to this and similar events, the Federal Railroad Administration has been directed by Congress to conduct a study to identify suitable toilet and waste retention technologies for future year passenger car acquisitions. The overall objective of this study is to identify, describe and evaluate suitable toilet and waste retention technologies that do not dump waste on the track.

To meet this objective, the following was accomplished:

1. Investigation and summary of existing waste disposal practices

   - on passenger cars currently operated by Amtrak
   - on other rail cars and locomotives operating in North America
   - on international rail systems outside North America

2. Identification, description and evaluation of available technologies that do not dump waste onto tracks. This includes:

   - Detailed descriptions of the identified systems
   - Analysis of capital, operating and maintenance costs, and of maintenance and servicing needs
   - Identification of fixed facilities required, and their location within the Amtrak network
   - Evaluation and identification of advantages and disadvantages of each system with respect to their installation into different kinds of new passenger cars (coaches, sleepers, etc.)
   - Discussion of environmental issues associated with waste handling and disposal, including the impact of the chemicals used in some systems, and the acceptability of the waste to local waste treatment systems.
   - Develop recommendations and a schedule for the installation of prototypes, a testing program and implementation of complete systems.

There are also some specific issues that are <u>not</u> addressed in the study. Most notably, these are:

- The study does not address the issue of whether or not the present practice of dumping waste on the tracks poses a public health hazard. The issue under investigation in the study is "given that waste retention systems are required, what technology is available to meet the requirement," not "what are the public health concerns associated with dumping waste on the tracks."

- The study also does not address any of the questions associated with <u>retrofitting</u> retention toilets to existing passenger cars in the Amtrak fleet. Obviously, much of the information in this report will be of value in evaluating the different technologies for a possible retrofit program. However, this is not the focus of this report. The technologies are only discussed in the context of installation in new cars yet to be built.

This report summarizes the work performed in the study and the principal findings.

Review and Analysis of Waste Retention Systems

This section briefly describes the work performed during the study. The basic approach consisted of a series of interviews followed by analyses. The interviews were conducted in person or by telephone with:

- All departments of Amtrak which could provide useful information on toilet and waste retention issues. These included representatives of departments concerned with new car engineering, car maintenance, passenger service (for information relating to passenger complaints, etc.), purchasing (for spare parts costs), and the Beech Grove shops (for information on toilet installation).

- Representatives of rail service operators elsewhere in North America, and in Europe and Japan. The interviewees were asked for some basic details about their operations, what retention toilet systems they have used, and their service experience with them. The following organizations were interviewed:

  North America:

  - Metro North Commuter Railroad
  - Long Island Railroad
  - Massachusetts Bay Transportation Authority
  - METRA (Chicago)
  - Via-Rail (Canada)
  - GO Transit (Toronto)

  International:

  - Japan Railways
  - British Rail
  - French National Railways (SNCF)
  - German Federal Railways (DB)
  - Danish State Railways (DSR)

- Each vendor of waste retention systems active in the North American market. Full details of all available "models" for rail passenger cars were obtained, including prototypes specifically developed to meet Amtrak's requirements.

The firms contacted were:

United States

- Monogram Sanitation
- Envirovac Inc. (EVAC)
- Chamberlain GARD
- Microphor Inc.

Canada

- Railtech Ltd.

Aqua Sans has also submitted information on a treatment system using an oil flush concept.

This field research was followed by analysis of three principal aspects:

- Retention System Performance Evaluation

  This includes defining a set of waste retention system performance criteria covering the following issues:

  - Passenger acceptability
  - Service reliability
  - Maintainability and ease of servicing
  - Environmental acceptability
  - Car configuration impacts
  - Ability to meet the 72-hour retention requirement

  Each proprietary system was rated against each criterion. Where it was possible to reach a factual conclusion based on the available evidence, this was done. In many cases, especially in areas relating to service reliability, insufficient information was available to support evaluation. This leads into requirements for an evaluation program, to resolve the unknowns.

- Cost Analysis

  The cost analysis provides estimates of capital, operating and maintenance costs for both in-car toilet systems and for equipment and operations at car servicing locations.

  The costs included in the analysis are:

  - Capital cost of waste retention systems, as provided by the manufacturers

- Capital cost of installing the systems in new cars during original manufacture. Note that costs of retrofitting waste retention systems to existing cars have not been addressed.
- Operating costs of waste retention systems, primarily for waste pumpout and disposal at car servicing locations
- Maintenance costs of in-car waste retention systems

Capital cost estimates for the different systems were obtained from the vendors and were based on the assumption of a reasonably sized order (for example, for 50 or 100 car-sets of equipment). All other costs were based on Amtrak's current experience of installing, operating and maintaining existing waste retention and disposal systems, with adjustments to reflect, as far as possible, differences between the systems currently operated by Amtrak and the full-retention systems offered by the supply industry.

Two spreadsheet computer models were developed: one calculates annual costs per car for different kinds of cars and trip lengths. The second calculates costs for typical routes, using the mix of cars and service frequencies appropriate to each route. Costs have also been aggregated to obtain total system costs, assuming that all services are operated with cars fitted with waste retention systems as original equipment. Since there is a wide range of uncertainty regarding costs, high, low and median estimates have been developed.

- Evaluation Program Recommendations

The evaluation of waste retention systems was based on past experience of similar systems on Amtrak and elsewhere (where available) and on a "desk" review of designs and schematics. This is necessarily incomplete, because adequate test and service experience data is lacking for many of the available systems. In response to this situation, a suggested evaluation program has been developed. This is designed to resolve the "unknowns" identified in the evaluation, and involves further "desk" analysis plus bench or laboratory tests and in-service testing. Soliciting passenger reactions to the systems is an important part of in-service trials.

Identification and Description of Waste Retention Technology

A number of waste retention technologies have been developed for use in transportation equipment. These range from large multi-toilet systems for cruise ships; the various systems developed for aircraft (probably the most significant market segment for suppliers); rail car systems; and single-unit systems for buses, recreational vehicles and pleasure boats.

In all cases, the requirement is to control release of waste. Also, in all cases, the technology development has concentrated on toilet systems. It appears that no systems have been developed for grey water waste (from washing, food service activities, etc.). Therefore, the review of technology focused on toilet waste retention, since there was no grey water technology to review.

The review also focused on systems designed or adapted for use in rail cars. Since there are a significant number of such systems which would meet Amtrak's needs, other technologies were not examined. Incineration which is used in some marine systems was not given further consideration due to its high energy requirements and impracticability to rail application.

Three generic technologies represented in the toilet waste retention systems are offered by the supply industry:

- Gravity/Air Pressure systems
- Recirculating systems
- Vacuum systems

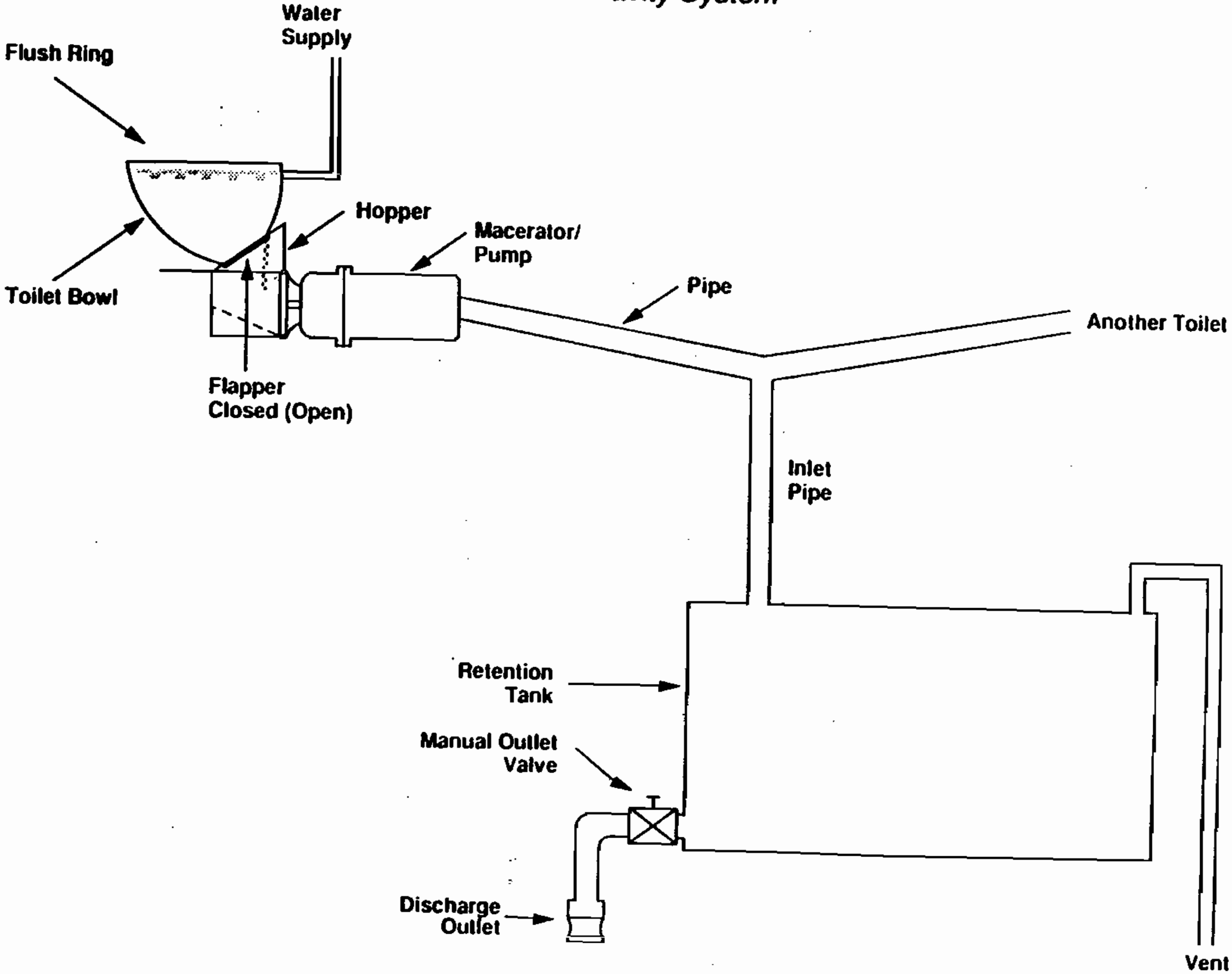
Each of these is now briefly described.

Gravity and air pressure systems are low fluid volume toilets which use gravity or compressed air to transport the waste from the toilet to the retention tank. Both systems use a macerator (grinder pump) to liquify the waste and facilitate easier transport.

A typical gravity system has a macerator just below the flapper (see Figure 1). After the water has entered the toilet bowl, the flapper opens and the waste drops into a hopper and is immediately ground by the macerator. It is pumped out of the macerator into sloped piping and drains to the retention tank.

Figure 1

Gravity System



The flush is initiated by an electro-mechanical button which sequences the introduction of water into the bowl, opens the flapper, runs the macerator for a predetermined length of time and closes the flapper. Since each toilet has its own macerator, all toilets can flush simultaneously without hampering the performance of the system. Water consumption per flush is typically in the range of 32 to 64 ounces.

Retention/dump versions of gravity/air pressure systems have proved reasonably satisfactory in Amtrak service. Gravity systems must have the holding tank below the level of the toilets and long pipe runs between toilet and tank should be avoided. This makes these systems difficult to apply to bilevel and sleeping cars.

Clogging generally only occurs when something jams in the flapper, or when the grinder is jammed. Macerators mounted horizontally with vertical slots on the bottom are especially prone to jamming.

Suppliers of gravity/air pressure systems in the United States are Microphor, Chamberlain GARD and Railtech. Figure 1 is typical of Microphor or GARD products. The Railtech products have a vertically-oriented macerator and holding tank directly below the bowl to facilitate clearing of obstructions.

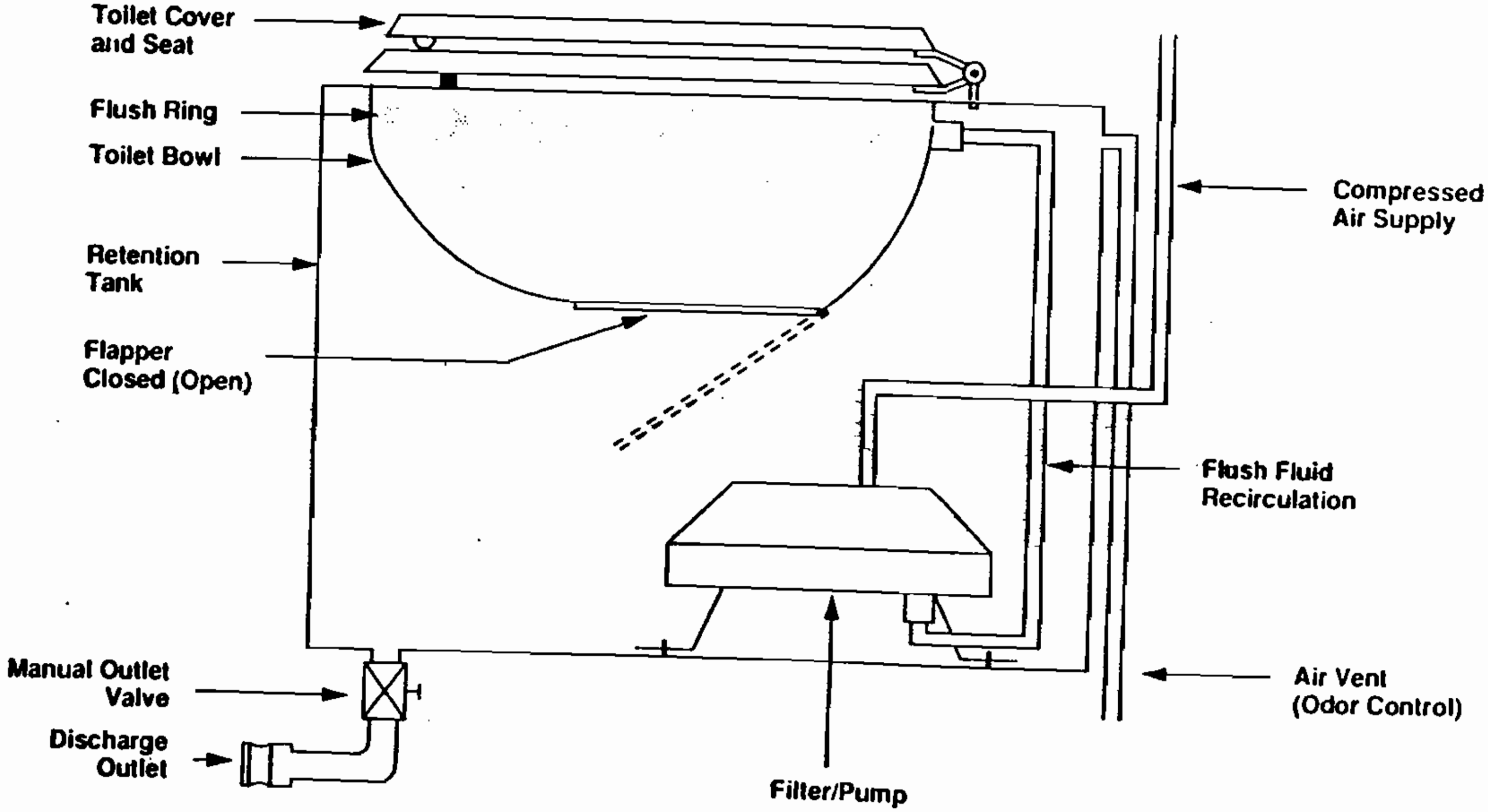
Recirculating toilets accomplish bowl clearing, bowl washing, and transport through the pipes (when necessary) by recirculating the fluid from the retention tanks. A typical system is illustrated in Figure 2.

