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of Transportation
**Federal Railroad
Administration**

Review and Analysis of Railroad Passenger Car Waste Retention Systems

Volume I: Report and Appendices A and B

**Office of Research and
Development
Washington DC 20590**

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Acorn Park
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**January 1991
Final Report**

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16. Abstract

The traditional practice of dumping railroad toilet and other waste directly onto the tracks is still used on most passenger cars operated by Amtrak. However, this practice is being questioned and legislation to require full waste retention systems is under consideration. This report has been prepared in response to a Congressional directive to identify, describe and evaluate waste-retention systems able to eliminate the need for direct dumping on the track.

This report provides the following information:

- A description of waste retention systems currently used by intercity and local passenger railroads in the United States and elsewhere, including service experience.
- A discussion of waste disposal and environmental issues.
- An evaluation of the performance of the different waste retention technologies and systems.
- Review and estimate of capital, operating and maintenance costs.
- Recommendations regarding test programs for waste retention systems.

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ENGLISH TO METRIC

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1 inch (in) = **2.5 centimeters (cm)**
 1 foot (ft) = 30 centimeters (cm)
 1 yard (yd) = 0.9 meter (m)
 1 mile (mi) = 1.6 kilometers (km)

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 1 square foot (sq ft, ft²) = 0.09 square meter (m²)
 1 square yard (sq yd, yd²) = 0.8 square meter (m²)
 1 square mile (sq mi, mi²) = 26 square kilometers (km²)
 1 acre = 0.4 hectares (ha) = 4,000 square meters (m²)

MASS - WEIGHT (APPROXIMATE)

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 1 pound (lb) = .45 kilogram (kg)
 1 short ton = 2,000 pounds (lb) = 0.9 tonne (t)

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1 teaspoon (tsp) = 5 milliliters (ml)
 1 tablespoon (tbsp) = 15 milliliters (ml)
 1 fluid ounce (fl oz) = 30 milliliters (ml)
 1 cup (c) = 0.24 liter (l)
 1 pint (pt) = 0.47 liter (l)
 1 quart (qt) = 0.96 liter (l)
 1 gallon (gal) = 3.8 liters (l)
 1 cubic foot (cu ft, ft³) = 0.03 cubic meter (m³)
 1 cubic yard (cu yd, yd³) = 0.76 cubic meter (m³)

TEMPERATURE (EXACT)

$$[(x - 32)(5/9)]^{\circ}\text{F} = y^{\circ}\text{C}$$

METRIC TO ENGLISH

LENGTH (APPROXIMATE)

1 millimeter (mm) = 0.04 inch (in)
 1 centimeter (cm) = 0.4 inch (in)
 1 meter (m) = 3.3 feet (ft)
 1 meter (m) = 1.1 yards (yd)
 1 kilometer (km) = 0.6 mile (mi)

AREA (APPROXIMATE)

1 square centimeter (cm²) = 0.16 square inch (sq in, in²)
 1 square meter (m²) = 1.2 square yards (sq yd, yd²)
 1 square kilometer (km²) = 0.4 square mile (sq mi, mi²)
 1 hectare (ha) = 10,000 square meters (m²) = 2.5 acres

MASS - WEIGHT (APPROXIMATE)

1 gram (gr) = 0.036 ounce (oz)
 1 kilogram (kg) = 2.2 pounds (lb)
 1 tonne (t) = 1,000 kilograms (kg) = 1.1 short tons

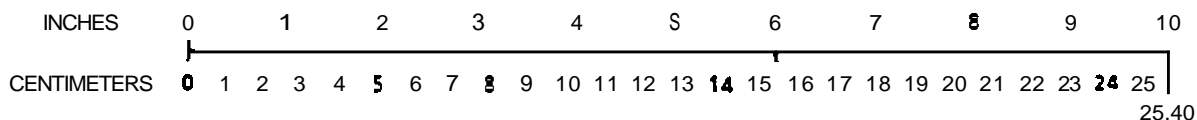
VOLUME (APPROXIMATE)

1 milliliter (ml) = 0.03 fluid ounce (fl oz)
 1 liter (l) = 2.1 pints (pt)
 1 liter (l) = 1.06 quarts (qt)
 1 liter (l) = 0.26 gallon (gal)
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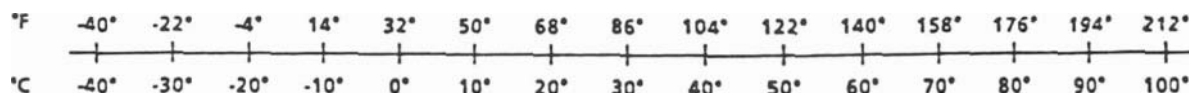
TEMPERATURE (EXACT)

$$[(9/5)y + 32]^{\circ}\text{C} = x^{\circ}\text{F}$$

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For more exact and/or other conversion factors, see NBS Miscellaneous Publication 286. Units of Weights and Measures. Price \$2.50. SD Catalog No. C1310266.

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Other Rail Svstems

Several rail systems responded to our inquiries or entertained visits by ADL staff. These included:

North America

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

International

Japan Railways
British Rail
Danish State Railways
German Federal Railways
French National Railways

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Chapter 1

BACKGROUND AND INTRODUCTION

1.1 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 was prohibited, and prohibitions were also applied at a few environmentally sensitive locations, for example, where the waste might contaminate a public drinking water supply (see Ref. 1).

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 equipment 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.

However, a regulation requiring **retrofitting** of waste retention systems to existing cars was never implemented, primarily because there was no equipment available on the market that could meet reliability and **performance** requirements. Even if such equipment had been available, retrofitting costs were estimated to be very high.

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. Thus, all new equipment acquired for such operations have been fitted with retention toilets or on-board waste treatment systems, and as far as we are aware, most older cars and locomotives were also were also retrofitted.

At the same time as exempting intercity rail transportation equipment from the prohibition on dumping **untreated** waste, Congress 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 (Ref. 2) 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.

As a result of this investigation, **all** new cars put into service by **Amtrak** since 1978 have embodied 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. The present legal situation is that intercity railroad cars are exempt from the requirements of Section 361 of the Public Health **Service** Act (Ref. 3).

This exemption has been recently called into question, and the dumping of untreated waste, or indeed any form of waste, is becoming increasingly unacceptable. The primary reason for this has been several instances of people being hit by waste dumped from passenger cars. As a result, the states of Oregon and Florida have filed suit against **Amtrak** to prevent this practice. **Like** most states, these states have laws regulating such dumping, but **Amtrak** contends that their exemption to the federal law overrides state laws. This contention is being tested in the courts. Furthermore, bills have been introduced into Congress to repeal the exemption enjoyed by **Amtrak**, and require waste retention systems to be fitted to **all** passenger cars within three years (Ref. 4).

In response to this and similar events, 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" (Ref. 5).

This **report** has been prepared in response to that directive.

1.2 Objective and Scope of Work

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. The evaluations are to be conducted with a view to installations on new-built intercity passenger cars.

More specifically, the scope of work and tasks that are to be performed to meet this objective are:

1. Investigate and summarize 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. Identify, describe and evaluate 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.
3. Prepare and submit to the FRA an outline for the report, a draft final report, and a final report. A presentation of results will also be required.

There are also some specific issues that are not addressed in this study. Most notably, these are:

- This 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 this 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 retrofitting 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.

1.3 Guide to This Report

The complete results of the study of waste retention systems are provided in **this report**. The systems are described and evaluated in the body of the report, and supplementary, detailed information is provided in Appendices. The layout of the **report** is as follows:

Chapter 2 describes the present situation regarding waste retention system practices on **Amtrak**, elsewhere in North America and internationally. The descriptions include what systems are in use, for how long, and in what kinds of rail passenger service. Where available, some comments on service experience are provided. Detailed descriptions of individual proprietary systems is generally not provided, as this is given in *Chapter 3*.

Chapter 3 describes all the proprietary waste retention systems that are available from the supply industry, and that potentially could meet Amtrak's service requirements. The retention systems are grouped by operating principle. There are three generic such principles represented, dependent on the process used to transport waste from a toilet to the holding tank.

- Gravity and air pressure systems
- Recirculating systems, which use the holding tank contents as a flushing fluid
- Vacuum systems

Chapter 4 discusses waste disposal, health and environmental issues, and particularly focuses on the acceptability of the waste to local public waste treatment facilities.

Chapter 5 provides *an* evaluation of the waste retention systems' performance relative to the desirable performance criteria. The performance criteria are formulated to be compatible with **Amtrak's** operating requirements, to provide a performance acceptable to **Amtrak's** passengers, and to provide adequate reliability and maintainability. Since many of the systems evaluated have no service history in the Amtrak environment or an equivalent, this chapter also identifies performance issues that can be evaluated only by a suitably designed test program.

Chapter 6 provides an analysis of waste retention system capital, operating and maintenance costs. Each individual cost is estimated from information supplied by the manufacturer, and current Amtrak practice and experience regarding toilet maintenance. The chapter describes the sources of the cost data used, the structure of

the Lotus spreadsheet PC model used to calculate costs, and provides a summary of the results. These results show capital, operating and maintenance costs **by** individual car type (coach, sleeper, etc.), individual service type (short haul, long haul), and for the **Amtrak** system as a whole. Costs of pump-out and pump-out facilities **are** included.

Chapter 7 summarizes **Amtrak's** present retention toilet evaluation program, and its current status. Based on the evaluation of toilet systems provided in Chapter 5, some recommendations are provided for an enhanced test **program** to provide the information needed to fully evaluate the ability of the different systems to meet **Amtrak's performance** needs. An estimated test schedule is also provided.

Chapter 8 provides a summary of the key results of the study:

- Domestic and international experience with waste retention systems,
- The technologies and their performance,
- Capital, operating and maintenance cost conclusions.

Chapter 2

RECENT TOILET PRACTICE AND EXPERIENCE

2.1 Introduction

Amtrak currently operates approximately 1500 passenger cars, excluding baggage handling and mail equipment. This passenger car fleet is comprised of five distinct subsets of equipment:

- Heritage (499)
- Amfleet I (483)
- Amfleet II (149)
- Superliner (282)
- Horizon (100)
- Viewliner (3)

The Heritage fleet consists of a heterogeneous mix of equipment inherited from Amtrak's predecessors. By contrast, the other five groups each consist of a single design or set of designs, in general manufactured by a single firm over a limited time frame. Subsystems, such as toilets, within each of these five groups are nearly identical. For example, if you examine a toilet installation on any two Amfleet II cars, they are likely to be identical. That is often not the case in the Heritage fleet. However, nearly all of the Heritage cars are equipped with the same generic type of toilet, though installation details are often quite different

In the following sections we will describe the current typical toilet equipment installation on each group of cars, Amtrak's operating experience with each distinct toilet installation, Amtrak modification programs of the original equipment and passenger acceptance for each toilet type, as well as an overview of passenger issues.

2.2 Recent Amtrak Practice and Experience

2.2.1 Heritage

The Heritage fleet has an average age of approximately 40 years. This equipment is used on both short and long distance trains.

2.2.1.1 Equipment Description

The cars in this fleet group are typically equipped with stainless steel toilets that are non-retention and use gravity and high water volume to flush directly to track. This is the basic "hole-in-the-floor" straight-through design common to most passenger rail equipment for the last hundred years.

The original equipment flush mechanism is a floor pedal, which when depressed with foot pressure, allows for the flow of water into the bowl, flushing the **contents** out of the bowl, down a short waste pipe that penetrates the car floor and extends downward by approximately one foot (see Figure 2.1).

If held down for an extended period or repeatedly depressed, this manual flush mechanism can lead to a high usage rate of the train's water supply. Because the water flush volume is generally manually controlled, precise volumes are difficult to estimate. However, based on limited observation, a typical flush might require 1-2 quarts of water.

2.2.1.2 Practice and Operating Experience

Since there is no water pressurizer, waste treatment, waste transport equipment, or waste storage of any **kind**, the failure modes are fairly limited:

- Freezing of the water supply line or lines, which can affect one or more toilets on a car
- Failure of the flush trigger mechanism
 - manual type: this may result from cracking or breaking of the foot pedal lever
 - electrical type: failure of the electrical supply, the switch or the electric solenoid may occur
- Presence of foreign material in the toilet bowl that will not flush (eg., sneakers or garments), discouraging subsequent use. Since only relatively large objects will cause such failure, these are relatively rare
- **Cracking** of the toilet assembly itself (bowl and pedestal)

The water supply freezing, **cracking** of the manual foot pedal flush lever and clogging of the bowl itself are the predominant failure modes.