Normally, the flush is initiated by an electro-mechanical button. Compressed air is injected into a filter/pump in the retention tank forcing the liquid waste through a filter and out through a tube into the flush ring. This fluid is used to clear the waste from the bowl and wash the bowl. Since many recirculating toilets have the retention tank directly below the bowl there is no need for pipe transport. The waste merely drops into the retention tank when the flapper opens.

Several types of filters and pumps are used in recirculating toilet systems. Newer models use a pin filter, a flat piece of plastic with a honeycomb arrangement of holes through it. A second piece of plastic is fitted against the honeycomb with pins sticking through each hole in the honeycomb. Each pin is of a diameter slightly smaller than the hole to allow

Figure 2

Self Contained Recirculating Toilet



only fluid to pass through. After the fluid has passed through the holes, the piece with the pins is withdrawn slightly to allow any buildup of solid waste to be removed by the surrounding fluid.

The pin filter is contained in a metal container approximately one foot in diameter and 4 inches high. The entire assembly is positioned in the retention tank. Inside the container there is also a diaphragm pump. When air is injected above the diaphragm, it expands to push waste against the filter and pump the liquid out the other side through a tube to the flush ring. When the air pressure is relieved, the diaphragm contracts to draw more waste into the container.

The advantage of a recirculating system is that less waste retention capacity is required. No flush fluid is added to the system with each successive flush, rather the fluid that is in the system (pre-charge and waste fluids) is recirculated. When the toilet is used, the only addition to the retention tank is the waste material itself. This also means that multiple flushes per toilet use do not cause capacity problems. Usually a pre-charge of one to two gallons of liquid is put in the retention tank. This fluid includes disinfectant, deodorizer and coloring (usually blue).

The disadvantages of recirculating toilets are:

- There are moving parts (i.e., filter pumps) in the waste material, making maintenance difficult.
- The odor suppression by the deodorizer in the pre-charge becomes less effective the longer the waste is kept in the tank and recirculated.
- When the retention tank is located below the toilet bowl and the only separation is the flapper, it is possible for the waste to spill out if a full tank is jolted.

Monogram Sanitation is the principal supplier of recirculating toilets. As well as the integral tank version illustrated in Figure 2, Monogram also makes systems with a "remote" holding tank. With purely gravity transport of the waste into the tank, and the need for recirculation, the "remote" holding tank must be situated below and near the toilet. As with gravity systems, this constraint makes the remote tank version unsuitable for bilevel cars with toilets on the lower level. The self-contained version can physically be used anywhere.

Vacuum toilet systems have been used primarily on aircraft. In these installations the vacuum is created by the differential pressure inside and outside the aircraft. Below 16,000 feet a vane pump or blower is used to create the vacuum (see Figure 3).

Flush initiation is accomplished by pushing an electro-mechanical switch. At this time, if there is a sufficient vacuum level in the retention tank, water is discharged into the bowl to clear the waste into the piping. The vacuum is used as both the transport mechanism to move the waste material through the pipe as well as for bowl clearing. If there is insufficient vacuum pressure, there will be a slight delay before the fluid is introduced to the bowl while the vacuum is being generated.

In general, vacuum systems use dry bowls without a flapper. They can, however, use either a dry or a wet bowl.

Vacuums can be generated in a variety of ways:

- Blowers are fans which create a vacuum in the waste retention tank by removing air either at the time a flush is initiated, or by holding a constant vacuum in the tank. In the latter case the blower operates whenever the vacuum level in the tank drops below a predetermined level. This can happen after flushing one or more of the toilets, or as a result of an air leak in the piping system.

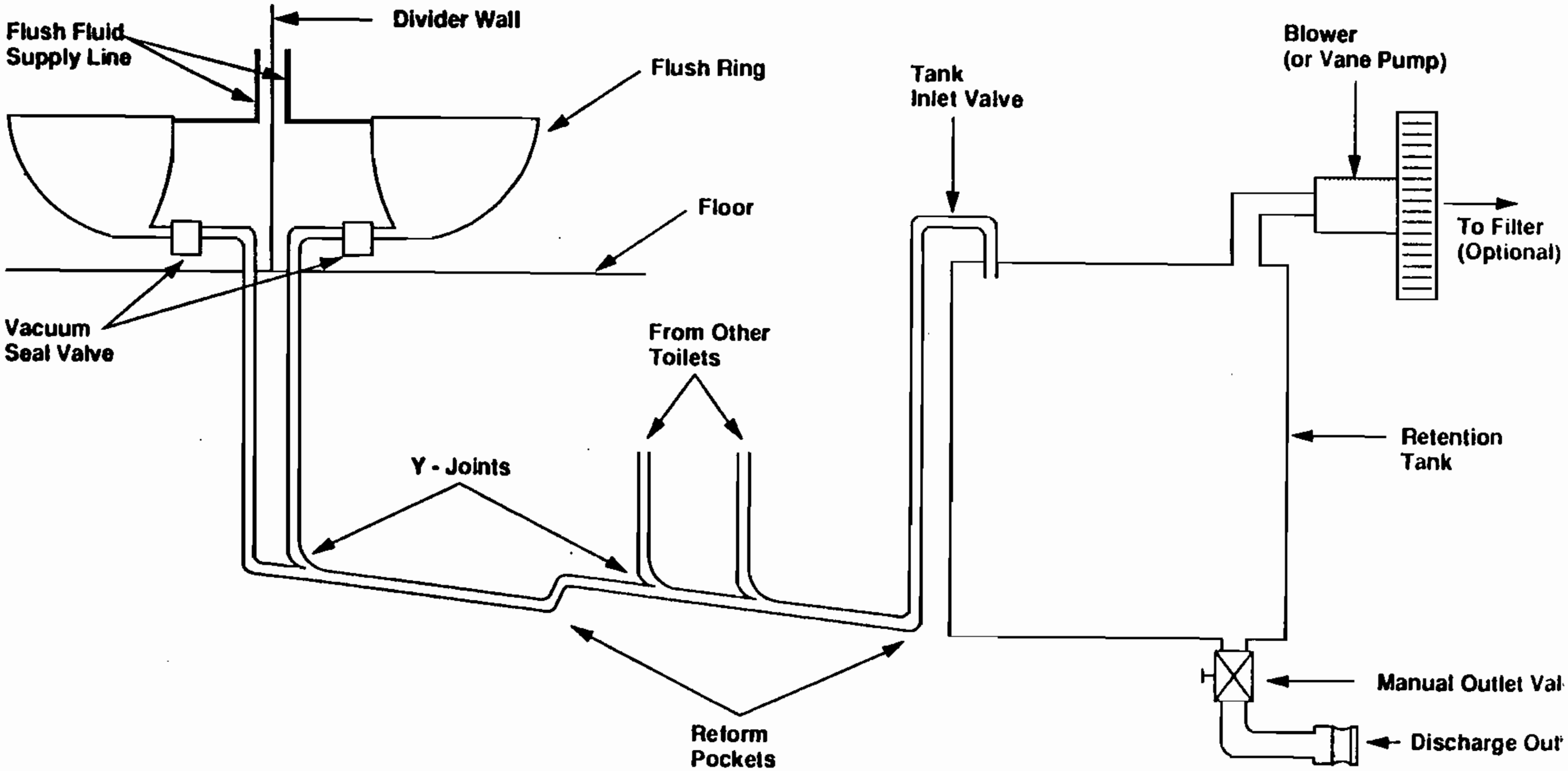
- Vane pumps can be used in the same way as blowers to generate a vacuum in the waste retention tank, but generally are not as efficient, reliable, or quiet. They will often be used in pairs where one blower would be used.

- Macerator pumps can also be used to generate a vacuum. By pumping the waste material currently in the holding tank through a venturi, low pressure is achieved by drawing waste through the piping into the tank. In essence, the waste is recirculated within the holding tank. This system would only begin to create the vacuum after a flush has been initiated.

The vacuum is used primarily as the means of transport from the toilet bowl to the retention tank. However, in one system, the vacuum is used both to clear the bowl and to draw air and water into the bowl to wash it.

Figure 3

Vacuum System



Properly functioning vacuum systems (no vacuum leaks) are not excessively prone to clogging due in part to the speed of the transport. Waste moves through the pipes at speeds up to 25 to 30 feet per second as compared to roughly 5 feet per second in a gravity system. This high velocity reduces the likelihood of clogging.

All the manufacturers offer one or more vacuum toilet systems.

The advantages of a vacuum system are that it confers considerable freedom in locating toilets and holding tanks in the car, and multiple toilets can be served by one system. It can be used in any kind of car. The disadvantages are that they are relatively complex and performance is sensitive to proper sizing and routing of pipework. Experience with early vacuum systems was not good. However, there has now been over a decade of engineering development and service experience with these systems, and it is to be hoped that performance and reliability problems have been overcome. They have also been generally adopted by commercial airplane manufacturers.

Existing Practice and Experience

This section summarizes existing practice and experience with passenger railcar waste retention systems, and other waste systems that embody technology similar to full retention systems. This will include the practice and experience of Amtrak, other North American operators of passenger cars, and Japanese and European operators.

Amtrak. Amtrak operates approximately 1,500 passenger cars of all types. About 440 of these are "Heritage" cars formerly owned by predecessor railroads and about 350 are equipped with traditional direct dump toilet systems. About 1,000 cars have been built for Amtrak since 1970. All of these are equipped with either full-retention toilets or systems that retain waste at speeds less than 25 mph but permit dumping at higher speeds. Apart from needing only small capacity holding tanks, and the presence of a speed-sensitive dump valve, these retention/dump systems are technically similar to full-retention systems.

The specific systems installed on Amtrak cars are:

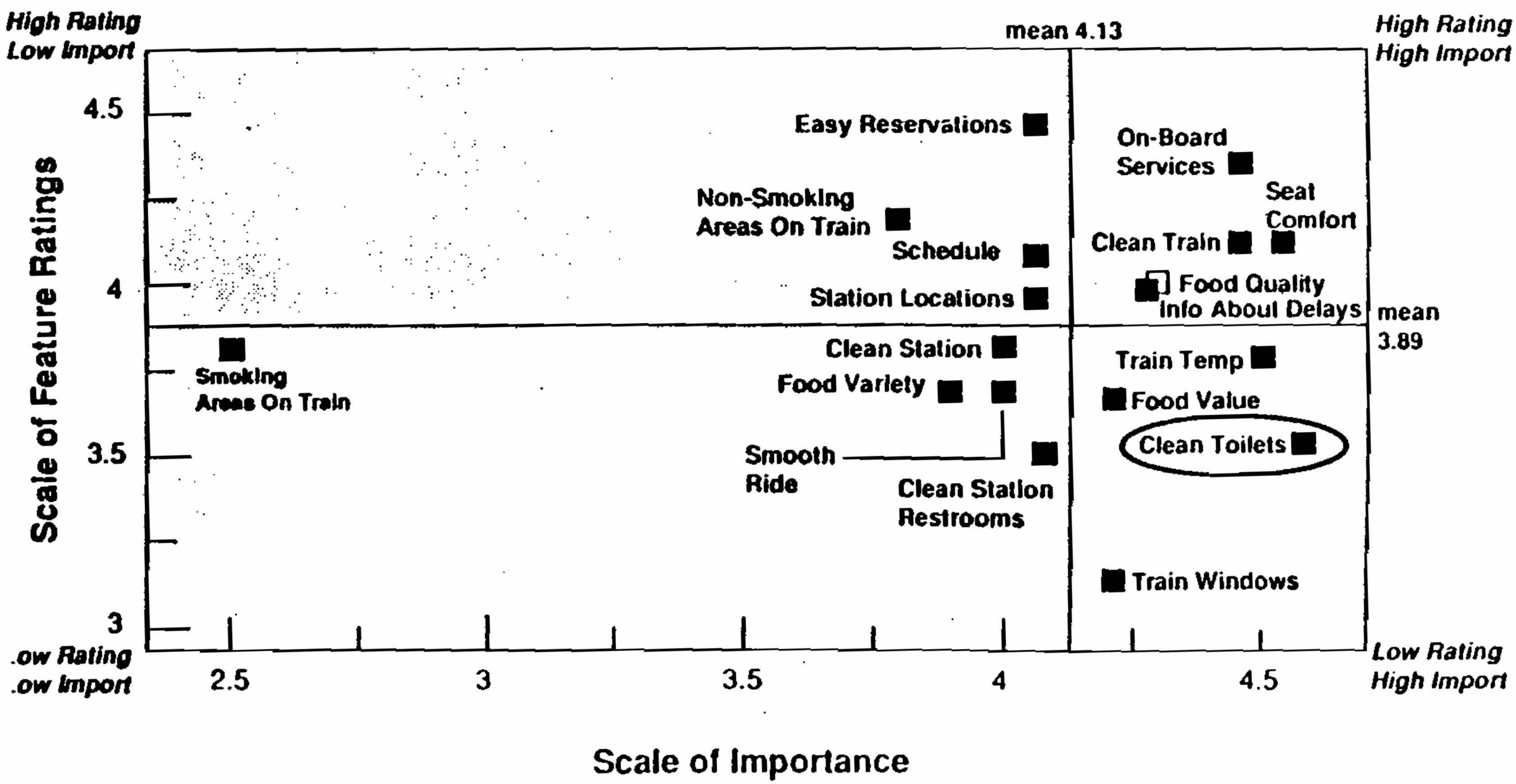
- The Monogram recirculating, full-retention toilet on the Amfleet I (483 cars)
- A Monogram vacuum retention/dump toilet on the Superliner cars (Approximately 240 cars with toilets)
- A Microphor gravity retention/dump toilet on the Amfleet II and Horizon cars (about 250 cars)

Service experience with these systems has not been good, especially the first two types for which substantial preventative maintenance programs are required to achieve adequate reliability. A series of detailed modifications have also been necessary. Amtrak is properly concerned that any new or modified full-retention toilet systems be highly reliable to avoid the maintenance costs and rail service quality problems associated with malfunctioning toilet systems.

It is worth noting that passengers rank clean and functioning toilet systems as one of the highest unmet needs associated with Amtrak service (Figure 4). Malfunctioning toilets are also a major source of passenger complaints. Quite apart from any need to comply with waste disposal regulations, the

Figure 4

Ratings and Importance of Features By Long Distance Passengers



design, installation and maintenance of toilets ought to receive serious attention in Amtrak's efforts to provide a good service to its customers.

Other North American Operators. Commuter rail operators in the United States are obliged by law to use toilet systems which do not discharge untreated waste on the track. Many authorities use full-retention systems in response to this requirement with generally fair results. The most common type of retention toilet used is the recirculating type similar to that installed on Amtrak's Amfleet I cars (Long Island Railroad and Metro North Commuter Railroad). Other operations with generally short trips (Massachusetts Bay Transportation Authority) have simply added a holding tank to the traditional direct dump systems. However, the service environment, with typically only four hours of intensive use daily and daily pump-out, is clearly much less demanding than for an intercity passenger car.

VIA Rail Canada, the Canadian long-distance rail passenger service operator, has adopted the retention/dump approach for new cars, using a Railtech gravity toilet system. In the VIA application, the waste is treated with disinfectant in the holding tank prior to dumping. There were some initial troubles with this system (aluminum car structure corrosion due to disinfectant leaks and jammed macerators) but these have now been resolved. The current tank capacity is enough for 99 flushes and the tank is dumped at speeds over 25 mph.

International. Full-retention toilets of the recirculating type have been fitted to very high-speed trains (Japan's "Shinkansen" and France's "Train a Grand Vitesse") over the past two decades. The reasons appear to be to seal the car for climate control and due to the concern that directly discharged waste would get spread all over the car at high speed, instead of just falling onto the track. More recently, public objections to direct dumping of waste have resulted in "no dumping" policies on some European rail systems. This is true in the United Kingdom (British Rail) (BR) and on the German and Danish national rail systems (DB and DSB). Service experience, however, is limited since these policies are of relatively recent initiation. There is no consistency of system choice. Both DB and DSB have standardized on vacuum systems, after extensive evaluation programs. BR is considering vacuum and gravity systems but has rejected recirculating systems because of odors and chemical waste disposal problems. On the other hand, France (SNCF) so far has exclusively used recirculating toilets.

Other than the aircraft-type recirculating toilets fitted to the TGV and Shinkansen, service experience has been limited, being confined to relatively few cars, or a relatively short time period. Also, journey times in Europe and Japan are relatively short, permitting daily pumpout. Probably the most important conclusions from the international survey are that the market for full-retention toilets is growing, leading to product development and interest among suppliers. This will clearly aid Amtrak in efforts to find suitable systems.

Evaluation of Waste Retention Systems

This section describes the results of a "desk" evaluation of the principal types of retention toilet systems currently available on the market.

The process started with an effort to define a set of performance criteria for the systems. These are listed in Figure 5 and cover the following groups of issues.

1. Passenger Acceptability.

This group covers any issues associated with the interaction between the user (the passenger) and the toilet system. These include general acceptability, appearance and ease of use, safety and health risks to the user (even if the user misuses the system), freedom from objectional odors, and ease of keeping the equipment clean.

Typical passenger acceptability problems include:

- Any system lacking a good seal between toilet and holding tank is likely to suffer from unpleasant odors.
- Any vacuum system lacking a deodorizing feature on the vacuum pump exhaust will create unpleasant odors outside the car.
- A system where a macerator is easily accessible below the bowl is a potential hazard, for example, when someone tries to retrieve a valuable object which has been dropped into the bowl.
- An improperly designed vacuum system can cause injury if flushed when the user is still seated on the equipment.

2. Service Reliability

This group covers reliability as quantified by the frequency and types of failures, and the ease with which such failures can be corrected. Situations where the toilet fails to function because of some failure of other car systems are included. A good example of the latter occurs in the retention/dump systems currently fitted to Amtrak cars. The train speed signal on which the dump valve depends is derived from wheel/axle mounted odometers which are part of the wheel

Figure 5 List of Waste Retention System Evaluation Criteria

Passenger acceptability
- Ergonomics
- Public Health Risk
- Personal Injury Risk
- Odor Exposure—On Train
- Odor Exposure—Wayside
- Cleanliness of Toilet
- Overall Aesthetics

Service Reliability
- Number of Failure Categories
- Acceptable Mean Time Between Failures
- Failure Modes Benign
- Dependence on Other Train Systems

Maintainability
- Ease of Periodic Servicing
- Ability to Keep Clean
- Employee Health & Safety Risk
- Tolerance to Passenger Abuse

Environmental Acceptability
- Waste Retention (for 72 hours)
- Waste Disposal

Car Configuration Acceptability
- System Weight
- Volume Requirements for Waste Storage
- Energy Requirements

slide protection system. If these are not working (which is not unusual), the small holding tank quickly fills up and the toilet becomes unusable.

Generally, reliability is the hardest performance criterion to evaluate without a service test. System complexity is one indicator—other things being equal, simple systems will be more reliable than complex, but much depends on the detailed design of individual components and installations.

3. Maintainability.

This group of issues is concerned with the ease with which the system can be kept in good working order. The systems should be compatible with Amtrak's normal 3 or 4 month inspection and maintenance cycle. All maintenance intensive items should be reasonably accessible for inspection and change-out if necessary. Some of the existing installations on Amtrak are poor in this respect. For example, Amtrak has found it best to entirely remove the integral-tank recirculating toilets from the car at four month intervals to clean and maintain the working parts. This is costly.

Another important area of maintainability is tolerance of abuse, usually in the form of foreign objects shoved into the system. Abuse is a major cause of toilet malfunction. While it is not reasonable that a system should continue to function regardless of abuse, it is important that it be designed so that abuse will not cause severe mechanical damage, and that obstructions can be easily removed. It is also important that there is little risk of abuse rendering all toilets in a car inoperative (especially applicable to vacuum systems).

The results of the qualitative review of performance by generic toilet type and principal performance criteria is provided in the table, Figure 6. System types are rated against criteria as follows:

Good — satisfies performance criteria
Fair — partially satisfies performance criteria
Poor — significant shortcomings identified

Figure 6

Evaluation of Retention Toilet Performance (Principal Criteria)			
Performance Criterion	**Gravity/Pressure**	**Recirculating**	**Vacuum**
Passenger Acceptability • Health and safety • Odor control • General acceptability	 Good Good Good	 Fair Poor Fair	 ? Fair/Good Good
Service Reliability • Quantitative reliability • Ease of repair	 ? Fair/Good	 ? Poor	 ? Fair/Good
Maintainability • Ease of servicing • Tolerance of abuse	 Fair/Good ?/Fair	 Poor ?/Poor	 Fair/Good ?/Fair
Car Configuration Acceptability • Volume of holding tank • Compatibility with car types	 Moderate/High Fair, Not Bilevel Fair/Poor for sleeping car	 Low Fair/poor, Not bilevel (remote tank) Poor for sleeping car	 Low/Moderate Good. All types OK

? = Could not be evaluated. Test and service trials required to provide answers.

Some comments on Figure 6 are:

- General acceptability and odor control of recirculation toilets are less than satisfactory. The chemicals used are strong smelling in any case, and become distinctly unpleasant when the holding tank nears capacity.

- Safety of vacuum systems must be carefully evaluated because of the risk of injury when the flush is initiated while a person is seated on the toilet.

- Reliability can only be determined through a properly designed test program.

- Ease of servicing of recirculating toilets is poor, because all working parts are situated inside the holding tank.

- While system configuration and past history give some idea of abuse tolerance, a test program is highly desirable to properly understand performance under this important criterion.

- Some system types are incompatible with certain car types (or could only be made compatible with additional equipment).

  - Systems relying on gravity to move waste to a holding tank cannot be used on the lower level of a bilevel car (gravity/pressure, and remote tank recirculating systems).

  - Because of odors, recirculating systems will not be attractive for sleeping car rooms.

  - Gravity systems are poor for sleeping cars, because of the multiple toilets and difficulty of locating holding tanks and "plumbing."

- To benchmark the influence of system type on holding tank volume, the following total volume is estimated to give a fully-occupied 60-seat coach a 72-hour capacity, given typical usage.

Gravity/pressure	399 gals.
Recirculating	115 gals.
Vacuum	184 gals.

Note that these are typical figures derived from a representative proprietary system, and with assumptions about daily usage, and the propensity of users to flush more than once per visit. Actual numbers could vary considerably, particularly with the gravity/pressure systems with relatively high flush volumes.

Capital, Maintenance and Operating Costs

Costs are presented for a range of car types, train services and for three generic toilet systems (gravity, recirculating, vacuum).

While capital costs are fixed for a specific car type, operating costs are greatly affected by assumptions about the number of trips per year, toilet usage, maintenance effort required, etc. To deal with this uncertainty, high and low bounds for annual costs have been calculated, as well as a median "expected" cost.

Note that capital costs are for installations in new cars. Costs for retrofitting these systems to existing cars will be higher, and have not been addressed in this study.

Cost data came from three sources: the manufacturers, Amtrak, and consultant estimates. During the course of the study, team members conducted on-site interviews and tours with the five U.S.-based retention toilet system manufacturers, and several visits to Amtrak offices and facilities.

Costs were modeled for five representative toilet systems manufactured by four of the five companies. They are:

Microphor Gravity System
Monogram "Modified Vacuum" System
Monogram Self-Contained Recirculating System
Evac Ultimate System
Railtech WTS 8300 Gravity System

These particular systems were chosen because they represent the primary retention solution offered by each manufacturer. They also enable cost analysis for each generic type of retention toilet system (e.g., recirculating, vacuum, etc.). Two Monogram systems were modelled because they are sufficiently different from each other (vacuum versus recirculating) and because the Monogram vacuum system is quite different from the Evac vacuum system.

The Gard Mk II Vacuum System was not included in the analysis because we were unable to obtain sufficient cost data during the timeframe of the study.

The manufacturers supplied approximate capital costs and operating characteristics (i.e. flush fluids required per flush, tank capacity). However, since Amtrak has not issued a specification as yet, these numbers are by no means firm.

Amtrak supplied approximate maintenance times, frequency of overhauls, labor rates, route and consist data, toilet configuration by car type, and fleet data. Amtrak also supplied human waste volume statistics and an estimation of the number of uses per person per day.

The consultant estimated waste disposal costs, pump-out time requirements, and installation time requirements.

Rough **capital costs** associated with each toilet system were provided by the manufacturers. They provide an indication of the order of magnitude costs of a system. They are not necessarily the actual cost of a given system, as that would be dependent on Amtrak's specifications for a particular car and the quantity ordered.

Installation costs are calculated according to the time taken to install the toilets and associated holding tanks and plumbing. They were derived by multiplying the number of hours for installation by the number of toilets and collection systems per car and by Amtrak's $36/hour labor cost. The installation time requirement for each system is a consultant estimate based upon the relative complexity of the toilet systems.

Operating costs were divided into those which are trip- or use-dependent, and those which are not trip-dependent. Examples of the former are:

- Cleaning costs
- Waste disposal costs
- Labor costs for pumping out the tanks

Non-trip related operating costs are for routine maintenance and spare parts.

In each instance there was insufficient data for accurately projecting the operating costs. Since none of these systems is currently in service under these conditions, there is no historical data. Therefore, the consultant estimated the costs. It is hoped that the recommended testing program will provide much of the data necessary to project costs more accurately.

All labor costs associated with operating and maintaining the toilet systems were calculated at the standard Amtrak rate of $36/hour.

Long-term maintenance is calculated by multiplying the frequency of servicing by the number of hours needed to service a toilet by the number of toilets per car. The labor rate used is the standard Amtrak rate of $36/hour.

Based on current Amtrak experience, only recirculating toilets are removed from the car and cleaned prior to servicing. For this reason we assumed that on average it would take eight hours to service a recirculating toilet as compared to two hours on average for non-recirculating toilets. The frequency of servicing is currently three times per year.

Since none of these toilet systems has a history of use in this environment (full retention for 72 hours), we estimated three ranges of spare parts costs based on an annual percentage of original capital cost. The base case assumed that the spare parts cost per toilet system would average 3% of original capital cost. The best and worse case scenarios were calculated using 1% and 5% respectively.

The cost model calculates operating and capital costs for each toilet system type by car type and route. The costs are assumed to be for new cars of the same general type as existing cars. The costs are generated under each of the three scenarios (expected, high bound, low bound).

Operating costs are divided into trip related and non-trip related costs. Trip related costs are those which are truly variable costs. They include waste disposal cost based on gallons of waste produced (this is a function of the number of passengers per coach, the length of trip, and the flush fluid used with each flush), labor for pumping out the waste as well as connecting and disconnecting the hoses, and cleaning the toilets at the end of a trip or service day. The non-trip related costs include maintenance and spare parts cost.

Capital costs are calculated for each car type regardless of route. These costs include the fixed cost for the toilets and collection system and the labor cost for installing the toilets and collection systems on new coaches.

Total costs are generated on a per trip basis when the number of trips per day is not more than one, or on a per service-day basis when the number of trips per day exceeds one. This is done because pump-out and cleaning is assumed to be done once per trip or once per day, whichever is longer.

The number of possible service days per year is calculated for each car on each route. Since not all routes run every day, and because car availability is reduced by routine maintenance, the number of available service days is less than the number of possible service days. The inputs to the analysis model included:

- Toilet capital cost (each)
- Collection System capital cost (usually one per car)
- Installation hours per toilet
- Installation hours per collection system
- Amtrak labor rates
- Retention tank capacity
- Flush fluids used per flush
- Estimation of volume of waste generated by one person per day
- Estimation of toilet uses per person per day
- Amtrak route data (length in miles, duration, and consist)
- Car configuration (passenger density and number of toilets)
- Waste disposal costs per gallon
- Frequency of major servicing

The input values for the three scenarios (Expected, High and Low Bound) varied in the number of uses per person per day, the average number of flushes per use (it is expected that the ratio of flushes to uses will exceed 1:1), the frequency of major servicing, the car availability percentage, and the spare parts cost.

The routes and car types modelled were chosen to fairly represent Amtrak's current fleet as well as to accommodate any type of car specification which should be issued in the future.

The results for a small number of representative car types and service are given in the tables, Figures 7.1, 7.2 and 7.3, for a representative cost of each generic toilet system.

Operating costs were broadly similar for all types of systems. Because of relatively high flush volumes, operating costs of gravity toilets were dominated by waste pumpout and disposal costs. Maintenance dominated operating costs for

Figure 7.1: REPRESENTATIVE CAPITAL AND OPERATING COSTS GRAVITY SYSTEM (Current $'s)

	Capital Cost	Annual Operating Costs		
		Expected	High Bound	Low Bound
Corridor Coach 84 Seats/2 Toilets	21,000	5,000	6,400	3,800
Eastern Long-Haul Single-Level Coach *	21,000	2,900	3,800	2,100
Easter Long-Haul Single-Level Sleeper 34 Berths/17 Toilets	100,000	19,800	24,800	14,700
Western Long-Haul Bi-Level Coach 75 Seats/6 Toilets	42,000	6,200	8,100	4,300
Western Long-Haul Bi-Level Sleeper 44 Berths/12 Toilets	74,000	11,100	14,400	7,400

* 60 seats/2 toilets

Figure 7.2: REPRESENTATIVE CAPITAL AND OPERATING COSTS SELF CONTAINED RECIRCULATING SYSTEM (Current $'s)

	Capital Cost	Annual Operating Costs		
		Expected	High Bound	Low Bound
Corridor Coach 84 Seats/2 Toilets	7,000	5,300	6,400	4,100
Eastern Long-Haul Single-Level Coach 60 Seats/2 Toilets	7,000	4,600	5,700	3,500
Eastern Long-Haul Single-Level Sleeper 34 Berths/17 Toilets	60,000	29,400	37,300	21,600
Western Long-Haul Bi-Level Coach 75 Seats/6 Toilets	21,000	11,200	14,000	8,300
Western Long-Haul Bi-Level Sleeper 44 Berths/12 Toilets	42,000	17,800	22,900	12,600

Figure 7.3: REPRESENTATIVE CAPITAL AND OPERATING COSTS VACUUM SYSTEM (Current $'s)

	Capital Cost	Annual Operating Costs		
		Expected	High Bound	Low Bound
Corridor Coach 84 Seats/2 Toilets	20,000	4,500	5,500	3,400
Eastern Long-Haul Single-Level Coach 60 Seats/2 Toilets	20,000	2,700	3,400	1,900
Eastern Long-Haul Single-Level Sleeper 34 Berths/17 Toilets	68,000	18,700	23,000	14,300
Western Long-Haul Bi-Level Coach 75 Seats/6 Toilets	33,000	5,500	7,000	4,000
Western Long-Haul Bi-Level Sleeper 44 Berths/12 Toilets	52,000	10,300	13,000	7,600

the other toilet. Note that all these costs assume reasonably satisfactory reliability performance. A highly unreliable system would cost substantially more.

In capital costs, recirculation toilets are by far the cheapest where there are only two toilets per car, but this advantage is much reduced when there are many toilets in the car. The collection system is the expensive component, particularly with the vacuum system, and the incremental cost of adding a toilet is relatively modest.

Waste Disposal, Health and Environmental Issues

Waste removal from the car can be accomplished in two acceptable ways:

1. Permanent pumpout manifold typically installed in larger undercover servicing and maintenance shops. The manifold can direct waste either into the sanitary sewer system (where available and acceptable) or to a holding tank for pumpout by a waste-disposal contractor.

2. Mobile pumpout truck, probably operated by a contractor, suitable for smaller train servicing locations where cars are serviced in the open, and there is road access alongside the tracks. Since such contractors charge by the hour, including travel time, the charges can be high.