The vulnerability of the water supply lines to freezing in older rail passenger car equipment is difficult to address. In cold weather, freezing **temperatures** often lead to a marked increase in toilet equipment failures and resulting passenger complaints on the **Amtrak** system as a whole (see Figure 2.2). Heritage cars, together with the Superliner fleet, are responsible for a considerable share of these complaints.

With regard to the foot pedal flush lever failures, Amtrak has over the years replaced a number of them with electric solenoid valves. This leads to controlled and most probably reduced water consumption and improved reliability and passenger convenience. We understand that maintenance experience for the solenoid has been **good**.

Figure 2.1
Heritage Non-retention Toilet

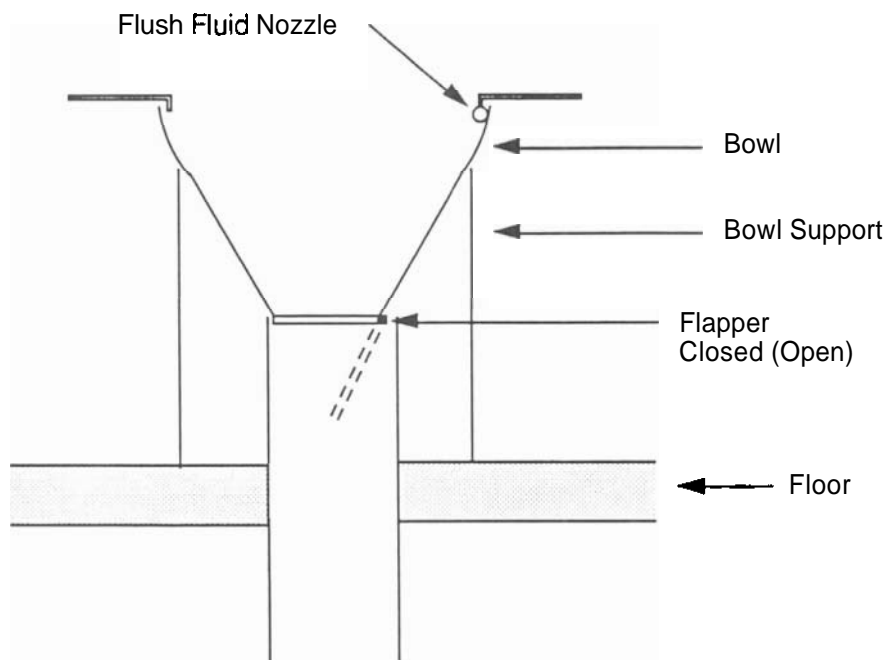
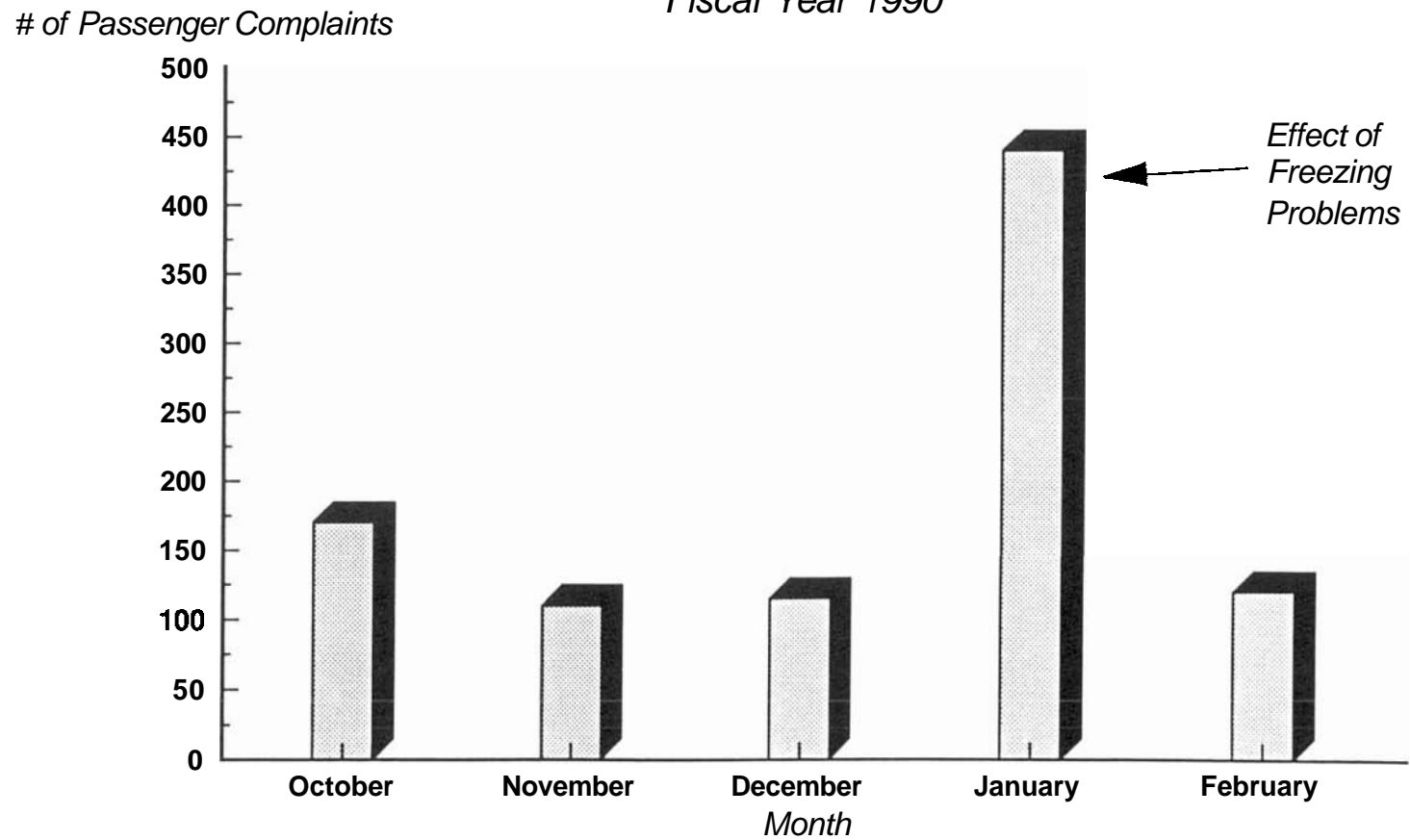


Figure 2.2

*Passenger Complaints Regarding
Condition of Restrooms
Fiscal Year 1990*



Source: AMTRAK Marketing

The opening in the toilet is offset from and narrower than the waste pipe, so that clogs are uncommon, though foreign material might have to be removed from the bowl itself. This is really a passenger behavior issue and not a reflection of toilet design or technology.

Because of the flush mechanism, the toilets cannot be prevented from flushing at inappropriate times (such as while in a station). Many of the Heritage car toilets still have manual controls. Those that have a solenoid device are not linked to any central control or **override** function that would prevent flushing at inappropriate times.

2.2.1.3 Appearance and Ease of Passenger Use

The Heritage fleet toilets typically have polished or brushed stainless steel bowls. These bowls do stain, requiring periodic removal of the toilet assembly for sanitizing and blasting to remove surface discolorations.

The manual flush mechanism requires the passenger to monitor the flush process to determine when the pedal can be released, or whether a **reflush** is required.

2.2.2 Amfleet I

The **Amfleet I** equipment, built by the Budd company between 1975 and 1976, operates primarily in the Northeast **Corridor**. This fairly narrow geographic deployment allows for a concentration of resources for operation and maintenance of this homogenous group.

2.2.2.1 Equipment Description

This segment of **Amtrak's** rolling stock is equipped with Monogram air-powered self-contained recirculating toilets. A general description of this type of toilet is presented below in Section 3.4.1.

2.2.2.2 Operating Experience

The recirculating toilet has been the standard device on-board jet aircraft for many years. However, in the air travel environment, mp lengths are generally shorter allowing for more frequent servicing, if necessary, than is possible in the rail passenger environment. In addition, usage of facilities may be less frequent on a per passenger basis given the reduced mobility of air passengers within the aircraft, as compared to rail travelers. In addition to these largely uncontrollable differences, Amtrak and its supplier of these particular toilets, Monogram, indicated that some of the problems with recirculating toilets in the rail environment may be attributable to

their **mixed** success in enforcing adherence by field maintenance personnel to the specified servicing procedures required for this equipment. For all of the above considerations, Amtrak's experience with recirculating toilet technology has been less than optimal, particularly when taking passenger acceptance into account.

The **recirculating** toilet can become non-functional through any of the following means:

- Flush system failure
 - Failure of **regulator/flush** valve that triggers diaphragm pump
 - Failure of diaphragm pump or connecting hoses
 - Failure to replenish pre-charge after draining waste tank
 - Clogging of the filter medium (this can lead to pump failure)
- Toilet bowl blockages due to introduction of foreign objects
- Tank filled to capacity
 - No warning indication offered (if bowl is full, passenger may nonetheless believe that flushing will clear bowl, which it will not)
 - **Waste/pre-charge** mix can slosh in bowl **and/or** spill onto floor

In addition to these outright failure modes, there is a gradually increasing unacceptability of performance as a **recirculating** toilet nears capacity. As the toilet nears capacity the odor given off by the mix of pre-charge and human waste can overcome the perfume component in the pre-charge and become quite unpleasant. The maximum desirable operating time between pump-out and servicing operations is about 8 hours.

The toilet could also fail due to loss of **train** line air pressure due to connecting pipe failure or total loss of train air. However, the latter problem would also disable the entire **train** and the former event is not a noted cause of failure.

In order to minimize flush system failures and maintain an acceptable appearance, these toilets typically receive a full overhaul every 120 days. Because a number of the working elements (diaphragm pump, filter, hoses) are actually immersed in waste while in use, servicing must be preceded by cleaning and decontamination steps that raise the servicing cost. Flush system failures have been reduced through modification of the filter, pump mounting and other minor changes, though at a significant maintenance cost.

Filter medium problems are minimized by use of normally self-clearing pin filters. However, deposition of paper towels into these toilets can cause clogging problems. **Introduction** of other foreign matter may block proper emptying of the toilet, but is less likely to prevent operation. A list of foreign matter reported by some of the manufacturers as found in Amtrak toilets is presented in Figure 2.3.

Amtrak indicated some difficulty in attaining error-free accomplishment of three routine servicing tasks on a continuing basis that are minimum requirements for the use of recirculating toilet technology:

- Waste clean-out at mp end points
- Proper use of non-abrasive cleaners on the bowl surface, and
- Replenishment of the pre-charge with the correct balance of **chemical/perfume** additive

Failure to service the toilets at end points will likely lead to a toilet reaching capacity en route. Because the **Amfleet** I toilets are stand alone units that do not share a single large waste storage reservoir, capacity may still be reached at a specific toilet, despite proper servicing. For example, frequency of use of a specific toilet on a train is often dependent on placement within the train, proximity to the **lounge/cafe** car and to the cleanliness and working condition of adjacent toilets. Some of these elements are simply not controllable, suggesting a need for either larger waste tanks for each toilet or more frequent servicing. Space and operating schedules make these "fixes" difficult, if not impossible.

2.2.2.3 Appearance and Ease of Passenger Use

A retention toilet is a relatively simple device when compared to other toilets, such as some of the vacuum toilet designs. However, on a system basis, a comparison of alternative toilet technologies as discussed in Section 5 below, retention toilets do not fare well, largely due to maintenance difficulties. And even when recirculating units work correctly, servicing is costly and requires special care to avoid health risk. In addition, odors can be unpleasant. When a recirculating toilet fails, the results can be particularly unpleasant for the passenger.

In **part** for aesthetic reasons, **airframe** builders are now switching to vacuum technology. Virtually all commercial airliners built in the U.S. since 1988 have incorporated vacuum as opposed to recirculating toilet technology. Boeing, **McDonnell Douglas** and Airbus Industries are making the switch to vacuum technology not only for aesthetics, but for these three other factors:

Figure 23

List of Foreign Objects Found In Toilet Systems

<u>Item</u>	<u>Source</u>
Hypodermic Needles	Microphor
Pencils	Microphor
Pens	Microphor
Eyeglasses	Microphor
Coins	Microphor
Crushed Soda Cans	Microphor
Hairpins	Microphor
Disposable Razors	Mimphor
Disposable Diapers	Microphor
Tampax Plastic Holders	Microphor
Pocket Knives	Microphor
1/4" Bolts	Mimphor
Underwear	Microphor
Headrest Covers (w/nylon string)	Microphor
Paper towels (biodegradable)	Monogram

- A significant reduction in the number of openings in the airplane outer skin can be attained when applying vacuum technology
- Faster ground servicing of the aircraft is attainable
- Elimination of waste retention in the passenger space envelope can be achieved for greater design ease of both the bathrooms and the below floor equipment configuration

Apart from the issue of openings in an aircraft skin, these considerations also apply to intercity rail passenger cars. They are further discussed in the following chapters. One final aesthetic consideration concerns the appearance of the toilet bowls. Like the Heritage series equipment, the **Amfleet I** toilets typically have polished or brushed stainless steel bowls. These bowls do stain, requiring periodic removal of the toilet assembly for sanitizing and blasting to remove surface discolorations.