At modernized Amtrak facilities like the one in South Boston, Massachusetts, pumpout and disposal practices are fully integrated with other train servicing functions. The cars serviced at Boston are Amfleet I's equipped with Monogram recirculating toilets. It takes two people approximately 60 minutes to service the toilets on one train (assuming 10 cars/train, two toilets per car).

A permanent manifold and quick-connect hoses are used to service all cars simultaneously. In the case of recirculation toilets, the servicing time includes recharging the toilet with chemicals.

The new facilities have been designed so that all the equipment (e.g., hoses, tanks, rinse water, catch basins and emergency gear) are easily accessible for the toilet pumpout and disposal practices.

Other water used during train servicing, including any spills from the toilet draining process, is collected through grating in the floor. This water is collected and sent to an oil skimmer to remove oil prior to discharging with the toilet waste, which is collected in a holding tank, to the sanitary sewer system.

The maintenance facilities that have not been modernized lack these features, although many of them do have simple dump pads for collecting and disposing of the waste. These allow waste to be dumped directly into the sanitary sewer system. Since this dump pad may only be long enough to accommodate a single car, costly and time-consuming switching moves may be required to service a train. It is also possible that a simple dump pad would be unacceptable, for reasons apart from cost and servicing time considerations. These could include:

- Inability to meter the amount of waste dumped
- Risk of unacceptable forms of waste being introduced into the local sewer system (e.g., fuel oil).
- Approval by FDA may be withheld because of health risk to maintenance workers or transfer of contaminants to other objects in the vicinity.
- It is likely to be an undesirable, smelly and unpleasant location to work, and thus be unacceptable to Amtrak workers.

The alternative to permanent dump facilities is to use mobile pumpout units-essentially a suitably sized tank-truck equipped with appropriate hoses and a pump. This is the process commonly used to service aircraft toilets, and chemical toilets used at construction sites, fairs, festivals and sports events, and also for domestic septic tanks. Pumpout contractor services are readily available in most medium and larger-sized communities. Mobile pumpout appears to be a suitable approach wherever cars are serviced in the open, there is access for a road vehicle alongside the cars, and the usage is too low to justify investment in permanent installation.

Municipal authorities at Amtrak car servicing locations were interviewed to determine the acceptability to them of toilet waste from trains. Each of those interviewed had in place operating Publicly-Owned Treatment Works (POTWs) that could treat the concentrated sanitary waste from the trains. Therefore, there is no need to investigate alternative treatment systems other than treatment by the local POTW. The authorities also expressed a willingness to take this type of waste. In fact, each of them currently receives waste streams similar to Amtrak's either from airplanes, buses or chemical toilets, and they had no problems with their treatment systems because of these types of wastes.

The authorities in each of the cities could not foresee any major problems permitting the concentrated waste stream, and in several instances they thought that a permit may not be necessary. There were only two concerns that were expressed about handling the waste:

1) The waste must be ground sufficiently to avoid buildup in the sewer lines. If this cannot be done, the waste will have to be trucked to the POTW.

2) A method must be developed to monitor the volume of sanitary waste discharged to the sewer for billing purposes.

Several chemicals have been used in the past for bactericides and disinfectants in chemical and recirculating toilets:

- Phenols;
- Formaldehyde;
- Bleach;
- Iodine; and
- Quaternary Ammonium Salts.

Of these chemicals, formaldehyde, bleach and iodine are no longer in use, except in special situations, because of their toxicity or corrosivity, and phenols are currently being phased out for the same reason. Therefore, the only major bactericide/disinfectant still in use is quaternary ammonium salts.

Quaternary ammonium salts are found in most household disinfectants as well as most industrial products, and their discharge to local sanitary sewers is not considered a problem. Amtrak is currently using two products with these compounds in its Amfleet I recirculating toilets and has had no problems except when the toilets are not emptied on a regular basis.

The manufacturers of bactericide/disinfectant products have tested the performance of their products for only 48 hours; therefore, on trips longer than two days there may be the need to add additional tablets or sachets to the toilets to avoid odor and color problems.

The railroad staff who are operating and maintaining the toilets are exposed to many pathogenic biological agents and possibly toxic chemicals and physically harmful materials.

Servicing and maintenance workers are directly exposed to the toilet waste during the cleaning operations. Spills are common through holes in the lightweight hoses and from leaks around the "quick connects." Also, waste splashing can occur when the hose is disconnected and dropped. Direct exposure is also possible in the lavatory when a toilet overflows.

The main concern associated with the exposure is possible infection due to the biological agents. Amtrak maintenance workers currently wear waterproof waders and rubber gloves, but additional safety measures may be warranted, including a short training program on the nature of the hazards and precautions against them, a medical monitoring program and increased protective equipment (possibly face shields).

Waste Retention System Evaluation Programs

This subsection addresses the question "what kind of evaluation programs are required to properly determine which waste retention systems best meet Amtrak requirements."

It makes sense at this stage to focus on retention toilet systems since these are on the market and available for evaluation. Total waste retention systems including grey water should be addressed later, should this be necessary.

The toilet systems described in this report are either at the prototype stage, or have been used in applications other than rail transportation or in rail passenger cars outside of the United States. Given this situation, a properly designed evaluation program is essential to ensure that systems eventually selected for installation in new Amtrak cars meet service requirements in all respects. Failure to do this can have severe adverse consequences, such as frequent failures in service, the need for costly modifications to correct problems, and passenger dissatisfaction.

A good evaluation program starts with a clear understanding of what performance is required. In the case of a toilet system, this will include:

- Meet basic "no dump" requirements for 72 hours
- Compatibility with car configuration and Amtrak operations (volume capacity, weight, bulk, power requirements, etc.)
- Acceptability to passengers
- Reasonable maintenance and servicing requirements
- Adequate reliability in service

Once these have been defined, then evaluation procedures are developed for each performance criterion.

The recommended evaluation program for waste retention systems has four principal steps:

1. Develop/refine evaluation criteria for the system and its installation

2. Design evaluation of each system and car installation

3. Functional evaluation of each system and car installation

4. Service evaluation of each system and car installation

Figure 5 presents an initial attempt to develop a set of Evaluation Criteria, based on observation of the past history of retention and retention/dump toilet systems. Amtrak should use this as a starting point, and convene a group of experienced managers to improve on the list, including:

- marketing/customer relations (very important)
- car engineering
- car servicing
- routine and heavy car maintenance

Issues to be addressed by this group are:

- Define good installation practice (independent of individual system technology):
  - routing and detail design of pipe work for accessibility, maintainability, freedom from freezing problems in cold weather
  - arrangements for power/air supplies, and backups if train power and air supply is not available, should these be considered necessary.

- Determine what design and operating features are desired by passengers. There is very little information on this—toilets have understandably not been a major focus of passenger surveys—yet there is a high level of dissatisfaction.

- Carry out more comprehensive study of routine and emergency maintenance records to better define requirements for acceptable reliability and maintainability. These should be in terms of Mean Time Between Failure (MTBF) for major components and the overall system, annual hours per car for maintenance, etc. Amtrak already collects much of this data.

- Determine what variations of requirements apply to specific car types. For example the "car interior odor control" requirement might be more stringent for toilets in sleeping rooms than those in the restroom of a coach car.

- Develop an importance ranking for the criteria, for example as follows:

  - Must have: essential requirement, no exception
  - Highly desirable: has significant impact on operating costs or passenger satisfaction
  - Nice to have: some impact on costs or passenger satisfaction

Establishing evaluation criteria would take some effort, but it would be beneficial to Amtrak if it reduces customer complaints.

- Suppliers would be presented with a much clearer definition of what Amtrak needs.

- Unsuitable systems can be rejected or modified at an early stage, saving the much larger effort involved in bench and service testing.

- Amtrak would have a significantly improved chance of getting waste retention systems that fully meet requirements.

The **design evaluation** is carried out on a generic technology, or on an installation of a particular retention system to a particular car. This can apply to either a new car or in a retrofit situation. The outcomes of such an evaluation will be:

- Technology or installation is rejected outright, as unable to meet some critical criteria.

- Technology or installation is only acceptable after modification.

- Technology or installation is accepted as meeting all essential requirements, and sufficient other criteria for it to be worth further evaluation.

Functional tests should be carried out on all car installations. In addition, it is desirable to carry out some kinds of bench tests, particularly "torture tests" to determine vulnerability to abuse. Such tests may be costly, but not as costly as installing unsuitable equipment in a revenue car. Such tests may reasonably be carried out in an old car stripped of its interior fitting and trim.

Functional test requirements are as follows:

- Bench Test. Set-up should consist of an individual toilet system, where the toilet/retention system is a self-contained unit (as with some recirculating models) or at least two toilets connected to a common retention system, for systems where multiple toilets can be served by a single retention tank. Key pressures in pneumatic systems, and when components such as valves and blowers operate, should be monitored to verify that the system operates as intended.

  Introduce a test object into toilet and observe results, such as:

  - object was passed through to retention tank
  - object was trapped and could be easily removed
  - object impaired toilet function in some respect and repairs were required to return toilet to use

- Operational Tests. These tests should be carried out on both the bench test installation and on the completed installation in a new car. These tests measure the toilet's ability to remove normal liquid and solid human waste and toilet paper, and to adequately clean the bowl.

- Abuse Test. One of the major causes of toilet malfunction is abuse by users, primarily the introduction of foreign objects into the toilet. Toilets should be designed such that abuse cannot cause severe mechanical damage, and obstructions are easily removed.

- Develop a list of test objects based on service experience.

Systems that successfully pass stages in the evaluation should be considered for a service test. Amtrak's present test program is primarily a service test. The service tests should ideally start with a functional test as described above and then the vehicle should be put into service.

The cars should be put into a service in which they will experience all climatic conditions. Since freezing is a common problem, the test service should include operation in Northern trains in winter. Data acquisition for a service test should comprise the following:

- A count of flushes of each toilet in the car by trip

- Measurement of the volume of waste removed from the car at each pumpout

- Careful recording of all servicing and maintenance performed on each toilet, including staff hours and spare parts consumed

- Regular inspection of the system by test personnel. For the first month these should be twice a week, and at longer intervals thereafter. Inspection should be performed at the end of a trip and prior to servicing and cleaning. Information recorded should include:

    - cleanliness
    - functionality with a "toilet paper" test
    - outward mechanical condition of equipment

- For a one-month period, a survey of passenger reactions to the system. This should be "calibrated" by surveying passengers in cars fitted with regular (non-test) toilet systems in the same train.

The service test should be long enough to reveal any generic problems with the equipment—rapid deterioration in performance or excessive maintenance. A period of about 4,000 service hours (approximately one year's normal service) should be sufficient. The test should be terminated earlier if repeated problems arise.

Conclusions

The principal conclusions from this study are as follows:

- Although normally considered an unattractive subject for study, toilets are important to a passenger rail service operator. They are costly to buy, install, maintain and operate and toilet malfunctions are a significant cause of customer dissatisfaction. Operating and maintenance cost variations can be up to four million dollars annually, plus an unknown amount of lost revenue due to passenger dissatisfaction. Therefore a carefully structured evaluation program is richly warranted.

- There are a number of full-retention toilet systems offered by the supply industry which could potentially meet the needs of Amtrak service. However, none of these systems are fully proven in the Amtrak environment. Previous experience with new, inadequately developed, toilet systems on Amtrak cars has not been good. This confirms the need for a properly structured test and evaluation program.

- There are no systems and technologies on the market or proposed for the full retention of "grey water" (from washing activities and dining car kitchens). Grey water retention poses a complex problem because of the high volume of water usage on specialty cars such as diners, lounges and sleeping cars.

  The vacuum and gravity/compressed-air waste retention systems are potentially adaptable to "grey water" retention, with increased complexity, and therefore higher capital and operating costs. The recirculating toilet technology cannot be so adapted and any grey water retention system would have to be entirely separate.

- Apart from developing grey water systems, should these be required, there is no justification for Amtrak, or the Federal Government, getting involved in developing new technology for passenger car waste retention. There is a thriving supply industry which can provide potentially suitable products, engineered for the rail car application. Other owners of potentially applicable technology should do likewise if they are interested in this market. Amtrak's role should be to develop a clear set of requirements for these systems and to evaluate potentially suitable products, leading to "type approval."

- Installation and maintenance costs for full-retention toilet systems will be similar to the retention and retention/dump systems presently operated by Amtrak.

Indeed, with careful evaluation and installation, reliability should be improved maintenance costs. The principal additional cost for full-retention over retention/dump systems is that of waste disposal. Annualized costs in the range $5 to $10 million are estimated for Amtrak's full fleet of cars. Since waste disposal charges primarily depend on volume of waste, ultra low-flush-volume systems have a significant operating cost advantage. The costs for retrofit of existing cars is not included in this estimate.

- There appears to be no significant environmental or engineering problems associated with toilet waste pumpout and disposal. Unless unusual chemicals are involved, waste from chemical and recirculating toilets, and concentrated waste from holding tanks are all acceptable to local waste treatment plants.

- A carefully structured evaluation program is essential if Amtrak is to avoid the kinds of reliability and maintainability problems that have plagued toilet installations in the past. This program should include development of a full set of evaluation criteria, an engineering evaluation of the toilet and waste retention system and its installation, a bench test, and an in-service evaluation.

- The evaluation program should particularly seek input from passengers both at the stage of developing evaluation criteria, and during service evaluations of individual systems and technologies. This should help reduce the level of passenger dissatisfaction with toilet and restroom amenities and potentially lead to increased revenue.

- The bench testing of candidate systems should include a deliverable abuse test. Passenger abuse is a major cause of toilet malfunction and toilet vulnerability to damage from this cause should be an important evaluation criterion.

- The timescale for a thorough evaluation program is estimated to be about 18 months, exclusive of the time taken to procure test toilet systems from the supplier. This includes a 12-month service evaluation period.

- It is reasonable to include a toilet system with retention capability on all future passenger cars.

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The service test should be long enough to reveal any generic problems with the equipment—rapid deterioration in performance or excessive maintenance. A period of about 4,000 service hours (approximately one year's normal service) should be sufficient. The test should be terminated earlier if repeated problems arise.

Functional test requirements are as follows:

- Bench Test. Set-up should consist of an individual toilet system, where the toilet/retention system is a self-contained unit (as with some recirculating models) or at least two toilets connected to a common retention system, for systems where multiple toilets can be served by a single retention tank. Key pressures in pneumatic systems, and when components such as valves and blowers operate, should be monitored to verify that the system operates as intended.

  Introduce a test object into toilet and observe results, such as:

  - object was passed through to retention tank
  - object was trapped and could be easily removed
  - object impaired toilet function in some respect and repairs were required to return toilet to use

- Operational Tests. These tests should be carried out on both the bench test installation and on the completed installation in a new car. These tests measure the toilet's ability to remove normal liquid and solid human waste and toilet paper, and to adequately clean the bowl.

- Abuse Test. One of the major causes of toilet malfunction is abuse by users, primarily the introduction of foreign objects into the toilet. Toilets should be designed such that abuse cannot cause severe mechanical damage, and obstructions are easily removed.

- Develop a list of test objects based on service experience.

- Develop an importance ranking for the criteria, for example as follows:

  - Must have: essential requirement, no exception
  - Highly desirable: has significant impact on operating costs or passenger satisfaction
  - Nice to have: some impact on costs or passenger satisfaction

Establishing evaluation criteria would take some effort, but it would be beneficial to Amtrak if it reduces customer complaints.

- Suppliers would be presented with a much clearer definition of what Amtrak needs.

- Unsuitable systems can be rejected or modified at an early stage, saving the much larger effort involved in bench and service testing.

- Amtrak would have a significantly improved chance of getting waste retention systems that fully meet requirements.

The **design evaluation** is carried out on a generic technology, or on an installation of a particular retention system to a particular car. This can apply to either a new car or in a retrofit situation. The outcomes of such an evaluation will be:

- Technology or installation is rejected outright, as unable to meet some critical criteria.

- Technology or installation is only acceptable after modification.

- Technology or installation is accepted as meeting all essential requirements, and sufficient other criteria for it to be worth further evaluation.

Functional tests should be carried out on all car installations. In addition, it is desirable to carry out some kinds of bench tests, particularly "torture tests" to determine vulnerability to abuse. Such tests may be costly, but not as costly as installing unsuitable equipment in a revenue car. Such tests may reasonably be carried out in an old car stripped of its interior fitting and trim.

2. Design evaluation of each system and car installation

3. Functional evaluation of each system and car installation

4. Service evaluation of each system and car installation

Figure 5 presents an initial attempt to develop a set of Evaluation Criteria, based on observation of the past history of retention and retention/dump toilet systems. Amtrak should use this as a starting point, and convene a group of experienced managers to improve on the list, including:

- marketing/customer relations (very important)
- car engineering
- car servicing
- routine and heavy car maintenance

Issues to be addressed by this group are:

- Define good installation practice (independent of individual system technology):
  - routing and detail design of pipe work for accessibility, maintainability, freedom from freezing problems in cold weather
  - arrangements for power/air supplies, and backups if train power and air supply is not available, should these be considered necessary.

- Determine what design and operating features are desired by passengers. There is very little information on this—toilets have understandably not been a major focus of passenger surveys—yet there is a high level of dissatisfaction.

- Carry out more comprehensive study of routine and emergency maintenance records to better define requirements for acceptable reliability and maintainability. These should be in terms of Mean Time Between Failure (MTBF) for major components and the overall system, annual hours per car for maintenance, etc. Amtrak already collects much of this data.

- Determine what variations of requirements apply to specific car types. For example the "car interior odor control" requirement might be more stringent for toilets in sleeping rooms than those in the restroom of a coach car.

Waste Retention System Evaluation Programs

This subsection addresses the question "what kind of evaluation programs are required to properly determine which waste retention systems best meet Amtrak requirements."

It makes sense at this stage to focus on retention toilet systems since these are on the market and available for evaluation. Total waste retention systems including grey water should be addressed later, should this be necessary.

The toilet systems described in this report are either at the prototype stage, or have been used in applications other than rail transportation or in rail passenger cars outside of the United States. Given this situation, a properly designed evaluation program is essential to ensure that systems eventually selected for installation in new Amtrak cars meet service requirements in all respects. Failure to do this can have severe adverse consequences, such as frequent failures in service, the need for costly modifications to correct problems, and passenger dissatisfaction.

A good evaluation program starts with a clear understanding of what performance is required. In the case of a toilet system, this will include:

- Meet basic "no dump" requirements for 72 hours
- Compatibility with car configuration and Amtrak operations (volume capacity, weight, bulk, power requirements, etc.)
- Acceptability to passengers
- Reasonable maintenance and servicing requirements
- Adequate reliability in service

Once these have been defined, then evaluation procedures are developed for each performance criterion.

The recommended evaluation program for waste retention systems has four principal steps:

1. Develop/refine evaluation criteria for the system and its installation

The main concern associated with the exposure is possible infection due to the biological agents. Amtrak maintenance workers currently wear waterproof waders and rubber gloves, but additional safety measures may be warranted, including a short training program on the nature of the hazards and precautions against them, a medical monitoring program and increased protective equipment (possibly face shields).

1) The waste must be ground sufficiently to avoid buildup in the sewer lines. If this cannot be done, the waste will have to be trucked to the POTW.

2) A method must be developed to monitor the volume of sanitary waste discharged to the sewer for billing purposes.

Several chemicals have been used in the past for bactericides and disinfectants in chemical and recirculating toilets:

- Phenols;
- Formaldehyde;
- Bleach;
- Iodine; and
- Quaternary Ammonium Salts.

Of these chemicals, formaldehyde, bleach and iodine are no longer in use, except in special situations, because of their toxicity or corrosivity, and phenols are currently being phased out for the same reason. Therefore, the only major bactericide/disinfectant still in use is quaternary ammonium salts.

Quaternary ammonium salts are found in most household disinfectants as well as most industrial products, and their discharge to local sanitary sewers is not considered a problem. Amtrak is currently using two products with these compounds in its Amfleet I recirculating toilets and has had no problems except when the toilets are not emptied on a regular basis.

The manufacturers of bactericide/disinfectant products have tested the performance of their products for only 48 hours; therefore, on trips longer than two days there may be the need to add additional tablets or sachets to the toilets to avoid odor and color problems.

The railroad staff who are operating and maintaining the toilets are exposed to many pathogenic biological agents and possibly toxic chemicals and physically harmful materials.

Servicing and maintenance workers are directly exposed to the toilet waste during the cleaning operations. Spills are common through holes in the lightweight hoses and from leaks around the "quick connects." Also, waste splashing can occur when the hose is disconnected and dropped. Direct exposure is also possible in the lavatory when a toilet overflows.

single car, costly and time-consuming switching moves may be required to service a train. It is also possible that a simple dump pad would be unacceptable, for reasons apart from cost and servicing time considerations. These could include:

- Inability to meter the amount of waste dumped
- Risk of unacceptable forms of waste being introduced into the local sewer system (e.g., fuel oil).
- Approval by FDA may be withheld because of health risk to maintenance workers or transfer of contaminants to other objects in the vicinity.
- It is likely to be an undesirable, smelly and unpleasant location to work, and thus be unacceptable to Amtrak workers.

The alternative to permanent dump facilities is to use mobile pumpout units-essentially a suitably sized tank-truck equipped with appropriate hoses and a pump. This is the process commonly used to service aircraft toilets, and chemical toilets used at construction sites, fairs, festivals and sports events, and also for domestic septic tanks. Pumpout contractor services are readily available in most medium and larger-sized communities. Mobile pumpout appears to be a suitable approach wherever cars are serviced in the open, there is access for a road vehicle alongside the cars, and the usage is too low to justify investment in permanent installation.

Municipal authorities at Amtrak car servicing locations were interviewed to determine the acceptability to them of toilet waste from trains. Each of those interviewed had in place operating Publicly-Owned Treatment Works (POTWs) that could treat the concentrated sanitary waste from the trains. Therefore, there is no need to investigate alternative treatment systems other than treatment by the local POTW. The authorities also expressed a willingness to take this type of waste. In fact, each of them currently receives waste streams similar to Amtrak's either from airplanes, buses or chemical toilets, and they had no problems with their treatment systems because of these types of wastes.

The authorities in each of the cities could not foresee any major problems permitting the concentrated waste stream, and in several instances they thought that a permit may not be necessary. There were only two concerns that were expressed about handling the waste:

Waste Disposal, Health and Environmental Issues

Waste removal from the car can be accomplished in two acceptable ways:

1. Permanent pumpout manifold typically installed in larger undercover servicing and maintenance shops. The manifold can direct waste either into the sanitary sewer system (where available and acceptable) or to a holding tank for pumpout by a waste-disposal contractor.

2. Mobile pumpout truck, probably operated by a contractor, suitable for smaller train servicing locations where cars are serviced in the open, and there is road access alongside the tracks. Since such contractors charge by the hour, including travel time, the charges can be high.

At modernized Amtrak facilities like the one in South Boston, Massachusetts, pumpout and disposal practices are fully integrated with other train servicing functions. The cars serviced at Boston are Amfleet I's equipped with Monogram recirculating toilets. It takes two people approximately 60 minutes to service the toilets on one train (assuming 10 cars/train, two toilets per car).

A permanent manifold and quick-connect hoses are used to service all cars simultaneously. In the case of recirculation toilets, the servicing time includes recharging the toilet with chemicals.

The new facilities have been designed so that all the equipment (e.g., hoses, tanks, rinse water, catch basins and emergency gear) are easily accessible for the toilet pumpout and disposal practices.

Other water used during train servicing, including any spills from the toilet draining process, is collected through grating in the floor. This water is collected and sent to an oil skimmer to remove oil prior to discharging with the toilet waste, which is collected in a holding tank, to the sanitary sewer system.

The maintenance facilities that have not been modernized lack these features, although many of them do have simple dump pads for collecting and disposing of the waste. These allow waste to be dumped directly into the sanitary sewer system. Since this dump pad may only be long enough to accommodate a the other toilet. Note that all these costs assume reasonably satisfactory reliability performance. A highly unreliable system would cost substantially more.

In capital costs, recirculation toilets are by far the cheapest where there are only two toilets per car, but this advantage is much reduced when there are many toilets in the car. The collection system is the expensive component, particularly with the vacuum system, and the incremental cost of adding a toilet is relatively modest.

Figure 7.2: REPRESENTATIVE CAPITAL AND OPERATING COSTS SELF CONTAINED RECIRCULATING SYSTEM (Current $'s)

	Capital Cost	Annual Operating Costs		
		Expected	High Bound	Low Bound
Corridor Coach 84 Seats/2 Toilets	7,000	5,300	6,400	4,100
Eastern Long-Haul Single-Level Coach 60 Seats/2 Toilets	7,000	4,600	5,700	3,500
Eastern Long-Haul Single-Level Sleeper 34 Berths/17 Toilets	60,000	29,400	37,300	21,600
Western Long-Haul Bi-Level Coach 75 Seats/6 Toilets	21,000	11,200	14,000	8,300
Western Long-Haul Bi-Level Sleeper 44 Berths/12 Toilets	42,000	17,800	22,900	12,600

Figure 7.3: REPRESENTATIVE CAPITAL AND OPERATING COSTS VACUUM SYSTEM (Current $'s)

	Capital Cost	Annual Operating Costs		
		Expected	High Bound	Low Bound
Corridor Coach 84 Seats/2 Toilets	20,000	4,500	5,500	3,400
Eastern Long-Haul Single-Level Coach 60 Seats/2 Toilets	20,000	2,700	3,400	1,900
Eastern Long-Haul Single-Level Sleeper 34 Berths/17 Toilets	68,000	18,700	23,000	14,300
Western Long-Haul Bi-Level Coach 75 Seats/6 Toilets	33,000	5,500	7,000	4,000
Western Long-Haul Bi-Level Sleeper 44 Berths/12 Toilets	52,000	10,300	13,000	7,600

Figure 7.1: REPRESENTATIVE CAPITAL AND OPERATING COSTS GRAVITY SYSTEM (Current $'s)

	Capital Cost	Annual Operating Costs		
		Expected	High Bound	Low Bound
Corridor Coach 84 Seats/2 Toilets	21,000	5,000	6,400	3,800
Eastern Long-Haul Single-Level Coach *	21,000	2,900	3,800	2,100
Easter Long-Haul Single-Level Sleeper 34 Berths/17 Toilets	100,000	19,800	24,800	14,700
Western Long-Haul Bi-Level Coach 75 Seats/6 Toilets	42,000	6,200	8,100	4,300
Western Long-Haul Bi-Level Sleeper 44 Berths/12 Toilets	74,000	11,100	14,400	7,400

* 60 seats/2 toilets

Total costs are generated on a per trip basis when the number of trips per day is not more than one, or on a per service-day basis when the number of trips per day exceeds one. This is done because pump-out and cleaning is assumed to be done once per trip or once per day, whichever is longer.

The number of possible service days per year is calculated for each car on each route. Since not all routes run every day, and because car availability is reduced by routine maintenance, the number of available service days is less than the number of possible service days. The inputs to the analysis model included:

- Toilet capital cost (each)
- Collection System capital cost (usually one per car)
- Installation hours per toilet
- Installation hours per collection system
- Amtrak labor rates
- Retention tank capacity
- Flush fluids used per flush
- Estimation of volume of waste generated by one person per day
- Estimation of toilet uses per person per day
- Amtrak route data (length in miles, duration, and consist)
- Car configuration (passenger density and number of toilets)
- Waste disposal costs per gallon
- Frequency of major servicing

The input values for the three scenarios (Expected, High and Low Bound) varied in the number of uses per person per day, the average number of flushes per use (it is expected that the ratio of flushes to uses will exceed 1:1), the frequency of major servicing, the car availability percentage, and the spare parts cost.

The routes and car types modelled were chosen to fairly represent Amtrak's current fleet as well as to accommodate any type of car specification which should be issued in the future.

The results for a small number of representative car types and service are given in the tables, Figures 7.1, 7.2 and 7.3, for a representative cost of each generic toilet system.

Operating costs were broadly similar for all types of systems. Because of relatively high flush volumes, operating costs of gravity toilets were dominated by waste pumpout and disposal costs. Maintenance dominated operating costs for

All labor costs associated with operating and maintaining the toilet systems were calculated at the standard Amtrak rate of $36/hour.

Long-term maintenance is calculated by multiplying the frequency of servicing by the number of hours needed to service a toilet by the number of toilets per car. The labor rate used is the standard Amtrak rate of $36/hour.

Based on current Amtrak experience, only recirculating toilets are removed from the car and cleaned prior to servicing. For this reason we assumed that on average it would take eight hours to service a recirculating toilet as compared to two hours on average for non-recirculating toilets. The frequency of servicing is currently three times per year.

Since none of these toilet systems has a history of use in this environment (full retention for 72 hours), we estimated three ranges of spare parts costs based on an annual percentage of original capital cost. The base case assumed that the spare parts cost per toilet system would average 3% of original capital cost. The best and worse case scenarios were calculated using 1% and 5% respectively.

The cost model calculates operating and capital costs for each toilet system type by car type and route. The costs are assumed to be for new cars of the same general type as existing cars. The costs are generated under each of the three scenarios (expected, high bound, low bound).

Operating costs are divided into trip related and non-trip related costs. Trip related costs are those which are truly variable costs. They include waste disposal cost based on gallons of waste produced (this is a function of the number of passengers per coach, the length of trip, and the flush fluid used with each flush), labor for pumping out the waste as well as connecting and disconnecting the hoses, and cleaning the toilets at the end of a trip or service day. The non-trip related costs include maintenance and spare parts cost.

Capital costs are calculated for each car type regardless of route. These costs include the fixed cost for the toilets and collection system and the labor cost for installing the toilets and collection systems on new coaches.

The manufacturers supplied approximate capital costs and operating characteristics (i.e. flush fluids required per flush, tank capacity). However, since Amtrak has not issued a specification as yet, these numbers are by no means firm.

Amtrak supplied approximate maintenance times, frequency of overhauls, labor rates, route and consist data, toilet configuration by car type, and fleet data. Amtrak also supplied human waste volume statistics and an estimation of the number of uses per person per day.

The consultant estimated waste disposal costs, pump-out time requirements, and installation time requirements.

Rough **capital costs** associated with each toilet system were provided by the manufacturers. They provide an indication of the order of magnitude costs of a system. They are not necessarily the actual cost of a given system, as that would be dependent on Amtrak's specifications for a particular car and the quantity ordered.

Installation costs are calculated according to the time taken to install the toilets and associated holding tanks and plumbing. They were derived by multiplying the number of hours for installation by the number of toilets and collection systems per car and by Amtrak's $36/hour labor cost. The installation time requirement for each system is a consultant estimate based upon the relative complexity of the toilet systems.

Operating costs were divided into those which are trip- or use-dependent, and those which are not trip-dependent. Examples of the former are:

- Cleaning costs
- Waste disposal costs
- Labor costs for pumping out the tanks

Non-trip related operating costs are for routine maintenance and spare parts.

In each instance there was insufficient data for accurately projecting the operating costs. Since none of these systems is currently in service under these conditions, there is no historical data. Therefore, the consultant estimated the costs. It is hoped that the recommended testing program will provide much of the data necessary to project costs more accurately.

Capital, Maintenance and Operating Costs

Costs are presented for a range of car types, train services and for three generic toilet systems (gravity, recirculating, vacuum).

While capital costs are fixed for a specific car type, operating costs are greatly affected by assumptions about the number of trips per year, toilet usage, maintenance effort required, etc. To deal with this uncertainty, high and low bounds for annual costs have been calculated, as well as a median "expected" cost.