2.2.3 Amfleet II

The **Amfleet II** equipment is quite similar to the **Amfleet I** series, though seating density is lower. This equipment is used on both short and long distance trips primarily in the eastern United States.

2.2.3.1 Equipment Description

While **Amfleet II**'s are similar to **Amfleet I**'s, the toilet systems on each series are quite dissimilar. This segment of Amtrak's rolling stock is equipped with **Microphor non-retention** type high water volume (48 ounce) flush toilets. A general description of this type of toilet is presented below in Section 3.3.3.

2.2.3.2 Practice and Operating Experience

The **Microphor** gravity flush toilet is subject to failure in the following areas:

- Freezing of the train's water reservoir or water supply line to toilet
- Failure of flap valve
 - Flap fails to open, preventing flushing of bowl contents
 - Flap fails to close negating water seal, allowing odor to reach passenger compartment
- Macerator pump jamming or failing

Failure of the speed sensor which provides the signal to dump waste when speed exceeds 25 mph. The small waste holding **tank** quickly fills to capacity, leading to toilet failure.

The toilet flap failure could also occur with loss of **train** line air pressure due to connecting pipe failure or total loss of **train** air. However, the latter problem would also disable the entire train and the former event is not a noted cause of failure.

Macerator pump breakdown has been a leading failure mode for this toilet system design. Typically something small, such as a coin, gets lodged in the bottom slots of the macerator, causing binding and motor failure. This design has been modified in new equipment (see Horizon discussion below).

The gravity dumping process can result in waste spraying the **undercarriage** of the rail passenger car during release. This is discussed further under environmental issues in Chapter 4.

2.2.3.3 Appearance and Ease of Passenger Use

The high water volume flush usually results in a clean bowl. The lack of retention usually means there is no significant odor problem, providing the dump sensor is working. Like the **Amfleet** I's, these toilets have stainless steel bowls. These bowls do stain requiring periodic removal of the toilet assembly for sanitizing and blasting to remove surface discolorations.

2.2.4 Superliner

The Superliner cars, built in **1976-1982** by Pullman Standard, are used in long distance trains, such as Chicago to Seattle, with **trip** durations up to 48 hours.

2.2.4.1 Equipment Description

The Superliner cars incorporated many new design elements, including a new toilet systems technology. The original equipment order incorporated a Monogram vacuum toilet system, which had several features that were quite different from other equipment in rail service in North America:

- Vacuum transport technology which uses vacuum rather than simply gravity or a fluid pump to **transport** the waste from toilet to holding tank
- Microprocessor control of toilet flush logic
- Dual waste tanks to enable chemical treatment and temporary retention to eliminate coliform bacteria prior to dumping on the **track**. This feature was abandoned before the cars were **introduced** into **service**, since the Rail Passenger Service Act of **1976** allowed for **Amtrak's** continued dumping of untreated waste

2.2.4.2 Practice and Operating Experience

The Superliners have undergone significant modifications to the toilet systems since the introduction of this equipment. In addition to the change in the waste storage and treatment arrangement, Amtrak has modified the piping configuration and microprocessor logic along with other changes.

The Superliner toilet system is vulnerable to failure in six system areas:

- Train line air
 - provides actuating force for flush valve
- Hotel power
 - **supports** flush control logic and flush mgger
 - maintains temperature for water supply and waste pipes
- Potable water supply
 - washes the toilet bowl
 - provides a water seal from waste odor
 - assures good vacuum
 - facilitates waste transport
- Vacuum blower and controls
 - waste transport
 - bowl clearing
- Vacuum waste transport pipe
- Macerator pump
 - empties waste storage **tank**

Since their introduction, the toilet systems on the Superliner have been plagued with a considerable number of problems involving all of the subsystems described above. These problems are summarized below:

- Vacuum failure, which would generally disable all the toilets on a single car
 - Failure of the vacuum blower itself which effectively makes all toilets on a single car inoperative
 - The sticking open of a ball valve of any one toilet on a car which effectively disables the whole system on a car due to loss of vacuum. This may be due to valve failure or loss of train air which is required for actuation of the valve.

- The jamming open of the valve as a result of passenger misuse, which often entails depositing foreign objects into the toilet. This would effectively disable the whole system on a car due to loss of vacuum.

Vacuum waste pipe **obstructions**, which may disable one toilet, a bank of toilets sharing a common line to the waste storage **tank**, or all of the toilets on a single car. The original design included three features that contribute to the frequency of occurrence of this type of failure:

- The toilet opening diameter (2 inches) is larger than the narrowest pipe diameter (1 1/2 inches)
- The original routing of waste piping for toilets on the upper deck was quite circuitous
- The original piping layout lacked adequate reform pockets. These are U-bands, similar to water traps, that enable waste en-route between toilet and holding **tank** to accumulate and fill the full cross-section of the pipe. This greatly aids effective transport

The **first** shortcoming is being addressed by introducing a modified toilet assembly with a more **restricted** opening in the bowl to compensate for the 1.5 inch diameter piping. The last two elements have been, or are being changed on each of the Superliners to eliminate the above problems.

- Freezing of water supply pipes, which may disable one toilet or a bank of toilets sharing a common water line
- Freezing of waste in vacuum piping, the storage **tank** or outlet pipe which may disable one toilet, a bank of toilets sharing a common line to the waste storage **tank**, or all of the toilets on a single car if the storage tank or outlet pipe is blocked.
- Failure of the logic controller or individual electrical controls to the toilet flush valves
- Failure of the macerator pump, thereby preventing the emptying of the waste tank
- Failure of the speed sensor which allows inappropriate waste dumping or prevents the macerator pump from operating to empty the holding **tank**

2.2.4.3 Appearance and Ease of Passenger Use

The Superliner vacuum system, when functioning properly, results in a clean bowl with an odor free seal of potable water. The steep sided teflon bowl, when properly

cared for is quite stain resistant. The flush sound is loud, but not nearly as loud as certain airplane vacuum systems at 30,000 feet. While failure rates inherent in the original design have had and continue to have negative passenger impacts, the system as modified, should outperform alternative systems with respect to both odor and bowl cleanliness.

2.2.5 Horizon

The 100-car Horizon series is the newest significant production-quantity addition to Amtrak's fleet. These cars supplement the Heritage fleet in eastern United States short and long distance trains.

2.2.5.1 Equipment Description

The Horizon toilets are essentially identical to the equipment on the Amfleet II's. However 20 percent of the Horizon series cars are equipped with non-bottom sloned macerators.

2.2.5.2 Practice and Operating Experience

Current operating practices and experience for the Horizon cars is similar to that of the Amfleet II's. However, the improvement in the macerator design is expected to reduce macerator jamming and subsequent motor failure and burnout.

2.2.5.3 Appearance and Ease of Passenger Use

The comments in Section 2.2.4.3 apply.

2.2.6 Viewliner

Only three Viewliners have been built to date. The equipment installed on them is essentially at the prototype stage and is discussed fully in section 3 of this report.

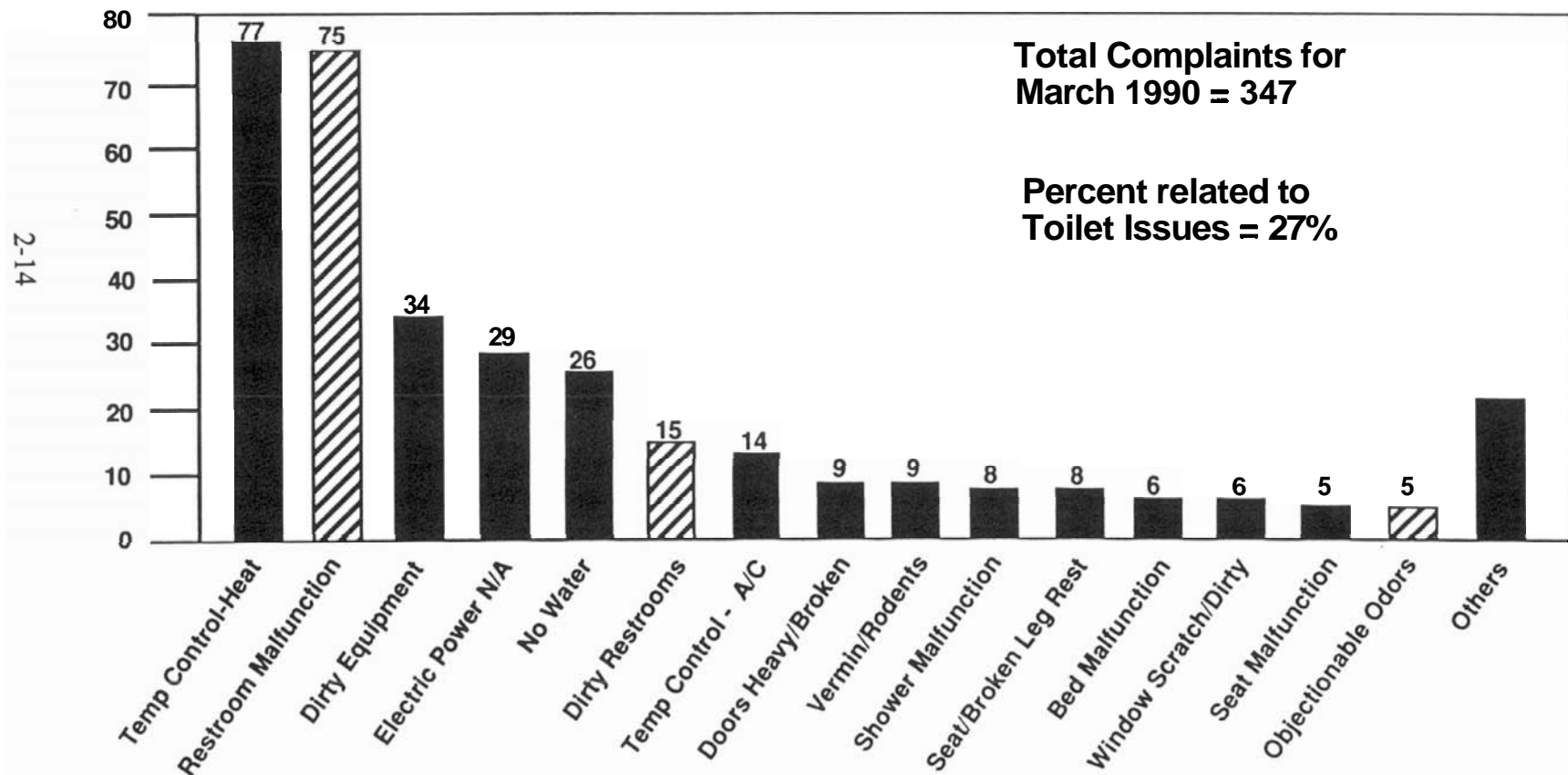
2.2.7 Passenger Acceptance Overview

Passenger complaints about toilet systems generally pertain to one or more of the following:

Figure 2.4

Equipment - Related Complaints Received In March 1990

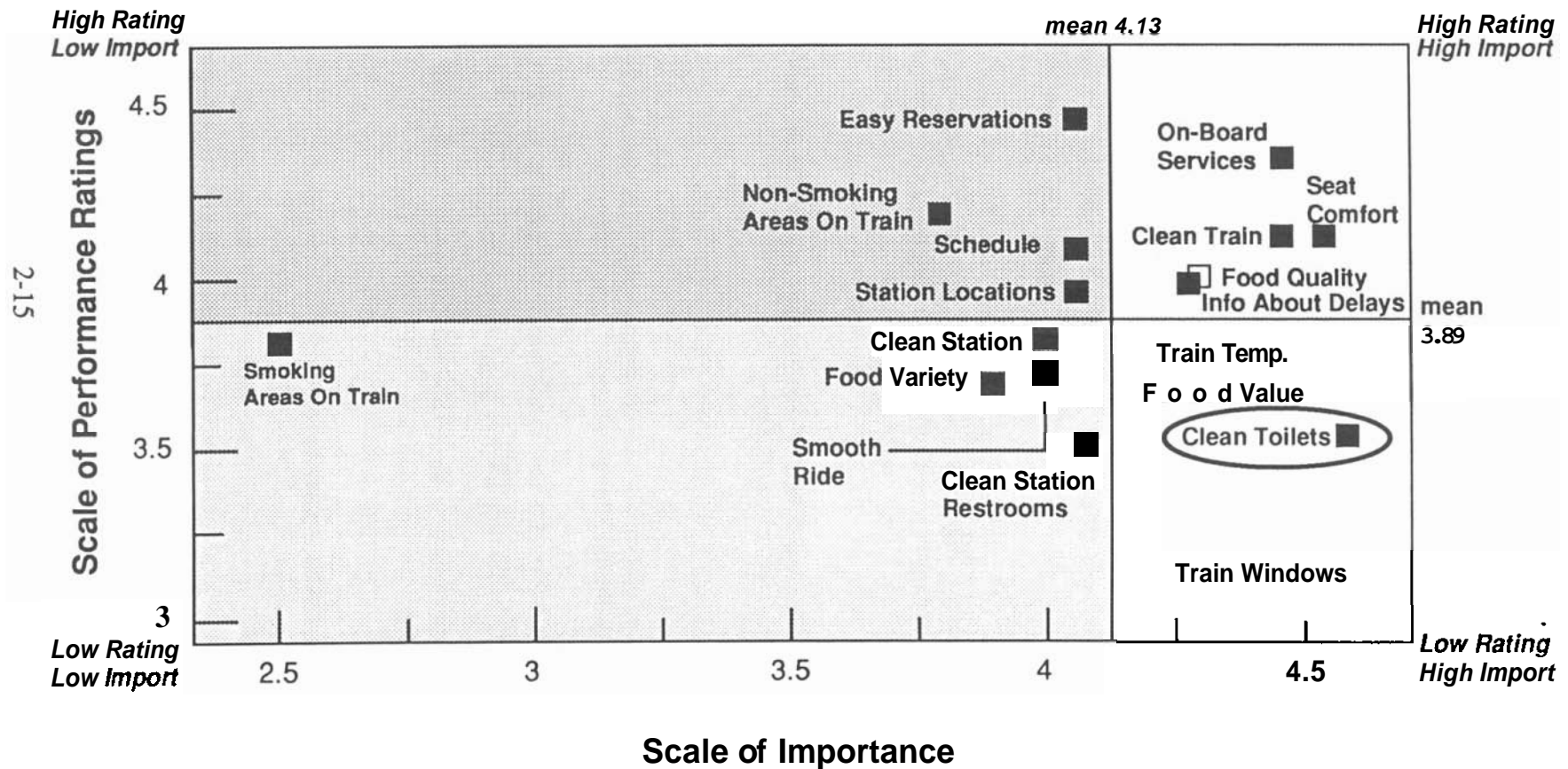
Complaints



Source: Amtrak

Figure 2.5

Performance Ratings and Importance of Features By Long Distance Amtrak Passengers



Source: Amtrak

- Failure to flush (due to frozen water, clogged pipes, foreign objects in toilet, **tank** capacity, valve or flush mgger failure, etc.)
- Odor (due to failure to flush, **tank** nearing or overflowing its capacity, or failure of bowl seal)
- Cleanliness of toilet (bowl, seat area, **etc.**)

Passenger **surveys confirm** that toilet systems are not viewed as performing satisfactorily (Figure 2.4) are of high concern to passengers and yet perform far below desired levels (See Figure 2.5).

Toilet design on Amtrak should take ergonomic, aesthetic, cost, and reliability factors into consideration. The focus of the current test program is on cost and reliability.

Toilet system complaints have not been analyzed, nor have passengers been surveyed to identify desired improvements in toilet system operation.

For example, the aesthetic trade-offs between recirculating and alternative toilet systems **are** significant. Odor control of various system types is significant. Even within one type—vacuum systems—significantly different approaches to odor control are utilized. Future efforts may be desirable to ensure such elements are considered in final design and passenger satisfaction is improved.

2.3 Recent Practice and Experience of Other North American Passenger Service Operators

We obtained relevant **information** from various commuter authorities in the **U.S.** and Canada as well as from the VIA Rail of **Canada**. This subsection describes their current practices regarding human waste disposal and their future plans. The practices at the following commuter services **are** described:

- Massachusetts Bay Transportation Authority (Boston)
- Go Transit (Toronto)
- **MetroNorth** (**New York**)
- Metropolitan Rail - METRA (Chicago)
- Long Island Rail Road - LIRR (**New York**)

2.3.1 MBTA (Boston)

The MBTA provides bus, subway, and commuter rail service around the Boston area. Their commuter rail fleet is composed of the following equipment:

- 59 Pullman cars
- **32 former** Budd Rail Diesel Cars (**RDCs**) (rebuilt by **Morrison Knudsen**)

- 67 Messerschmidt **Bolkow Blohm (MBB)** cars
- 147 Bombardier cars
- 75 Kawasaki cars (on order)

Of these cars, all of the MBB, 14 Pullman and 7 of the rebuilt Budd cars have toilets. The rest of the cars do not have toilets. The operational strategy is to include one car with a toilet in each consist. Thus, the Bombardier and Kawasaki cars will be coupled with MBB cars to form 4-9 car consists.

The MBTA uses retention type toilets in their rail cars. These toilets do not have a circulating fluid—they get water from a water **tank** mounted in the ceiling of the vestibule of the car (approximate capacity 100 gallons). The retention tank has a capacity of 55 gallon—about half of which is likely to **be** human waste.

The tanks are emptied out daily in Franklin, East Junction (Attleboro), South Hampton (Boston) and **Needham**. The waste goes **straight** into sewer systems at the **first** three sites. In **Needham** a contractor carries out waste in a truck and disposes of it.

The Pullman cars have toilets made by Walton Co. The other cars have either Monogram or **Microphor** toilets.

A typical passenger commute on an MBTA **commuter train** is 45-50 minutes, with some commutes (**e.g.**, Fitchburg and Providence) as long as 75 minutes.

Each car seats 99-105 people. The cars **are** quite full **during** the rush hours. The ridership was 13.6 million passenger **trips** and 243 million passenger-miles in 1987. Ridership has grown significantly in the past 3 years with longer trains and increased service **levels**.

2.3.2 Go Transit (Toronto)

Go Transit system provides commuter service in the Toronto area. They currently have 274 cars and **are** likely to reach a fleet size of 334 cars by 1991. All of the rolling stock is bi-level equipment made by **UTDC**.

The cars have retention-type toilets, each with capacity of 35 imperial gallons. Each car has one toilet which receives flush water from a 50-gallon (imperial) **tank**. A chemical (antifreeze and disinfectant) made by Head-o-matic Co. of Toronto is metered into the flush water. Go Transit has experienced no major problems with their toilets.

The **trains** typically have 6-12 cars with an average of 10 cars. The car capacity is 162 seats, but as many as 200 people ride each car in rush hour. A typical passenger commute is 45 minutes. The longest commuter route is 1 hour and 15 minutes.

The majority of the cars (90 percent) make just 2-3 nips per day. They get serviced every 7 days. The rest of the cars run all day and get serviced more frequently.

During servicing, the train goes on a special track where each car is connected by flexible sewer line to a sewer manifold pipe that allows each of the 10 cars to empty simultaneously. The waste manifold connects to a **sanitary** sewer using gravity feed.

2.3.3 MetroNorth (NY)

MetroNorth provides commuter service to people living **north** of New York and west into Connecticut. Half of the 400 self-propelled cars of **MetroNorth** have Monogram retention toilets, identical to those used on the **Amfleet** I. Half of the 30 locomotive-hauled Bombardier cars have the **Microphor** Type H system which is described in Section 3.3.2 below. These systems treat sewage on-board and discharge bacteria-free residue. This system has been in use for some time and is reported to be trouble-free.

A typical self-propelled **train** has 8 cars, while the locomotive-hauled trains have 6. The ridership is such that on average, there **are** 250 people per toilet during peak periods. The average passenger commute is 1 hour, with the longest commuter route being 2 hours.

Eighty-five percent of the retention toilets get emptied every day. The remainder of the retention toilets **are** emptied once every two to three days. The capacity of each toilet is 15 gallons of which 5 gallons are initial charge and 10 gallons represent waste capacity.

MetroNorth has 5 facilities to take care of waste. They **are** located in **Harmon**, White Plains, Brewster, Stamford and New Haven. They employ their own **trucks** and people to handle waste. On an average, there are 60,000 dumps per year, each consisting of approximately 10 gallons of human waste. The ridership in 1987 was 56 million passenger nips.

MetroNorth would prefer to have a Microphor system in the future cars because the retention types cost too much to service.

2.3.4 METRA (Chicago)

METRA provides commuter service in the Chicago area. Each of the 700 self-propelled cars in the METRA fleet has a retention toilet—400 made by Monogram, 300 by Prime. These are pneumatically operated diaphragm pump type toilets. The locomotive-hauled MU cars do not have toilets and there are 165 of these in the fleet.

Each car carries 145-150 people. The longest commuter route is 1.5 hours.

The capacity of the toilet is 7 gallons including 4-5 gallons of initial charge. Thus only 2-3 gallons of waste can be collected. Each toilet gets dumped **once every** week or so on average—some daily, some once every two weeks. The waste goes into a sanitary sewer at every yard. The frequency of dumping is somewhat lower in winter.

The dumping operation is very labor-intensive. The major problem is that passengers stuff things into them (e.g., sanitary napkins, towels). Despite these problems, METRA will continue with the same type of toilets in the future, except that future train **restrooms** will be handicapped-accessible.

2.3.5 LIRR (NY)

The Long Island Rail Road provides commuter service to two boroughs of New York City and to Long Island's Nassau and **Suffolk** counties. It is the largest passenger rail service operation next to Amtrak. Thus, additional effort was spent in obtaining information on their operation.

LIRR has 934 electric and 193 diesel hauled cars. One out of every two electric cars has a retention type Monogram toilet (car types **M1** and **M3**) while about 90-95 of the diesel-hauled cars have on-board treatment type **Microphor** toilets (Type H). An average train has 9 cars with 4-5 toilets per train.

The average number of passengers per **train** (taken over a 24-hour period) is 377. However, as many as 1600 people ride a **12-car** rush-hour train. The average trip length is 26.9 miles and the average time, 45 minutes.

The Monogram retention toilet has a capacity of 17 gallons and is initially charged with 6.5 gallons of water plus 6 ounces of chemicals. The effective holding capacity is therefore reduced to approximately 10 gallons. The toilets are emptied, on **an** average, every 3 days. There are **four** locations on the system where this is **done**—**Ronkonkoma**, Jamaica, **Flatbush** Avenue Yard and West Side Yard. An outside contractor provides this service. The 567,300 gallons per year of waste is dumped into the municipal sewage system.

The **LIRR** is encountering quite a few problems with the retention toilets. Most of the problems are caused by the riders or **by the** poor maintainability of the system. **All** types of garbage are found in the holding **tank**, including rags, paper (converted into mush), beer cans, hypodermic needles and "crack" vials. These items clog up the toilet pump and can plug the overflow outlet. Although these toilets are serviced every 3 days or so (with a variation of from 3 **times/day** to weeks at a time), this is not frequent enough to prevent the clogging problems (airlines service almost identical toilets every **trip** and they do not have to contend with beer cans and "crack" vials).

LIRR management expressed the view that the Monogram toilet is not sturdy enough for their environment. They have made some changes, such as the introduction of a stainless steel tank, but there are continuing problems with leakage due to corrosion of copper piping from exposure to urine. The pump lasts on an average 3 years and 10 months. **Ideally**, LIRR staff would like to see pump life extended to 6 years to match the car overhaul cycle.) The pump has to be cleaned while servicing, since it does not drain itself and creates a smell. Also, the pump regulator needs periodic adjustment. Finally, the unit is not easy to maintain. The pump is not easily reachable and the cramped quarters of the toilet makes in-place servicing **difficult**. The removal and servicing of the whole system takes about 8 hours. The cost of a new pump is about \$400, and the entire system costs about \$2,650.

The Microphor system has its own set of problems. It requires a fresh water supply to operate, unlike the circulating retention system which, once charged, can keep on operating. Replenishing the fresh water tank can sometimes be difficult at the end stations. The chlorination tablets required by these toilets can become a target for theft (since they can also be used in swimming pools), but not using them can create heavy stench and unpleasant situations for **people** involved in servicing the cars.