Note that capital costs are for installations in <u>new</u> cars. Costs for retrofitting these systems to existing cars will be higher, and have not been addressed in this study.

Cost data came from three sources: the manufacturers, Amtrak, and consultant estimates. During the course of the study, team members conducted on-site interviews and tours with the five U.S.-based retention toilet system manufacturers, and several visits to Amtrak offices and facilities.

Costs were modeled for five representative toilet systems manufactured by four of the five companies. They are:

- Microphor Gravity System
- Monogram "Modified Vacuum" System
- Monogram Self-Contained Recirculating System
- Evac Ultimate System
- Railtech WTS 8300 Gravity System

These particular systems were chosen because they represent the primary retention solution offered by each manufacturer. They also enable cost analysis for each generic type of retention toilet system (e.g., recirculating, vacuum, etc.). Two Monogram systems were modelled because they are sufficiently different from each other (vacuum versus recirculating) and because the Monogram vacuum system is quite different from the Evac vacuum system.

The Gard Mk II Vacuum System was not included in the analysis because we were unable to obtain sufficient cost data during the timeframe of the study.

Note that these are typical figures derived from a representative proprietary system, and with assumptions about daily usage, and the propensity of users to flush more than once per visit. Actual numbers could vary considerably, particularly with the gravity/pressure systems with relatively high flush volumes.

Some comments on Figure 6 are:

- General acceptability and odor control of recirculation toilets are less than satisfactory. The chemicals used are strong smelling in any case, and become distinctly unpleasant when the holding tank nears capacity.

- Safety of vacuum systems must be carefully evaluated because of the risk of injury when the flush is initiated while a person is seated on the toilet.

- Reliability can only be determined through a properly designed test program.

- Ease of servicing of recirculating toilets is poor, because all working parts are situated inside the holding tank.

- While system configuration and past history give some idea of abuse tolerance, a test program is highly desirable to properly understand performance under this important criterion.

- Some system types are incompatible with certain car types (or could only be made compatible with additional equipment).

  - Systems relying on gravity to move waste to a holding tank cannot be used on the lower level of a bilevel car (gravity/pressure, and remote tank recirculating systems).

  - Because of odors, recirculating systems will not be attractive for sleeping car rooms.

  - Gravity systems are poor for sleeping cars, because of the multiple toilets and difficulty of locating holding tanks and "plumbing."

- To benchmark the influence of system type on holding tank volume, the following total volume is estimated to give a fully-occupied 60-seat coach a 72-hour capacity, given typical usage.

Gravity/pressure	399 gals.
Recirculating	115 gals.
Vacuum	184 gals.

Figure 6

Evaluation of Retention Toilet Performance (Principal Criteria)			
Performance Criterion	**Gravity/Pressure**	**Recirculating**	**Vacuum**
Passenger Acceptability • Health and safety • Odor control • General acceptability	 Good Good Good	 Fair Poor Fair	 ? Fair/Good Good
Service Reliability • Quantitative reliability • Ease of repair	 ? Fair/Good	 ? Poor	 ? Fair/Good
Maintainability • Ease of servicing • Tolerance of abuse	 Fair/Good ?/Fair	 Poor ?/Poor	 Fair/Good ?/Fair
Car Configuration Acceptability • Volume of holding tank • Compatibility with car types	 Moderate/High Fair, Not Bilevel Fair/Poor for sleeping car	 Low Fair/poor, Not bilevel (remote tank) Poor for sleeping car	 Low/Moderate Good. All types OK

? = Could not be evaluated. Test and service trials required to provide answers.

slide protection system. If these are not working (which is not unusual), the small holding tank quickly fills up and the toilet becomes unusable.

Generally, reliability is the hardest performance criterion to evaluate without a service test. System complexity is one indicator—other things being equal, simple systems will be more reliable than complex, but much depends on the detailed design of individual components and installations.

3. Maintainability.

This group of issues is concerned with the ease with which the system can be kept in good working order. The systems should be compatible with Amtrak's normal 3 or 4 month inspection and maintenance cycle. All maintenance intensive items should be reasonably accessible for inspection and change-out if necessary. Some of the existing installations on Amtrak are poor in this respect. For example, Amtrak has found it best to entirely remove the integral-tank recirculating toilets from the car at four month intervals to clean and maintain the working parts. This is costly.

Another important area of maintainability is tolerance of abuse, usually in the form of foreign objects shoved into the system. Abuse is a major cause of toilet malfunction. While it is not reasonable that a system should continue to function regardless of abuse, it is important that it be designed so that abuse will not cause severe mechanical damage, and that obstructions can be easily removed. It is also important that there is little risk of abuse rendering all toilets in a car inoperative (especially applicable to vacuum systems).

The results of the qualitative review of performance by generic toilet type and principal performance criteria is provided in the table, Figure 6. System types are rated against criteria as follows:

Good – satisfies performance criteria
Fair – partially satisfies performance criteria
Poor – significant shortcomings identified

Figure 5 List of Waste Retention System Evaluation Criteria

Passenger acceptability
- Ergonomics
- Public Health Risk
- Personal Injury Risk
- Odor Exposure—On Train
- Odor Exposure—Wayside
- Cleanliness of Toilet
- Overall Aesthetics

Service Reliability
- Number of Failure Categories
- Acceptable Mean Time Between Failures
- Failure Modes Benign
- Dependence on Other Train Systems

Maintainability
- Ease of Periodic Servicing
- Ability to Keep Clean
- Employee Health & Safety Risk
- Tolerance to Passenger Abuse

Environmental Acceptability
- Waste Retention (for 72 hours)
- Waste Disposal

Car Configuration Acceptability
- System Weight
- Volume Requirements for Waste Storage
- Energy Requirements

Evaluation of Waste Retention Systems

This section describes the results of a "desk" evaluation of the principal types of retention toilet systems currently available on the market.

The process started with an effort to define a set of performance criteria for the systems. These are listed in Figure 5 and cover the following groups of issues.

1. Passenger Acceptability.

This group covers any issues associated with the interaction between the user (the passenger) and the toilet system. These include general acceptability, appearance and ease of use, safety and health risks to the user (even if the user misuses the system), freedom from objectional odors, and ease of keeping the equipment clean.

Typical passenger acceptability problems include:

- Any system lacking a good seal between toilet and holding tank is likely to suffer from unpleasant odors.
- Any vacuum system lacking a deodorizing feature on the vacuum pump exhaust will create unpleasant odors outside the car.
- A system where a macerator is easily accessible below the bowl is a potential hazard, for example, when someone tries to retrieve a valuable object which has been dropped into the bowl.
- An improperly designed vacuum system can cause injury if flushed when the user is still seated on the equipment.

2. Service Reliability

This group covers reliability as quantified by the frequency and types of failures, and the ease with which such failures can be corrected. Situations where the toilet fails to function because of some failure of other car systems are included. A good example of the latter occurs in the retention/dump systems currently fitted to Amtrak cars. The train speed signal on which the dump valve depends is derived from wheel/axle mounted odometers which are part of the wheel

Other than the aircraft-type recirculating toilets fitted to the TGV and Shinkansen, service experience has been limited, being confined to relatively few cars, or a relatively short time period. Also, journey times in Europe and Japan are relatively short, permitting daily pumpout. Probably the most important conclusions from the international survey are that the market for full-retention toilets is growing, leading to product development and interest among suppliers. This will clearly aid Amtrak in efforts to find suitable systems.

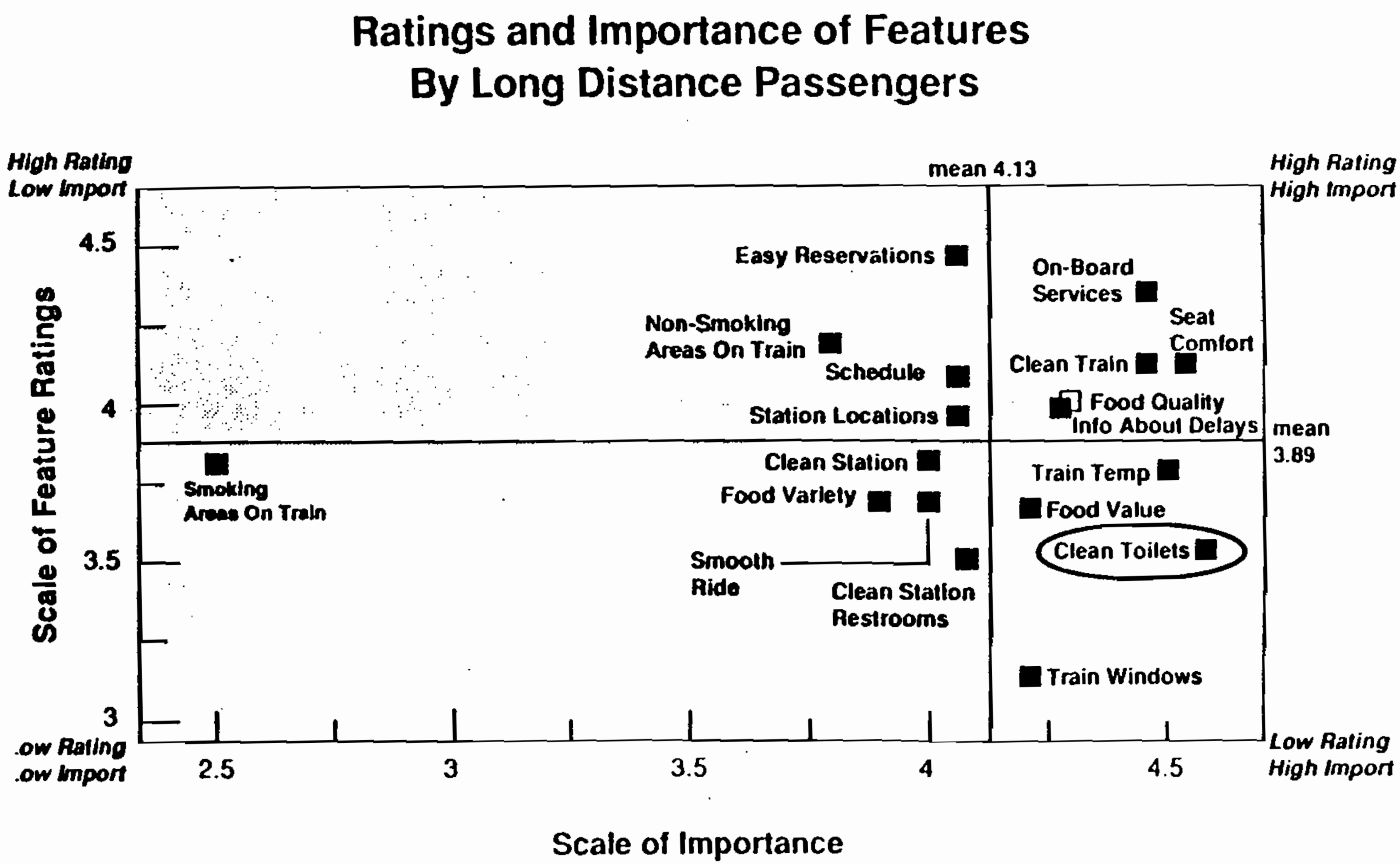
design, installation and maintenance of toilets ought to receive serious attention in Amtrak's efforts to provide a good service to its customers.

Other North American Operators. Commuter rail operators in the United States are obliged by law to use toilet systems which do not discharge untreated waste on the track. Many authorities use full-retention systems in response to this requirement with generally fair results. The most common type of retention toilet used is the recirculating type similar to that installed on Amtrak's Amfleet I cars (Long Island Railroad and Metro North Commuter Railroad). Other operations with generally short trips (Massachusetts Bay Transportation Authority) have simply added a holding tank to the traditional direct dump systems. However, the service environment, with typically only four hours of intensive use daily and daily pump-out, is clearly much less demanding than for an intercity passenger car.

VIA Rail Canada, the Canadian long-distance rail passenger service operator, has adopted the retention/dump approach for new cars, using a Railtech gravity toilet system. In the VIA application, the waste is treated with disinfectant in the holding tank prior to dumping. There were some initial troubles with this system (aluminum car structure corrosion due to disinfectant leaks and jammed macerators) but these have now been resolved. The current tank capacity is enough for 99 flushes and the tank is dumped at speeds over 25 mph.

International. Full-retention toilets of the recirculating type have been fitted to very high-speed trains (Japan's "Shinkansen" and France's "Train a Grand Vitesse") over the past two decades. The reasons appear to be to seal the car for climate control and due to the concern that directly discharged waste would get spread all over the car at high speed, instead of just falling onto the track. More recently, public objections to direct dumping of waste have resulted in "no dumping" policies on some European rail systems. This is true in the United Kingdom (British Rail) (BR) and on the German and Danish national rail systems (DB and DSB). Service experience, however, is limited since these policies are of relatively recent initiation. There is no consistency of system choice. Both DB and DSB have standardized on vacuum systems, after extensive evaluation programs. BR is considering vacuum and gravity systems but has rejected recirculating systems because of odors and chemical waste disposal problems. On the other hand, France (SNCF) so far has exclusively used recirculating toilets.

Figure 4



Ratings and Importance of Features
By Long Distance Passengers
High Rating
Low Import
High Rating
High Import
mean 4.13
mean
3.89
Low Rating
Low Import
Low Rating
High Import
Scale of Feature Ratings
Scale of Importance
4.5
4
3.5
3
2.5
3
3.5
4
4.5
Easy Reservations
On-Board
Services
Seat
Comfort
Non-Smoking
Areas On Train
Schedule
Clean Train
Food Quality
Info About Delays
Station Locations
Clean Station
Train Temp
Smoking
Areas On Train
Food Variety
Food Value
Clean Toilets
Smooth
Ride
Clean Station
Restrooms
Train Windows

Existing Practice and Experience

This section summarizes existing practice and experience with passenger railcar waste retention systems, and other waste systems that embody technology similar to full retention systems. This will include the practice and experience of Amtrak, other North American operators of passenger cars, and Japanese and European operators.

Amtrak. Amtrak operates approximately 1,500 passenger cars of all types. About 440 of these are "Heritage" cars formerly owned by predecessor railroads and about 350 are equipped with traditional direct dump toilet systems. About 1,000 cars have been built for Amtrak since 1970. All of these are equipped with either full-retention toilets or systems that retain waste at speeds less than 25 mph but permit dumping at higher speeds. Apart from needing only small capacity holding tanks, and the presence of a speed-sensitive dump valve, these retention/dump systems are technically similar to full-retention systems.

The specific systems installed on Amtrak cars are:

- The Monogram recirculating, full-retention toilet on the Amfleet I (483 cars)
- A Monogram vacuum retention/dump toilet on the Superliner cars (Approximately 240 cars with toilets)
- A Microphor gravity retention/dump toilet on the Amfleet II and Horizon cars (about 250 cars)

Service experience with these systems has not been good, especially the first two types for which substantial preventative maintenance programs are required to achieve adequate reliability. A series of detailed modifications have also been necessary. Amtrak is properly concerned that any new or modified full-retention toilet systems be highly reliable to avoid the maintenance costs and rail service quality problems associated with malfunctioning toilet systems.