The redwood fibers used in the treatment system in these toilets have a life span of 5-6 years. After that the entire sealed **tank** containing them needs to be replaced at a cost of \$1,436.

Unless a Microphor system is flushed every time it is used, it overflows. The **button** for flushing has to be located so that a man standing up while using the toilet can see and use it.

Overall, toilets cause the largest number of passenger complaints received by the **LIRR**. In addition to the problems caused by unsatisfactory operation of its toilets, complaints **are** often received regarding waste odor of "working" systems.

LIRR management prefer the retention **type** toilets but wish that they were built sturdier and that their operations allowed for more frequent servicing. The **10** prototype bi-level coaches being built for diesel hauled service will have Monogram toilets.

2.3.6 Via Rail (Canada)

Via Rail provides limited intercity and long distance passenger train service in Canada.

Currently the rail car fleet of Via Rail includes 393 old cars that have traditional direct-dump type toilets and **100** new cars made by Bombardier (LRC cars) that have partial retention type toilets. These toilets dump when speed is more than 30 mph. A

one-gallon chloride dispenser is provided to disinfect the waste prior to it being dumped. It is checked every six days and refilled if necessary.

The LRC toilets are made by **Railtech** of **Dorval**, Quebec (near Montreal) and are described in Section **3.3**.

The locomotives in the Via fleet used to have incineration type toilets. Now, they all have retention toilets with **3-4** gallon capacity. They are emptied every six days or when reported full. The waste is dumped into the city sewer.

Each car has 2 toilets, one for handicapped (both sexes), the other for women only.

Initially, the partial retention toilets fitted to the LRC cars gave trouble. This included:

- corrosion of the aluminum car **structure** due to leakage of the chloride disinfectant
- jamming of the macerator

These problems have now been solved.

Via Rail expects to continue using the partial retention type toilets. The full retention systems **are** considered too expensive.

2.4 European and Japanese practice and experience

2.4.1 Japan Railways

We requested information from three of the six constituent railways of Japan Railways. These are the three railways situated on the main island of Honshu which operate all of the Shinkansen services and numerous local services.

Shinkansen trains use a **recirculating** retention **type** toilet with a tank capacity of 1000 liters (264 gallons). Two toilets share one **tank**. The flushing water is recycled and a deodorant is added. The tanks is emptied in the **train** yard once every one to three days (depending on passenger volume). A typical 16-car Shinkansen train has 16 toilets (two in every second car) and 8 tanks. There are only minor differences between the different series of Shinkansen trains.

The local trains, on the other hand, have only one toilet per train and the tank capacity is only **34** liters (9 gallons). Also, they employ a "cassette type disposal system" in which a sieve is employed to separate solid waste from liquid.

The only technical issue mentioned in response to our inquiries was that unpleasant odors were a problem, and that they **are** investigating alternative deodorizing and sterilizing chemicals to address this problem.

A rough sketch of the **Shinkansen** toilet system has been obtained and is shown in Figure 2.6. This system is manufactured by the Teshika Company of Tokyo. In concept the system is similar to the **Monogram** recirculating system with remote **rank**, but there **are** a number of detail differences. We believe that both "Eastern" and "Western" toilet styles are fitted to the Shinkansen cars.

2.4.2 British Rail

Currently, most toilets in passenger equipment operated by British Rail are direct dump type. The exceptions are:

Mark III sleeping cars, built in the early **1980s**, employ a simple gravity retention toilet that has no vacuum or pressure assist. This approach is feasible because of the British practice of installing two toilets at the end of the car instead of in each sleeping compartment. This leads to relatively low usage, and thus a reasonable retention **tank** volume requirement. One gallon of water is used for flush. The principal pump-out facility is at Willesden (North London) where all sleeping cars are serviced. A permanent manifold is installed.

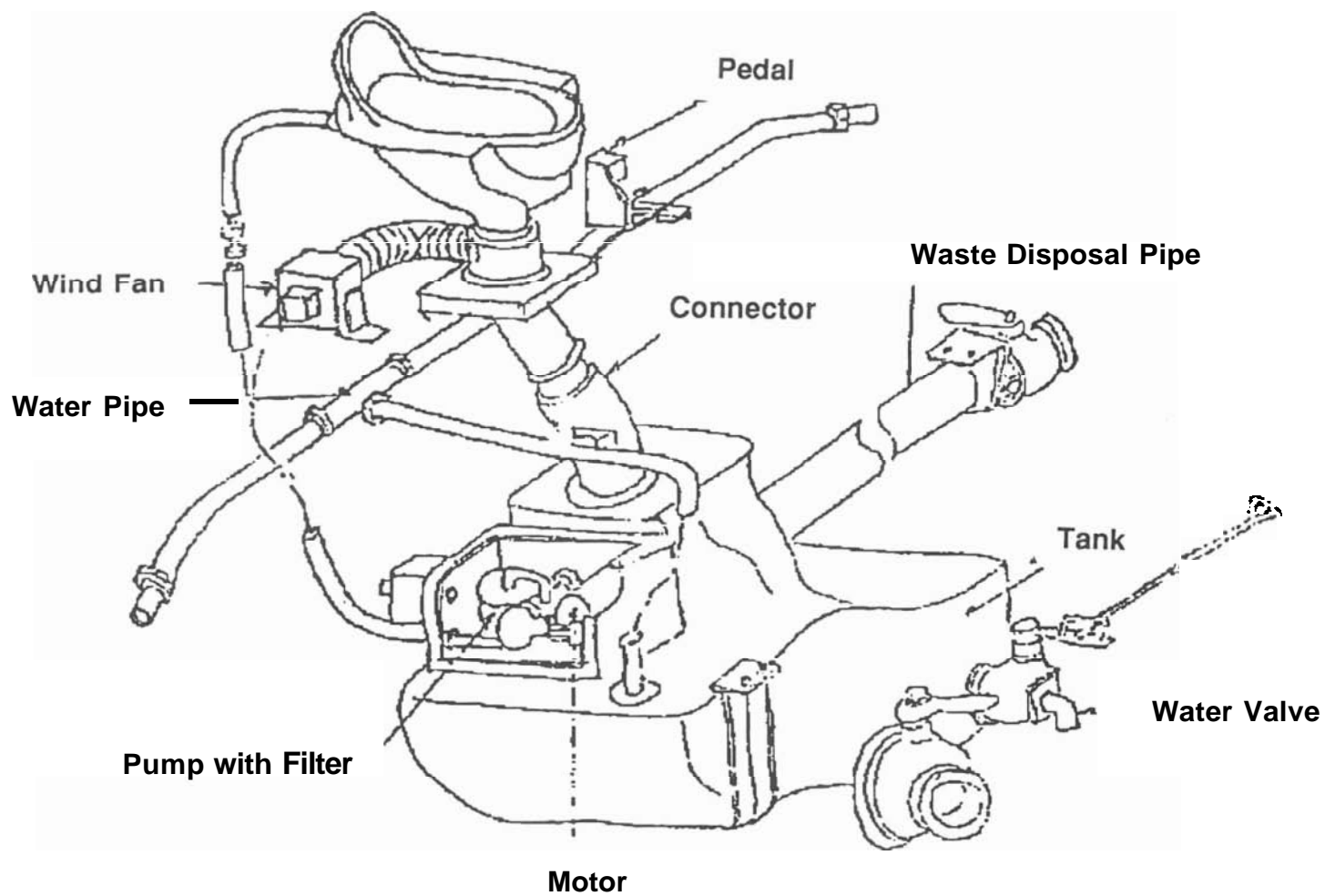
- Mark IV intercity passenger cars which are just coming into service use a retention toilet, but the name of the supplier was not available.
- The class 158 Diesel MU trains currently being built have a **Microphor moderate-volume** flush (**2 liter**) gravity retention toilet system
- The Class 442 **Electric** MU will be converted from direct dump to retention type toilets. These **trains** are used on medium-distance services between London and **the** South Coast—up to 2.5 hour **journey** time. The supplier is not selected yet.
- The Class 465 EMU for London Commuter **train** will also have retention toilets.

In the future, British Rail passenger cars of all types will have retention toilets.

British Rail current specification calls for the following:

- ceramic bowl
- low volume water flush
- maximum **2** liters water per flush
- recirculating **type** (blue fluid) not acceptable
- must meet all "handicapped" toilet requirements

Figure 2.6 Reclrculating Retention Toilet Made by Teshlka Co., Tokyo, Japan



The preferences are:

- To have standing water in toilet, and a water-trap to prevent escape of odors (this has influence on **flush/retention** performance).
- To avoid very low volume flush (**e.g.**, the **0.2** liter of the EVAC **2000**) because they **are** concerned that this may not clean the bowl adequately, even if bowl is **PTFE-coated**. Their specifications do not exclude this type of system, however, nor do they have any service experience to support this concern.

Overall, **BR's** philosophy is to make the on-rain toilet as much like a domestic toilet as possible, because in their judgment, this is a worthwhile contribution to making the passenger environment as attractive as possible.

Their usage figure is **0.26** flushes per seat per hour, and is written into their design specification. They believe this figure originated with a supplier (EVAC?), and is an average, not a peak use figure. They are comfortable with using an average in a design specification because, typically, a car will make several trips per day at both peak and off-peak times. Daily pump-out is assumed, although they **are looking** for two days retention for some types of equipment used on low **traffic** routes. The object of this is to minimize the number of locations which have to have pump-out facilities. At the same time they are looking at a portable pump-out equipment for low **traffic** locations.

They have carried out an informal **survey** which indicated that toilets were occupied for **3** to 4 minutes per visit, and that those near food-service car were used most. They have not carried out any rigorous surveys.

Some BR toilets have powered doors (to facilitate handicapped access). They are considering automatic "out of use" signs and locking of door **if** toilet holding **tank** is full, or if the toilet is malfunctioning.

Recirculating toilets are unacceptable to BR because of the following reasons:

- Difficulty of disposal of formaldehyde **based** fluids (they did not seem to be aware of non-formaldehyde alternatives).
- Unattractive appearance and smell

BR prefers to avoid (or be very careful about) any pneumatic systems that exhaust air outside the vehicle. This can lead to unpleasant smell around a vehicle standing in a station. The BR has had problems with the **Microphor** flap valve (seal degradation) and poor cleaning due to imperfect flush pattern.

2.4.3 French National Railways (SNCF)

The SNCF has standardized on the recirculating toilet system for their fleet of high speed **trains (TGVs)**. Details about this system and the reasons for this choice are given in Reference 7. This system is the Monogram remote recirculating toilet, manufactured in France under license by the Faiveley Company, and with minor changes to comply with the space constraints in the TGV passenger car. One toilet per car is fitted. Note that the TGV articulated cars are relatively short, with approximately 40 seats in **first** class and **60** seats in second class.

The choice of this toilet system arose out of test experience with the experimental Gas Turbine **TGV001** in the early and mid-1970s. They experience problems with the traditional toilet systems on this train at high speed and determined that an **aircraft**-style recirculating toilet would be necessary for the TGV trains to be used on the Paris-Lyons line. Such systems were tested in service on the RTG gas turbine trains (similar to those supplied to Amtrak and now used in New York-Albany services) and then installed in the TGV trains.

The TGV trains are all serviced at a purpose-built facility at Conflans near Paris. A **permanently** installed manifold and hoses with quick-connect couplings are used to empty the toilet storage tanks. Connections are provided to service two trains simultaneously on 400-meter long servicing tracks. The article also states that tanks are typically emptied once every three or four days, although this seems rather **unlikely** in view of the experience and practices of other operators.

The waste is pumped to an underground storage **tank** and then **transferred** to a nearby major municipal waste treatment facility.

The Conflans facility serves the 100 trains used to provide the Paris-South-East TGV services. A similar facility has been provided at **Montrouge**, near **Montparnasse** station, to **service** the **73** trains under construction for TGV Atlantique services.

The SNCF is also testing alternative toilet systems, such as the EVAC vacuum system, but no series of cars have been purchased with such systems. Nor does the SNCF currently install retention toilets in passenger cars other than the TGV cars, although this is mentioned as being likely in the future.

2.4.4 German Federal Railways (DB)

The DB is fitting retention toilets to all new intercity passenger cars. Approximately 1000 units are now in service or on order, split approximately 50-50 between EVAC and the similar SEMVAC. The primary reason for going to retention toilets was the need to seal the interiors of high-speed intercity passenger cars against external air pressure pulses. These occur when two trains pass at high speed, especially in

tunnels. Obviously, this is not possible with the traditional direct dump toilet. Other contributing reasons given for choosing retention toilets are

- at high speed, waste is dismbuted all over the car, instead of falling directly onto the track
- to improve working conditions for car servicing and maintenance workers

Further information about DB's experience and background to their choice of systems is provided in an article by Mr. **Rasche** of the DB (Reference 9). It concludes that among the currently available systems, the vacuum system best meets the DB requirements, which are

- ease of installation into new and existing cars
- highest possible flexibility in the position of toilets and other equipment within the car
- acceptance by the user
- future-oriented system
- centralized pump-out location for disposal

2.4.5 Danish State Railways (DSB)

Danish State Railways has standardized on the SEMVAC vacuum toilet system, which is being installed in all new passenger cars and is also being **retrofitted** to existing cars as these become due for renovation. We understand that full retention toilets are now a legal requirement in Denmark.

DSB's interest in retention toilets originated about 10 years ago. Among other concerns, DSB wished to eliminate the dumping of waste from stationary cars on train-ferries and to minimize this in urban **areas**.

They considered that of the systems on the market at the time, an early EVAC model was the best, but this still did not meet all **performance** and reliability requirements. They then embarked on a development program in cooperation with a local firm, SEMCO, which resulted in the SEMVAC system. Today, they consider that there is little difference between SEMVAC and EVAC, but SEMVAC is preferred because it is a local Danish firm.

During their various test programs, DSB has tested numerous chemical and recirculating toilet systems, but considers that they are all inferior to the vacuum systems. Among other objectives, they have concerns over the disposal of the chemical waste from such toilets.

Chapter 3

OVERVIEW OF RETENTION TOILET TECHNOLOGY

3.1 Introduction and Scope

In this chapter we will discuss the various **retention** toilet systems currently available in North America. In section **3.2** we describe the features which are common to almost **all** retention toilet systems in order to simplify the ensuing descriptions which are specific to make and model. In sections **3.3** through **3.5** we will describe the generic type of toilet technology (**e.g.** gravity, recirculating, and vacuum), followed by descriptions of each particular system **observed** in the course of this study.

Within each sub-section the various toilets **are** described in alphabetical order of manufacturer. For each system we have included a schematic drawing of the toilet, valves, piping and holding tank configuration. We have also included engineering drawings from the manufacturer when they were available.

There **are** three primary types of retention toilet systems: gravity, recirculating, and vacuum. Each system has advantages and disadvantages with regard to efficiency of bowl clearing, bowl washing, **transport** through the pipes to the holding tank, and cleanliness and odor **control**.

For each system we will discussed, the major operating features such as flush initiation device, type of bowl and bowl closure, amount of water used per flush and method of transporting the waste to the holding **tank** will be described. In addition, any current use or testing by **Amtrak** will be noted.

The descriptions do not include detailed specifications for the systems because in nearly every instance, the manufacturer can alter the design to accommodate Amtrak's operating specifications. Many of these systems are in a pre-production or prototype stage as there has never yet been demand for full retention toilet systems on trains.

3.2 Features Common to all Systems

There **are** a number of features and components common to **all**, or nearly all, of the toilet systems irrespective of the manner of bowl clearing, washing, maceration (if any), and transport to the retention **tank**. While the necessity of some of these components is self-evident (**i.e.** a flush initiation device), there are certain characteristics which are vital to the proper functioning of a **retention** transportation sewage disposal system.

These components are as follows:

- **Flush Initiation Device.** This device initiates the flush cycle. It is often an **electro-mechanical button** which is pressed by the user. Some systems, however, use reed switches concealed within the toilet shroud which initiate a flush cycle only when the toilet seat is put down.
- **Flush Control Device.** A flush control device is a logic control unit which coordinates the different events in the flush cycle. For example, when the flush button is depressed the control system initiates the flow of water into the bowl, opens the flapper, turns the macerator on, terminates the flow of water, closes the flapper, and turns the macerator off. On vacuum systems it may also sequence simultaneous flushes of two or more toilets on the same vacuum collection system to ensure that there is sufficient vacuum pressure for each flush. A logic control system is not required on all systems.

Toilet Bowl and Seat. Toilet bowl shape, material and coating are the key characteristics of toilet bowl design. Since most of these systems use very low volumes of water to clear the waste from the bowl and to wash the bowl during the flush cycle, it is critical that the level of friction be as low as possible. There are several approaches which have been proposed to accomplish this with none clearly better than any other. Each design has advantages and disadvantages in terms of durability, appearance, and level of friction.

In addition, some bowls have flappers which seal the bowl from the piping system. Some use a **water spot** to trap odor and to provide an appearance more like that of a domestic toilet.

- **Flush Ring.** All systems utilize a component through which water is introduced into the toilet bowl for clearing and washing. While this is not always a ring, the concept is the similar.

A typical flush ring is a metal **tube** which is positioned below the top rim of the bowl just under the seat. When the toilet is flushed, water is let into the ring and exits through holes on the lower surface of the ring and washes down the walls of the bowl. On systems which use a very low flush fluid volume, there will often be spray **nozzles** on the ring and the flush fluid is forced under pressure into the bowl to aid in clearing and washing the bowl.

Some systems do not use a ring at all. They may employ only one nozzle which directs the flush fluid (usually a larger volume) in a swirling motion around the sides of the bowl.

- **Odor Control Mechanism.** Odors emanating from the retention tank can cause substantial **discomfort** to passengers on a train. Given the requirement that the

systems be capable of retaining sewage for up to **72** hours, odor **control** represents an important function for any toilet system.

The primary methods for sealing the **tank** from the toilet **are** flappers at the bottom of the toilet, ball valves, sluice valves, pinch valves or rotating discs in the piping between the toilet and the retention **tank**. The susceptibility to incomplete closure, jamming, or opening after loss of train air distinguish their ability to perform the odor control function. This will be discussed at length below.

- **Maceration Device.** Macerators **are** devices which grind the waste and flush water into near liquid form. This is done to enhance the ease of transport through the pipes, as a means of pumping the material through the pipe, and in an effort to reduce the likelihood of clogs in the pipe. In addition, it eases the unloading of the storage **tank**. Not all systems use macerators, however. Vacuum systems, for example, often have enough force to move the waste material through the piping without maceration.
- **Piping from Toilet to Tank.** The key characteristics of this component are the diameter, materials, and profiling. Diameter is important for the simple reason that clogged pipes can put a toilet, or even an entire car, out of service. Materials are important as they affect the cost of installation and maintenance. Profiling is important primarily for vacuum systems, but when done properly can reduce clogs in all types of systems. Profiling encompasses the level of grade in the piping and the location of reform pockets and "Y" junctions in vacuum systems.
- **Retention Tank.** Retention toilet systems use at least one retention **tank** per car and some have up to one retention tank per toilet. The **tank** capacity is critical because of **Amtrak's** requirement that the system have capacity for three days of use between servicing. Since no retention toilet systems are in use now, **tank** sizing is still an open issue. In addition to variations in **tank** capacity, they vary in material, coating, heat wrapping, and location and size of inlet and outlet openings. However, none of these characteristics need to be vendor or system-type dependent.
- **Discharge Mechanism.** This refers to the method and mechanism by which the waste is removed from the retention tanks. The critical aspects are susceptibility to clogging or spilling, and the speed of discharge.

3.3 Gravity and Air Pressure Systems

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 to liquify the waste and facilitate easier transport. One type

of gravity system has a macerator (grinder pump) just below the flapper (see Figure 3.1). 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~~. ~~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.

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.

3.3.1 GARD Amfleet II Prototype

The GARD **Amfleet II** Prototype Toilet System (see Figure 3.2) was tested by **Amtrak** on an **Amfleet II** car. It **features** an electro-polished stainless steel bowl without a flapper. The bowl closure is a rotating ball valve (modified from a pinch valve) and uses a small water spot to trap odors.

The flush is initiated by means of an electro-mechanical button. A electric flush valve allows between **32** and 48 ounces of potable train water into the bowl to clear the waste and wash the bowl sides. At the same time the ball valve is opened and the waste is washed through a **1-1/2** inch round drain into the horizontally mounted macerator. The macerator is a sump pump which has had blades added to provided the grinding effect. The waste then drains by gravity to the stainless steel holding ~~tank~~ which is mounted below the **floor** of the **train**.

An elecmcally operated, speed controlled ball valve is automatically actuated to empty the holding ~~tank~~ in the **retention/dump** version of this system fitted to the **Amfleet II**. For manual draining, a valve is opened on a **1-1/2** inch pipe mounted at the bottom of the **tank**. At discharge, the waste material is drained from the ~~tank~~ by gravity.

3.3.2 Microphor Redwood Fiber H-Series Commuter/Locomotive

The **Microphor** H-Series On-Board Sewage Treatment System (see Figure **3.3**) is currently used on both commuter rail cars as well as locomotives. It is unique in the sense that it biologically decomposes the waste material on board the rail car using redwood fibers. The degree to which the waste treatment system is applicable to high passenger density operations will not be addressed here.