It is worth noting that passengers rank clean and functioning toilet systems as one of the highest unmet needs associated with Amtrak service (Figure 4). Malfunctioning toilets are also a major source of passenger complaints. Quite apart from any need to comply with waste disposal regulations, the

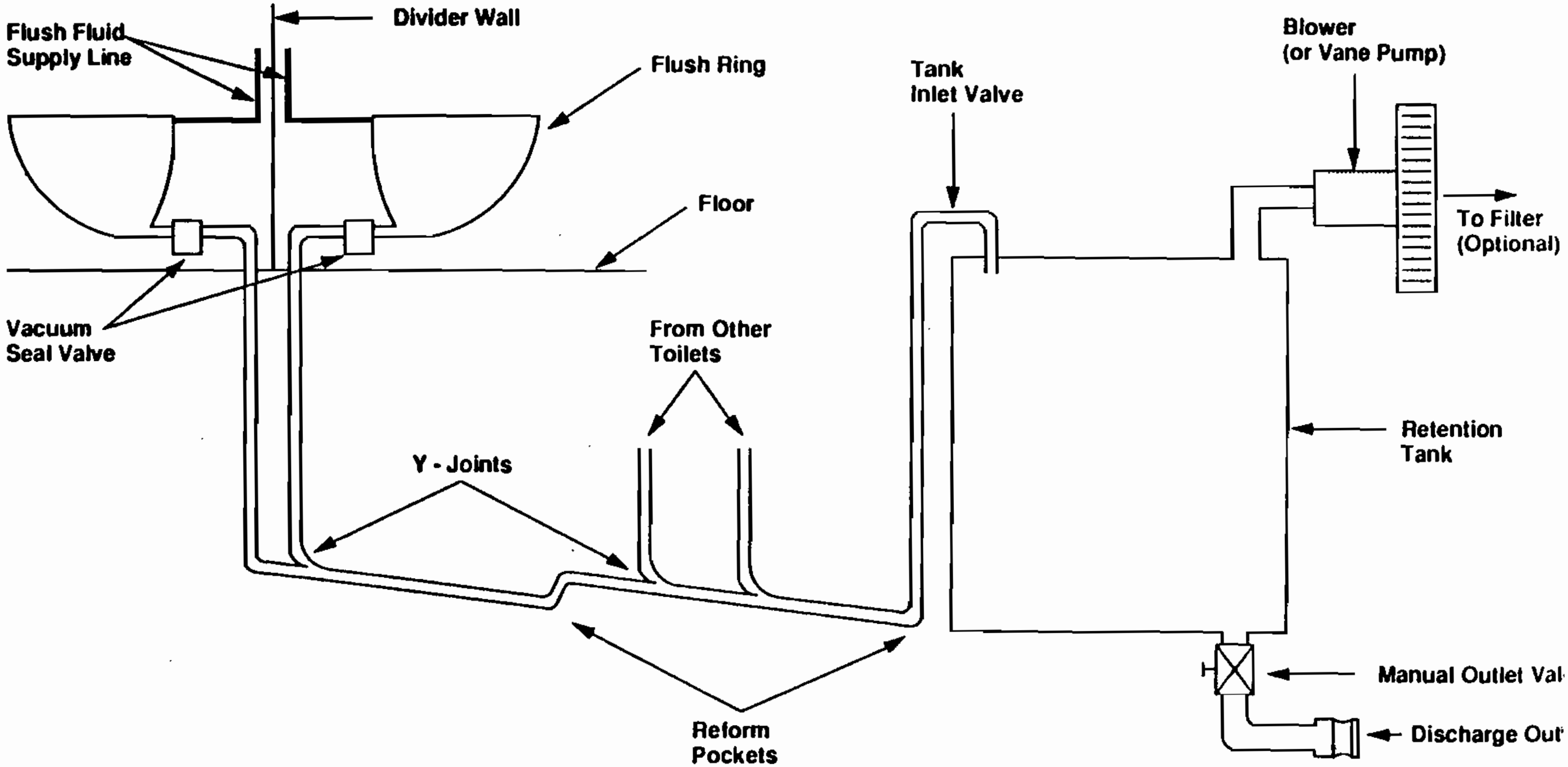
Properly functioning vacuum systems (no vacuum leaks) are not excessively prone to clogging due in part to the speed of the transport. Waste moves through the pipes at speeds up to 25 to 30 feet per second as compared to roughly 5 feet per second in a gravity system. This high velocity reduces the likelihood of clogging.

All the manufacturers offer one or more vacuum toilet systems.

The advantages of a vacuum system are that it confers considerable freedom in locating toilets and holding tanks in the car, and multiple toilets can be served by one system. It can be used in any kind of car. The disadvantages are that they are relatively complex and performance is sensitive to proper sizing and routing of pipework. Experience with early vacuum systems was not good. However, there has now been over a decade of engineering development and service experience with these systems, and it is to be hoped that performance and reliability problems have been overcome. They have also been generally adopted by commercial airplane manufacturers.

Figure 3

Vacuum System



Vacuum toilet systems have been used primarily on aircraft. In these installations the vacuum is created by the differential pressure inside and outside the aircraft. Below 16,000 feet a vane pump or blower is used to create the vacuum (see Figure 3).

Flush initiation is accomplished by pushing an electro-mechanical switch. At this time, if there is a sufficient vacuum level in the retention tank, water is discharged into the bowl to clear the waste into the piping. The vacuum is used as both the transport mechanism to move the waste material through the pipe as well as for bowl clearing. If there is insufficient vacuum pressure, there will be a slight delay before the fluid is introduced to the bowl while the vacuum is being generated.

In general, vacuum systems use dry bowls without a flapper. They can, however, use either a dry or a wet bowl.

Vacuums can be generated in a variety of ways:

- Blowers are fans which create a vacuum in the waste retention tank by removing air either at the time a flush is initiated, or by holding a constant vacuum in the tank. In the latter case the blower operates whenever the vacuum level in the tank drops below a predetermined level. This can happen after flushing one or more of the toilets, or as a result of an air leak in the piping system.

- Vane pumps can be used in the same way as blowers to generate a vacuum in the waste retention tank, but generally are not as efficient, reliable, or quiet. They will often be used in pairs where one blower would be used.

- Macerator pumps can also be used to generate a vacuum. By pumping the waste material currently in the holding tank through a venturi, low pressure is achieved by drawing waste through the piping into the tank. In essence, the waste is recirculated within the holding tank. This system would only begin to create the vacuum after a flush has been initiated.

The vacuum is used primarily as the means of transport from the toilet bowl to the retention tank. However, in one system, the vacuum is used both to clear the bowl and to draw air and water into the bowl to wash it.

only fluid to pass through. After the fluid has passed through the holes, the piece with the pins is withdrawn slightly to allow any buildup of solid waste to be removed by the surrounding fluid.

The pin filter is contained in a metal container approximately one foot in diameter and 4 inches high. The entire assembly is positioned in the retention tank. Inside the container there is also a diaphragm pump. When air is injected above the diaphragm, it expands to push waste against the filter and pump the liquid out the other side through a tube to the flush ring. When the air pressure is relieved, the diaphragm contracts to draw more waste into the container.

The advantage of a recirculating system is that less waste retention capacity is required. No flush fluid is added to the system with each successive flush, rather the fluid that is in the system (pre-charge and waste fluids) is recirculated. When the toilet is used, the only addition to the retention tank is the waste material itself. This also means that multiple flushes per toilet use do not cause capacity problems. Usually a pre-charge of one to two gallons of liquid is put in the retention tank. This fluid includes disinfectant, deodorizer and coloring (usually blue).

The disadvantages of recirculating toilets are:

- There are moving parts (i.e., filter pumps) in the waste material, making maintenance difficult.

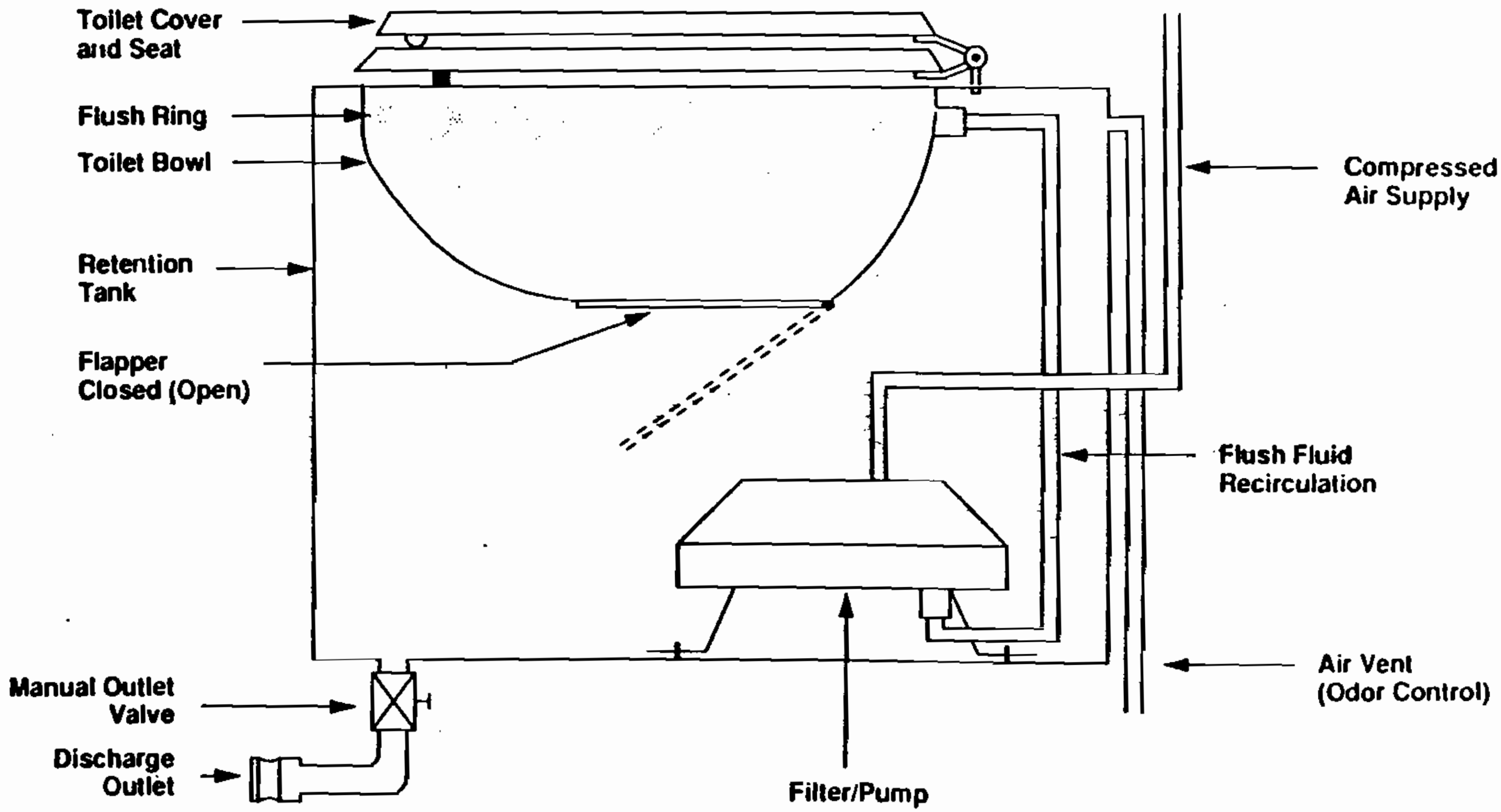
- The odor suppression by the deodorizer in the pre-charge becomes less effective the longer the waste is kept in the tank and recirculated.

- When the retention tank is located below the toilet bowl and the only separation is the flapper, it is possible for the waste to spill out if a full tank is jolted.

Monogram Sanitation is the principal supplier of recirculating toilets. As well as the integral tank version illustrated in Figure 2, Monogram also makes systems with a "remote" holding tank. With purely gravity transport of the waste into the tank, and the need for recirculation, the "remote" holding tank must be situated below and near the toilet. As with gravity systems, this constraint makes the remote tank version unsuitable for bilevel cars with toilets on the lower level. The self-contained version can physically be used anywhere.

Figure 2

Self Contained Recirculating Toilet



The flush is initiated by an electro-mechanical button which sequences the introduction of water into the bowl, opens the flapper, runs the macerator for a predetermined length of time and closes the flapper. Since each toilet has its own macerator, all toilets can flush simultaneously without hampering the performance of the system. Water consumption per flush is typically in the range of 32 to 64 ounces.

Retention/dump versions of gravity/air pressure systems have proved reasonably satisfactory in Amtrak service. Gravity systems must have the holding tank below the level of the toilets and long pipe runs between toilet and tank should be avoided. This makes these systems difficult to apply to bilevel and sleeping cars.

Clogging generally only occurs when something jams in the flapper, or when the grinder is jammed. Macerators mounted horizontally with vertical slots on the bottom are especially prone to jamming.

Suppliers of gravity/air pressure systems in the United States are Microphor, Chamberlain GARD and Railtech. Figure 1 is typical of Microphor or GARD products. The Railtech products have a vertically-oriented macerator and holding tank directly below the bowl to facilitate clearing of obstructions.

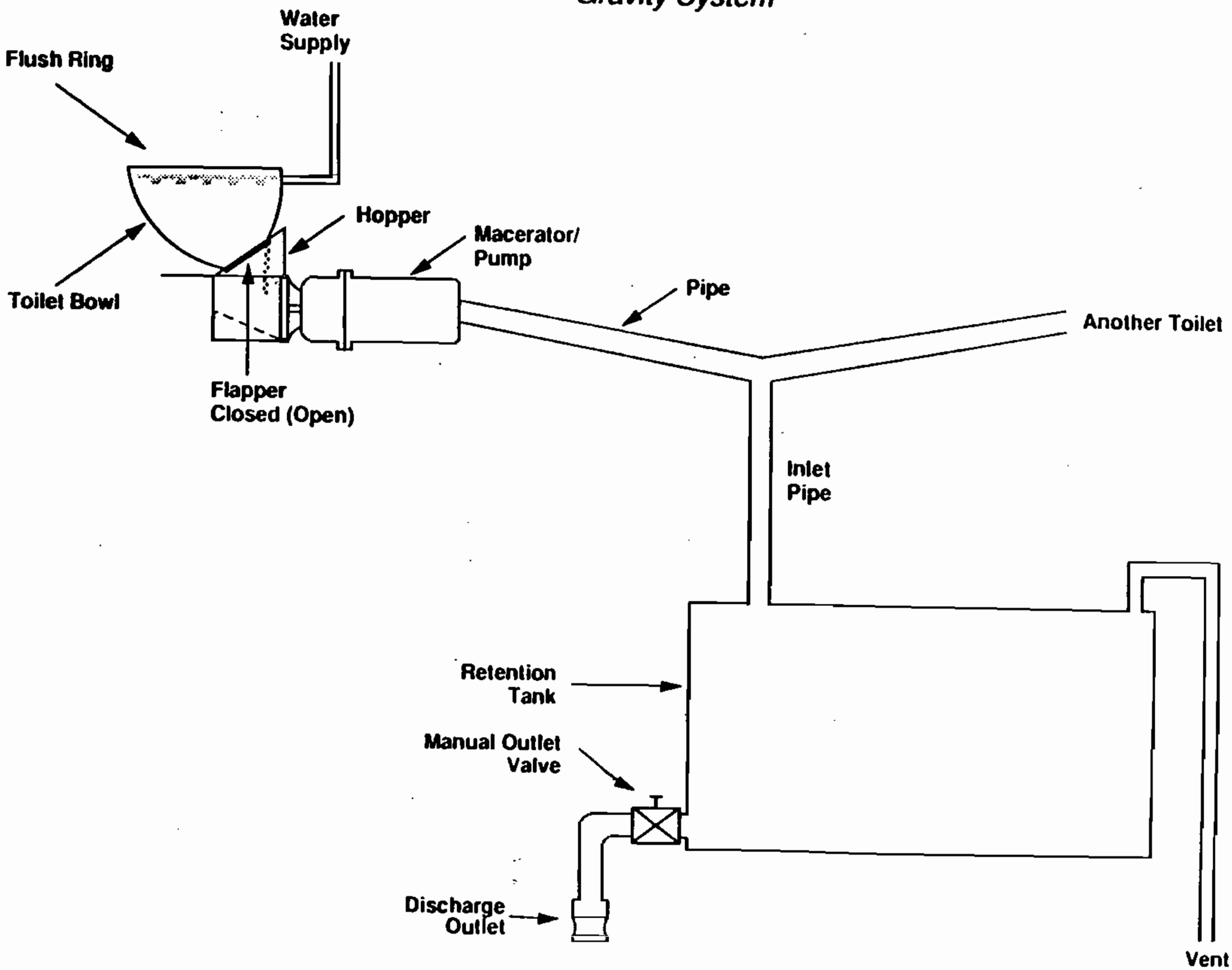
Recirculating toilets accomplish bowl clearing, bowl washing, and transport through the pipes (when necessary) by recirculating the fluid from the retention tanks. A typical system is illustrated in Figure 2.