Figure 3.1
Gravity System

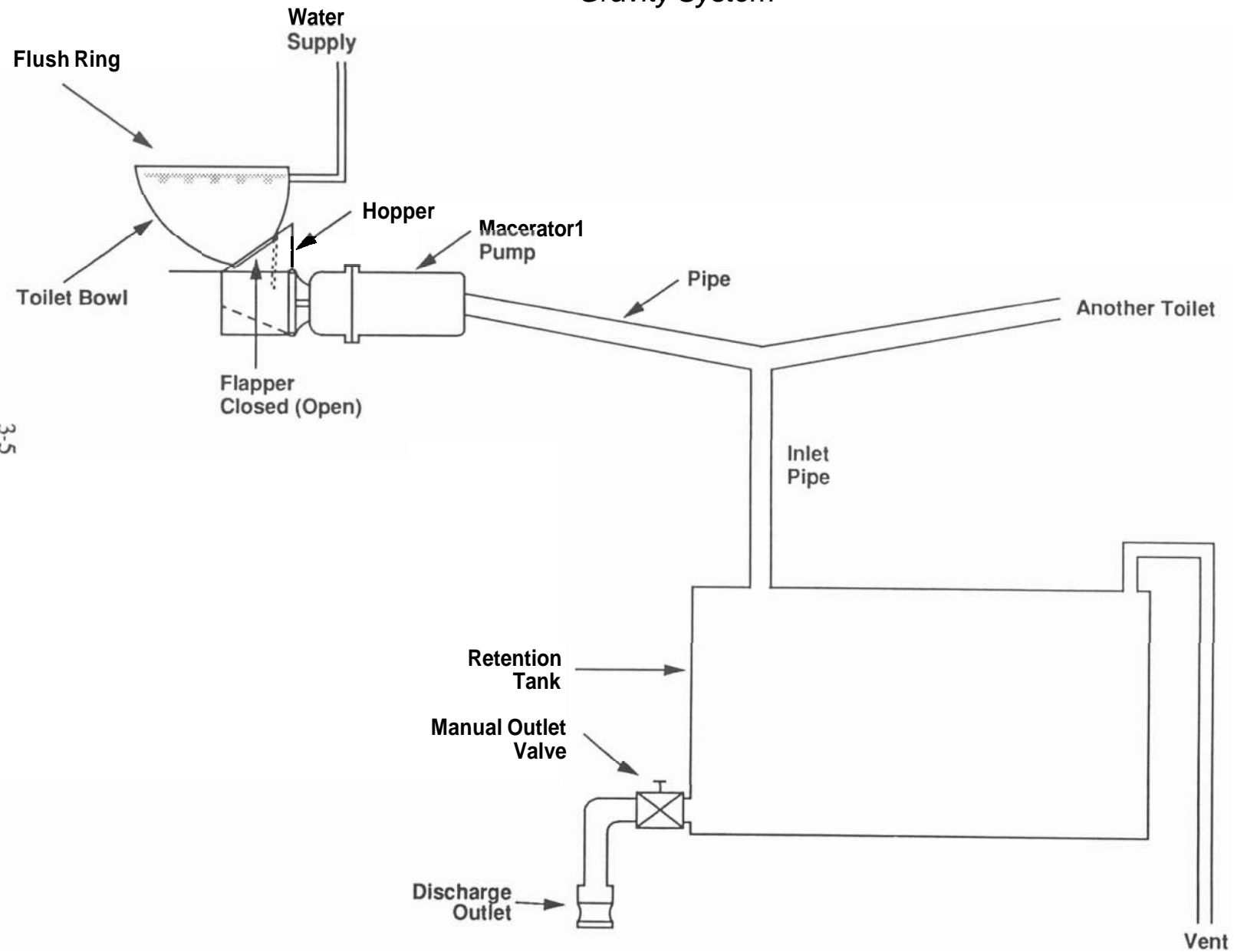


Figure 3.2

GARD Amfleet II Prototype

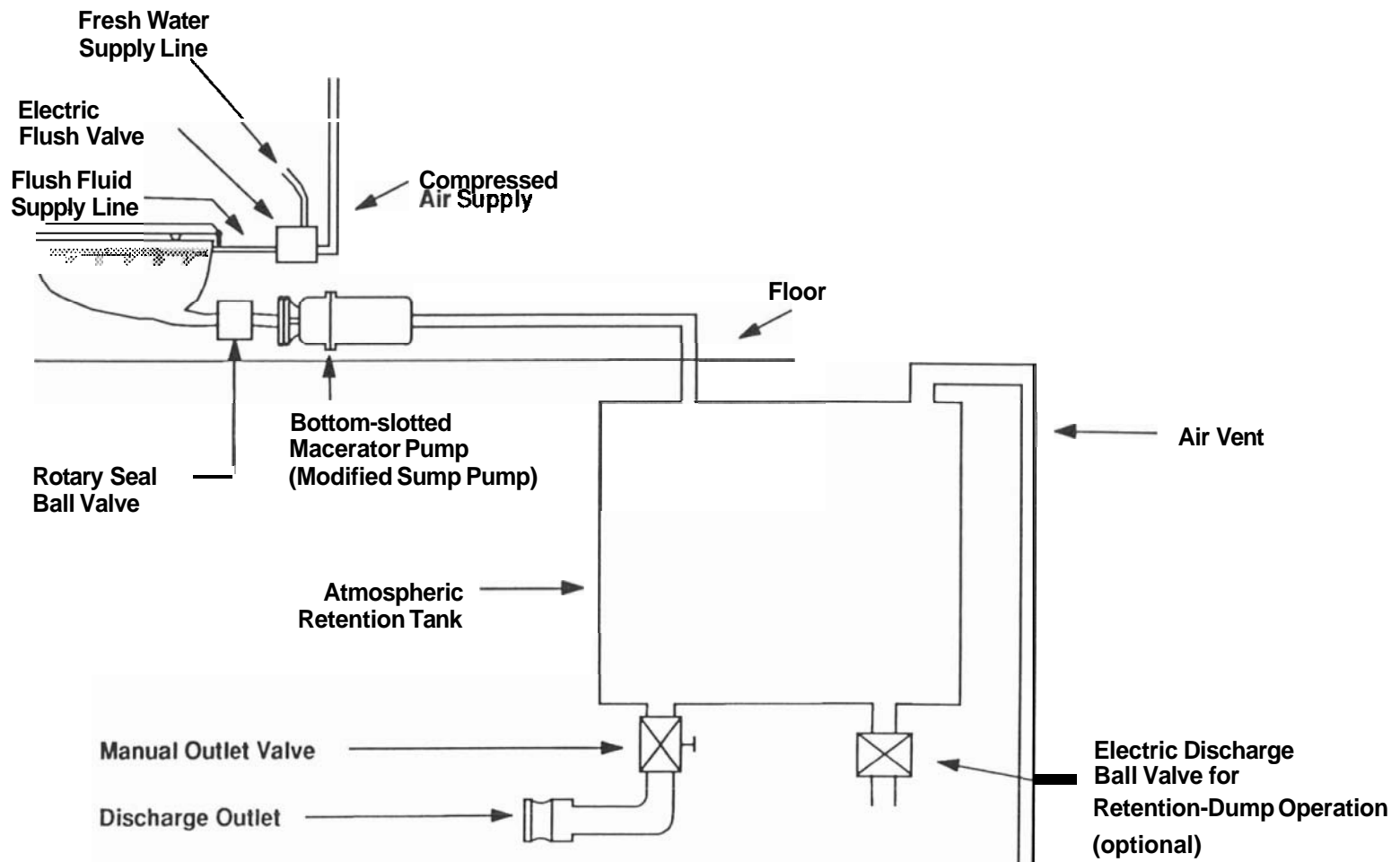
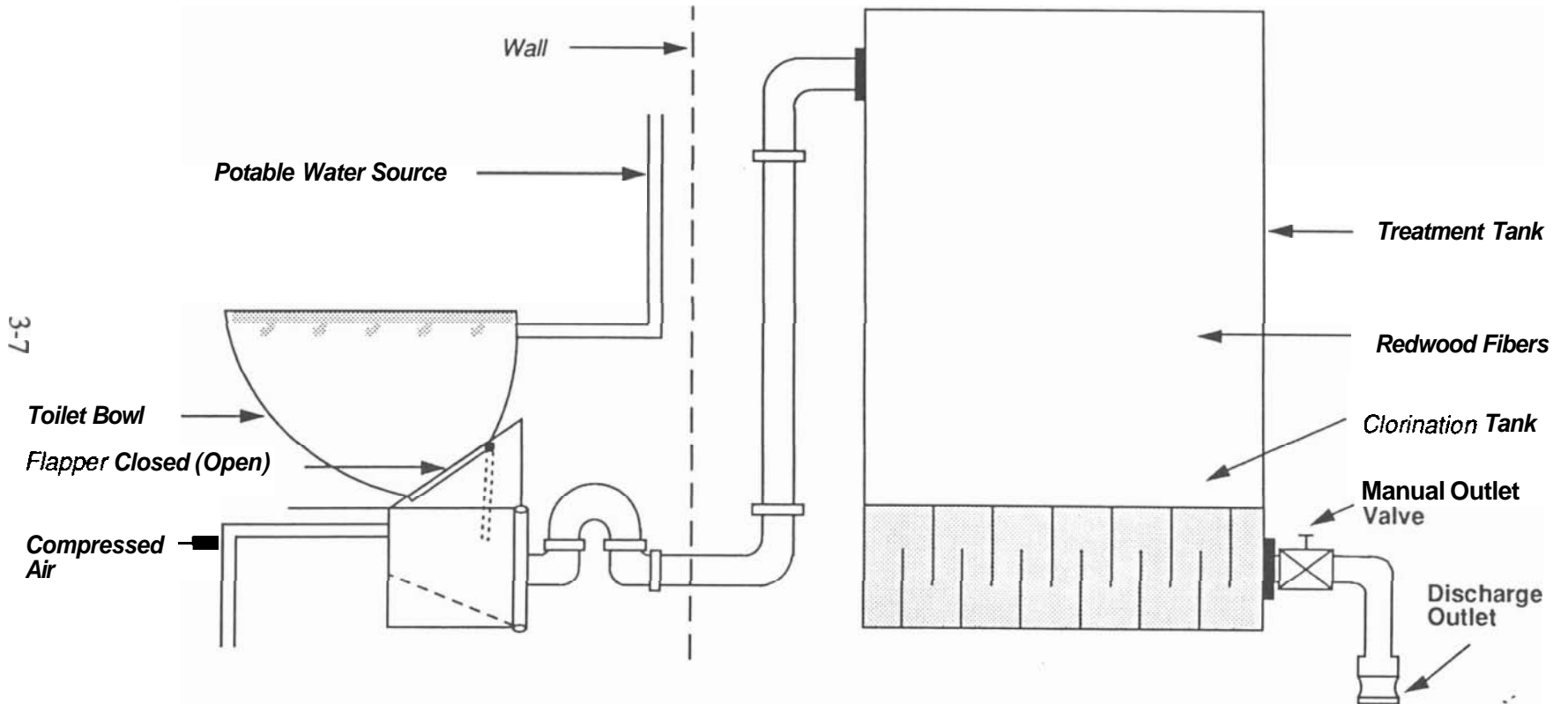


Figure 3.3

Microphor H-Series



The Microphor toilet is flushed when the user depresses a wall mounted lever or button. A compressed *air* signal is sent which enables water to begin to enter the toilet bowl, and at the same time to open the flapper at the base of the bowl. The waste falls into a chamber below the bowl as the water washes the sides of the bowl. The current configuration uses 2 quarts of potable water per flush.

After approximately 5 seconds the flapper is closed and **hermetically** sealed while the chamber is pressurized with air forcing the waste through the pipe into a holding tank. The system also replenishes the water level in the toilet bowl such that there is a water spot of approximately 2 quarts for the next flush. The bowl is **electro-polished** stainless steel.

The **treatment** system is a two stage system. The **first** stage is natural biological decomposition in a redwood fiber filled tank. The waste circulates amongst the redwood fibers and is broken down by the bacteria into liquid and gas. The gas is vented out the top and the liquid flows into a chlorinator and then a secondary tank to lengthen the amount of time which the liquid is in contact with the sodium **hypochlorite**. This system effectively kills all of the bacteria in the effluent. After chlorination, the liquid is discharged directly to the roadbed.

The system requires both **train** air at 60 psi, and potable **train** water at 1 to 50 psi. The toilet will not work **in** the absence of either.

The system can be plugged when any object becomes stuck in the piping. Since there is no macerator, any object which can fit through the flapper opening can become jammed in the 1-1/2 inch P trap. A plunger (plumber's friend) can be used to remedy plugs.

Odor control is achieved by keeping the flapper shut and maintaining an air tight seal by means of a water seal.

The **main** differences between the system used on commuter passenger cars and on locomotives **are** capacity. The locomotive system also uses a plastic treatment tank where the commuter system uses a coal **tar** epoxy-treated steel **tank**. The locomotive system also uses less water per flush: 48 ounces.

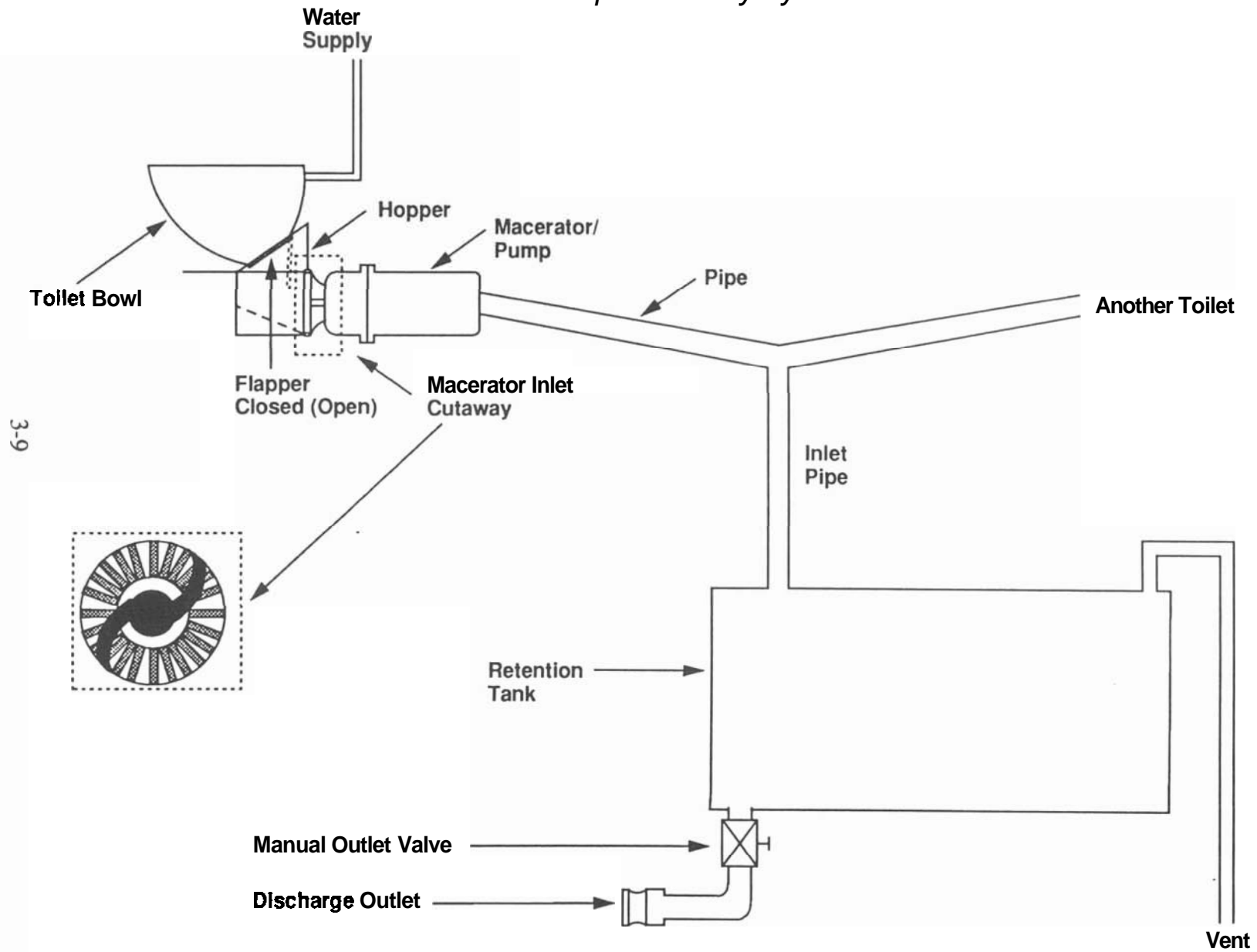
Due to the amount of time required for decomposition, and the amount of space which the redwood fiber filled **tank** occupies, it has never been recommended by its manufacturer for retention systems on intercity passenger railroads such as Amtrak.