Normally, the flush is initiated by an electro-mechanical button. Compressed air is injected into a filter/pump in the retention tank forcing the liquid waste through a filter and out through a tube into the flush ring. This fluid is used to clear the waste from the bowl and wash the bowl. Since many recirculating toilets have the retention tank directly below the bowl there is no need for pipe transport. The waste merely drops into the retention tank when the flapper opens.

Several types of filters and pumps are used in recirculating toilet systems. Newer models use a pin filter, a flat piece of plastic with a honeycomb arrangement of holes through it. A second piece of plastic is fitted against the honeycomb with pins sticking through each hole in the honeycomb. Each pin is of a diameter slightly smaller than the hole to allow

Figure 1

Gravity System



Identification and Description of Waste Retention Technology

A number of waste retention technologies have been developed for use in transportation equipment. These range from large multi-toilet systems for cruise ships; the various systems developed for aircraft (probably the most significant market segment for suppliers); rail car systems; and single-unit systems for buses, recreational vehicles and pleasure boats.

In all cases, the requirement is to control release of waste. Also, in all cases, the technology development has concentrated on toilet systems. It appears that no systems have been developed for grey water waste (from washing, food service activities, etc.). Therefore, the review of technology focused on toilet waste retention, since there was no grey water technology to review.

The review also focused on systems designed or adapted for use in rail cars. Since there are a significant number of such systems which would meet Amtrak's needs, other technologies were not examined. Incineration which is used in some marine systems was not given further consideration due to its high energy requirements and impracticability to rail application.

Three generic technologies represented in the toilet waste retention systems are offered by the supply industry:

- Gravity/Air Pressure systems
- Recirculating systems
- Vacuum systems

Each of these is now briefly described.

Gravity and air pressure systems are low fluid volume toilets which use gravity or compressed air to transport the waste from the toilet to the retention tank. Both systems use a macerator (grinder pump) to liquify the waste and facilitate easier transport.

A typical gravity system has a macerator just below the flapper (see Figure 1). After the water has entered the toilet bowl, the flapper opens and the waste drops into a hopper and is immediately ground by the macerator. It is pumped out of the macerator into sloped piping and drains to the retention tank.

- Capital cost of installing the systems in new cars during original manufacture. Note that costs of retrofitting waste retention systems to existing cars have not been addressed.
- Operating costs of waste retention systems, primarily for waste pumpout and disposal at car servicing locations
- Maintenance costs of in-car waste retention systems

Capital cost estimates for the different systems were obtained from the vendors and were based on the assumption of a reasonably sized order (for example, for 50 or 100 car-sets of equipment). All other costs were based on Amtrak's current experience of installing, operating and maintaining existing waste retention and disposal systems, with adjustments to reflect, as far as possible, differences between the systems currently operated by Amtrak and the full-retention systems offered by the supply industry.

Two spreadsheet computer models were developed: one calculates annual costs per car for different kinds of cars and trip lengths. The second calculates costs for typical routes, using the mix of cars and service frequencies appropriate to each route. Costs have also been aggregated to obtain total system costs, assuming that all services are operated with cars fitted with waste retention systems as original equipment. Since there is a wide range of uncertainty regarding costs, high, low and median estimates have been developed.

- Evaluation Program Recommendations

The evaluation of waste retention systems was based on past experience of similar systems on Amtrak and elsewhere (where available) and on a "desk" review of designs and schematics. This is necessarily incomplete, because adequate test and service experience data is lacking for many of the available systems. In response to this situation, a suggested evaluation program has been developed. This is designed to resolve the "unknowns" identified in the evaluation, and involves further "desk" analysis plus bench or laboratory tests and in-service testing. Soliciting passenger reactions to the systems is an important part of in-service trials.

The firms contacted were:

United States

- Monogram Sanitation
- Envirovac Inc. (EVAC)
- Chamberlain GARD
- Microphor Inc.

Canada

- Railtech Ltd.

Aqua Sans has also submitted information on a treatment system using an oil flush concept.

This field research was followed by analysis of three principal aspects:

• Retention System Performance Evaluation

  This includes defining a set of waste retention system performance criteria covering the following issues:

  - Passenger acceptability
  - Service reliability
  - Maintainability and ease of servicing
  - Environmental acceptability
  - Car configuration impacts
  - Ability to meet the 72-hour retention requirement

  Each proprietary system was rated against each criterion. Where it was possible to reach a factual conclusion based on the available evidence, this was done. In many cases, especially in areas relating to service reliability, insufficient information was available to support evaluation. This leads into requirements for an evaluation program, to resolve the unknowns.

• Cost Analysis

  The cost analysis provides estimates of capital, operating and maintenance costs for both in-car toilet systems and for equipment and operations at car servicing locations.

  The costs included in the analysis are:

  - Capital cost of waste retention systems, as provided by the manufacturers

Review and Analysis of Waste Retention Systems

This section briefly describes the work performed during the study. The basic approach consisted of a series of interviews followed by analyses. The interviews were conducted in person or by telephone with:

- All departments of Amtrak which could provide useful information on toilet and waste retention issues. These included representatives of departments concerned with new car engineering, car maintenance, passenger service (for information relating to passenger complaints, etc.), purchasing (for spare parts costs), and the Beech Grove shops (for information on toilet installation).

- Representatives of rail service operators elsewhere in North America, and in Europe and Japan. The interviewees were asked for some basic details about their operations, what retention toilet systems they have used, and their service experience with them. The following organizations were interviewed:

  North America:

  - Metro North Commuter Railroad
  - Long Island Railroad
  - Massachusetts Bay Transportation Authority
  - METRA (Chicago)
  - Via-Rail (Canada)
  - GO Transit (Toronto)

  International:

  - Japan Railways
  - British Rail
  - French National Railways (SNCF)
  - German Federal Railways (DB)
  - Danish State Railways (DSR)

- Each vendor of waste retention systems active in the North American market. Full details of all available "models" for rail passenger cars were obtained, including prototypes specifically developed to meet Amtrak's requirements.

the different technologies for a possible retrofit program. However, this is not the focus of this report. The technologies are only discussed in the context of installation in new cars yet to be built.

This report summarizes the work performed in the study and the principal findings.

To meet this objective, the following was accomplished:

1. Investigation and summary of existing waste disposal practices

   - on passenger cars currently operated by Amtrak
   - on other rail cars and locomotives operating in North America
   - on international rail systems outside North America

2. Identification, description and evaluation of available technologies that do not dump waste onto tracks. This includes:

   - Detailed descriptions of the identified systems
   - Analysis of capital, operating and maintenance costs, and of maintenance and servicing needs
   - Identification of fixed facilities required, and their location within the Amtrak network
   - Evaluation and identification of advantages and disadvantages of each system with respect to their installation into different kinds of new passenger cars (coaches, sleepers, etc.)
   - Discussion of environmental issues associated with waste handling and disposal, including the impact of the chemicals used in some systems, and the acceptability of the waste to local waste treatment systems.
   - Develop recommendations and a schedule for the installation of prototypes, a testing program and implementation of complete systems.

There are also some specific issues that are <u>not</u> addressed in the study. Most notably, these are:

- The study does not address the issue of whether or not the present practice of dumping waste on the tracks poses a public health hazard. The issue under investigation in the study is "given that waste retention systems are required, what technology is available to meet the requirement," not "what are the public health concerns associated with dumping waste on the tracks."

- The study also does not address any of the questions associated with <u>retrofitting</u> retention toilets to existing passenger cars in the Amtrak fleet. Obviously, much of the information in this report will be of value in evaluating response to this request, the Department of Health, Education and Welfare conducted a comprehensive study of the public health, environmental, financial and other aspects of the Federal regulations of waste discharge from railroad vehicles. The resulting report concluded that:

- There was no identifiable public health risk arising from the discharge of untreated waste from intercity rail passenger cars.

- New passenger cars should be fitted with systems that retained waste at speeds below 25 mph. This would reduce dumping in or near urban areas where dumping causes the greatest potential risk to health, and considerable aesthetic offense. A manual override should be provided to prevent discharge at other designated locations (such as drinking water watersheds).

- Retrofitting older passenger cars could not be justified in view of the low health risks, high costs, and limited future life of these vehicles.

Following these recommendations, all new cars put into service by Amtrak since 1978 have included systems providing for the automatic retention of waste at speeds below 25 mph. No changes have been made to cars manufactured prior to 1970. This policy is apparently voluntary rather than required by Federal regulation. Intercity railroad cars are exempt from the requirements of Section 361 of the Public Health Service Act that prohibits the dumping of untreated waste.

The dumping of untreated waste, or indeed any form of waste, is being questioned by several state and local governments. There have been several instances of people being hit by waste dumped from passenger cars and this has focused attention on the issue. As a result, the States of Oregon and Florida have filed suit against Amtrak to prevent this practice, relying on state environmental protection laws. Furthermore, bills have been introduced into Congress to repeal the exemption enjoyed by Amtrak, and to require waste retention systems to be fitted to all passenger cars within three years.

In response to this and similar events, the Federal Railroad Administration has been directed by Congress to conduct a study to identify suitable toilet and waste retention technologies for future year passenger car acquisitions. The overall objective of this study is to identify, describe and evaluate suitable toilet and waste retention technologies that do not dump waste on the track.

Background

Since the earliest days of long distance rail passenger service, passenger cars have been provided with on-train toilets and washing facilities. Up until about 1970, toilets were simple water-flush units that discharged waste directly on the track. Use in stations and at a few environmentally sensitive locations was prohibited.

In the early 1970s, there was heightened concern that the dumping of waste from railroad equipment might represent a public health hazard. This led to legislation requiring railroad locomotives, cabooses and passenger cars to be fitted with systems to prevent discharge of untreated waste onto the track. New equipment constructed after March 31, 1971 had to comply with this regulation, and existing vehicles had to be retrofitted with such equipment by December 31, 1974.

As a result, the Amfleet I cars ordered by Amtrak for delivery in 1975 and 1976 were fitted with aircraft-style recirculating retention toilets. These cars are used on short-haul corridor-type services. Similar action was taken by commuter rail service operators such as the Long Island Railroad.

The regulation requiring retrofitting of waste retention systems to existing intercity cars was never implemented, primarily because there was no equipment available on the market that could meet reliability and performance requirements at an acceptable cost.

The legislative situation changed in 1976 by enactment of the Railroad Revitalization and Regulatory Reform Act of 1976, P.L. 94-210, as amended by the Rail Transportation Improvement Act of 1976, P.L. 94-535. These acts exempted intercity rail transportation services from Section 361 of the Public Health Service Act (42 U.S.C. 264). Commuter and freight railroad operations were not exempted, and equipment acquired for such operations have been fitted with retention toilets or on-board waste treatment systems. Retrofits to existing equipment were also carried out.

When Congress exempted intercity rail transportation equipment from the prohibition on dumping untreated waste, it also directed that a study be made of this issue. In

- There are no systems or technologies on the market or in prototype form that provide for the retention of "grey" water (from washing or dining car activities). If Amtrak were required to fit such systems, it would have to start from scratch. Given that the technically more demanding problem of toilet waste retention has largely been solved, grey water retention systems are technically feasible. However, they will add complexity; therefore, capital and operating costs will increase. Waste disposal costs, in particular, will increase because disposal charges by waste treatment facilities are based on volume.

- There appear to be no significant environmental or engineering problems associated with toilet waste pumpout and disposal. Both chemically treated waste from recirculating toilets and concentrated waste from holding tanks are acceptable to local waste treatment plants.

The principal findings of this study are as follows:

- There are a number of railroad toilet waste retention systems developed by the supply industry which can potentially meet the performance requirements for Amtrak's coach and sleeping cars. However, some of these systems are only at the prototype stage of development and none have had sufficient service experience in an environment similar to Amtrak, where a 72-hour retention capability is required.

- It is reasonable to include a toilet system with retention capability on all future passenger cars.

- Amtrak's past experience with retention toilet systems on existing passenger coaches has not been good. The retention and retention-dump systems have been fitted to all cars purchased since Amtrak's formation in 1970. Some of these systems have been unreliable and Amtrak has been forced to adopt costly preventive maintenance procedures to keep them working satisfactorily. Passenger surveys have shown that good restroom facilities are of high importance to passengers. A high level of passenger dissatisfaction exists with the condition of restrooms, as seen by the number of customer complaints.

- A carefully structured evaluation program for waste retention systems is essential if Amtrak is to avoid the kinds of reliability and performance problems that have plagued toilet systems in the past. This program should include:

  - Establishment of system performance criteria
  - "Desk" evaluation of system performance
  - Bench tests of critical components or complete systems, especially "abuse" tests
  - Service evaluation of systems that have "passed" desk evaluations and bench tests. These should include surveys of passenger response.

- The bench test should include an abuse test. Passenger abuse is a major cause of toilet malfunction, and vulnerability to damage from this cause should be an important evaluation criterion.

- Life cycle costs should be emphasized in evaluating the economics of alternative systems. Such evaluations should consider capital outlays for the toilets, installation of the toilets and other support facilities, as well as continuing operating and maintenance expenses.

Executive Summary

Amtrak presently is permitted to dump untreated waste from passenger train toilets and washing facilities directly onto the track. Older cars (predating Amtrak's formation in 1970) have no capability to retain waste. Recently constructed cars are fitted with either full-retention, or short-term retention systems which dump waste on the track at speeds over 25 mph.

This practice is being questioned by several state and local governments, and legislation has been introduced in Congress that would require Amtrak to fit full-waste-retention systems to all cars. As part of this process, Congress has requested that a study be made to identify and evaluate waste disposal technologies suitable for application in future Amtrak passenger cars. This report summarizes the results of the study.

The study includes the following:

- A review of existing waste retention practices on rail services in North America, Europe and Japan. The purpose is to determine what technologies are available, what systems are in use, and the nature and extent of service experience with them.

- A full description and evaluation of waste retention technologies currently offered in the United States by the supply industry. This evaluation covers various aspects of the performance and reliability of the systems, as well as capital and operating cost estimates for different types of cars.

- A review of waste disposal issues, including acceptability of the chemical or highly concentrated waste produced by transportation waste retention systems to waste treatment facilities, and associated costs.

- A review of the requirements for a test and evaluation program to confirm that retention systems fully meet Amtrak performance requirements for 72-hour retention capability.

Preface

The Fiscal Year 1989 House Appropriations Committee (H.R. 3015) directed the Federal Railroad Administration (FRA) to undertake an analysis of suitable toilet and waste retention technologies for use on future passenger cars. Specifically, the Conference Report stated:

> "Of the funds made available to the Federal Railroad Administration under the head "Railroad Research and Development," $500,000 shall be available to identify suitable toilet and waste retention technologies that do not discharge onto tracks to be included as part of future year passenger car acquisitions. The Federal Railroad Administration shall report its findings to the appropriate committees within nine months after passage of this Act."

This report addresses the conclusions of the study to identify suitable toilet and waste retention technologies.

This report is divided into the following sections:

- Introduction and Background
- Review and Analysis of Waste Retention Systems
- Identification and Description of Waste Retention Technology
- Existing Practices and Experience
- Evaluation of Waste Retention Systems
- Capital, Maintenance, and Operating Costs
- Waste Disposal, Health, and Environmental Issues
- Waste Retention System Evaluation Programs
- Conclusions

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