3.3.3 Microphor Gravity System

The Microphor Gravity Toilet System (see Figure 3.4) is currently in use on **Amtrak** **Amfleet** II cars and on some 80% of **Amtrak** Horizon cars.

Figure 3.4

Microphor Gravity System



This system uses the same bowl and flapper **arrangement** that is used on the H-Series toilets described above. The primary difference is the mode of transport of the effluent from the hopper to the retention **tank**. This system does not use **airpressure**, instead the waste is macerated just below the bowl and pumped to the **tank** through piping with a slight gradient.

The amount of water per flush is 48 ounces and the water spot is much smaller at 6 to 8 ounces.

The following is a description of the flush cycle provided by the manufacturer:

The toilet is flushed by pushing the wall mounted push-button. The button activates the timing sequence controls. One complete flush cycle consists of the following steps:

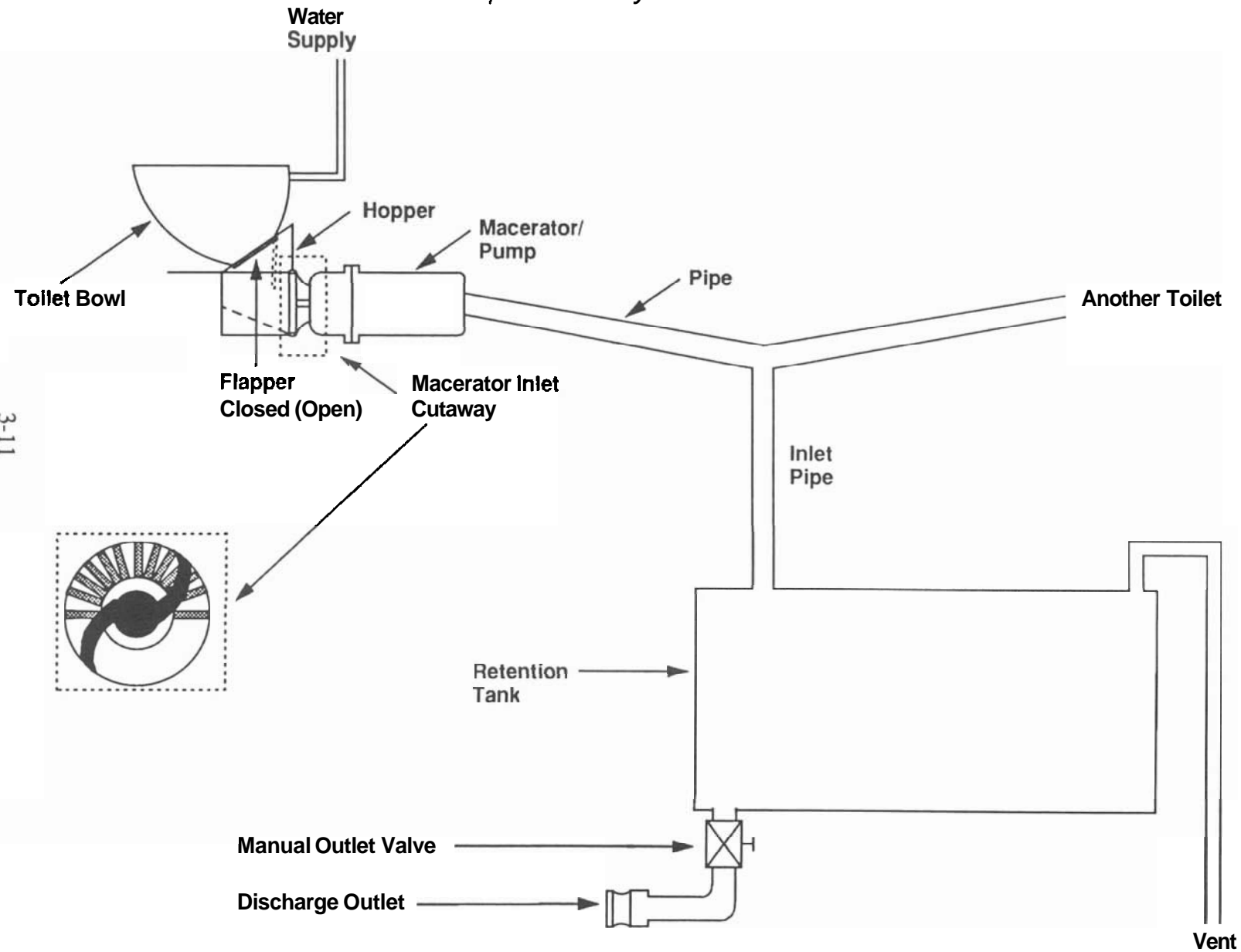
- (1) By actuating the elecme circuit the macerator starts, flapper opens and the flush water washes the waste into the hopper.
- (2) Ten seconds into the cycle the flapper closes.
- (3) The macerator and water is timed to **run** for another **6** seconds after the flapper is closed. This period of time is sufficient to grind the waste to a particulate size of 118 inch or less and to pump it to the holding **tank**.
- (4) A complete cycle is initiated every time the push button is depressed. Re-depressing during the cycle has no effect.

The temporary holding **tank** has a 60 gallon capacity (approximately **70** flushes). When the **train** reaches a preset train speed of approximately **25** mph a speed sensor switch mnggers a dump valve to open allowing the release of whatever has accumulated in the holding **tank**. Unlike the system described above, the waste is not **treated** in any way prior to dumping, with the exception of maceration.

There is one variation to this system installed on approximately **20%** of **Amtrak's** Horizon fleet. It is essentially the same as the previous system except for one modification: the macerator has been modified to remove the slots from the edges of the lower side wall. This **modification** helped to reduce the occurrence of **jams** due to coins getting stuck in the slot and **preventing** the grinder blades **from moving** (see Figure 3.5).

Figure 3.5

Microphor Gravity w/Modified Macerator



3.3.4 Microphor Prototype

The **Microphor** Prototype retention toilet system has been developed in response to the need for a total retention toilet system. It is currently undergoing testing on an **Amtrak Amfleet II** car.

The toilet system is essentially a hybrid of the H-Series and the gravity system described above. The primary difference is a lower flush fluid volume (**22 ounces**) and the combination use of injected air below the flapper and maceration for transport to the holding tank.

The system uses an electro-polished stainless steel bowl with a flapper and small water spot (6 to 8 ounces). During the flush cycle, the flapper opens and the waste drops into a hopper. Since the system uses less water to flush, air is injected into the chamber forcing the waste into a macerator where it is ground and pumped to a 300 gallon stainless steel holding tank.

3.3.5 Railtech WTS 8300

The **Railtech WTS 8300** system (see Figure 3.6) has been installed on VIA Rail in Canada since **1977**. It is currently a 'treatment and dump en route' system, but can be made into a total retention system through minor modifications to the tank.

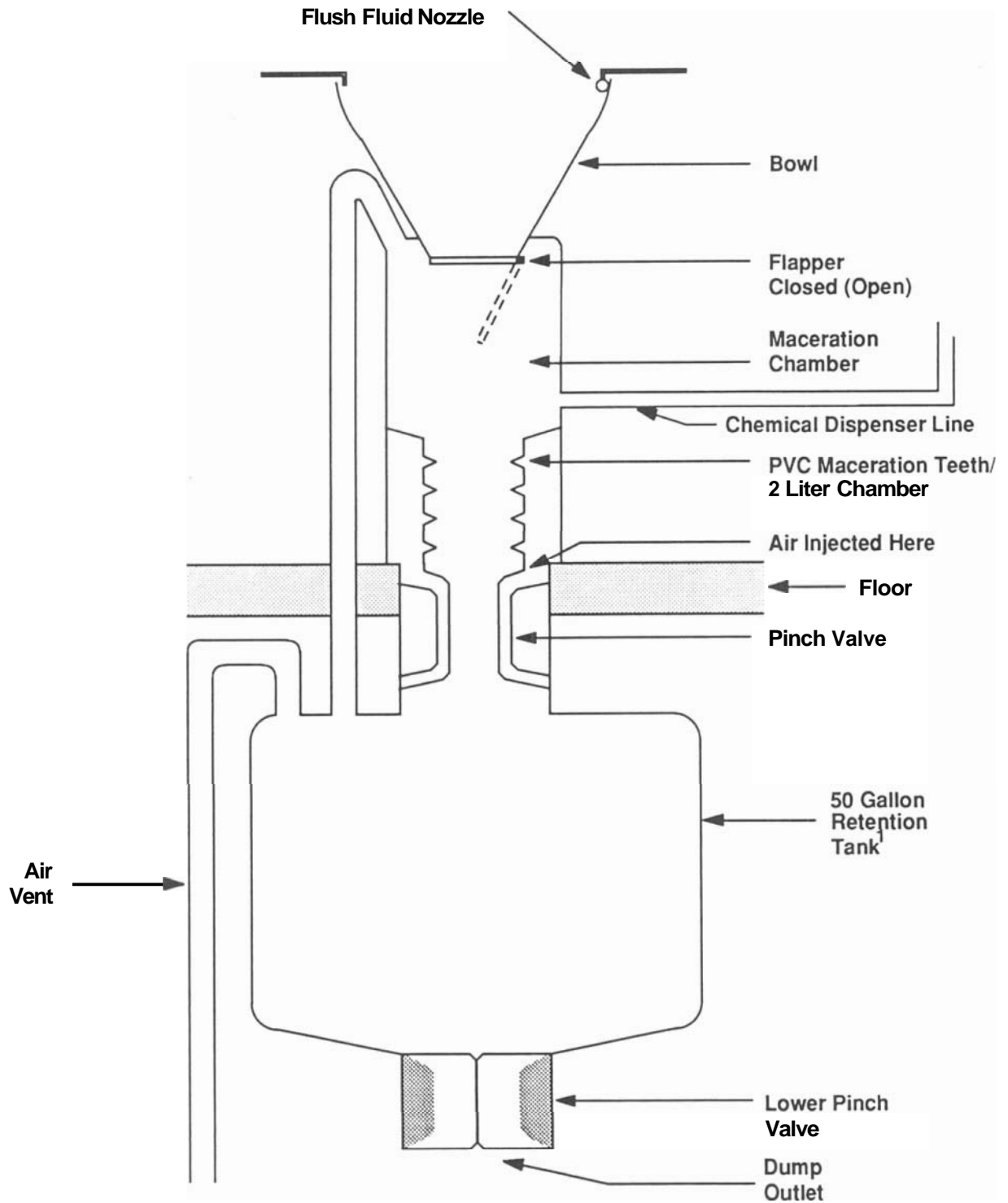
The system uses an **electro-polished** stainless steel bowl and flapper. The system is configured with a maceration chamber and retention tank directly below the toilet bowl.

When the flush is initiated, flush water is injected into the bowl at train pressure through a single nozzle. The flapper opens and the waste drops into the cylindrical maceration chamber below. At the bottom of the maceration chamber is a air operated pinch valve which prevents the waste **from** entering the holding tank prior to maceration.

The walls of the **cylinder** have teeth **protruding** into the cylinder made of **PVC**. Train air, regulated to **120 psi** (dynamic) is injected into the chamber and creates an air **vortex** to circulate the waste material and flush fluid around and across the spikes for just over eighty seconds. During the maceration **2mL (approx.)** of liquid anti-bacterial solution is added to kill bacteria. As this is happening, the flapper is closed and a small amount of water is allowed into the bowl to provide an odor seal as well as for visual appeal.

Figure 3.6

Railtech WTS 8300



Note 1: Tank size determined by undercar space available and service requirements.

When the cycle is complete the pinch valve at the **bottom** of the chamber opens and the waste drops into the retention tank. Any **non-destructible** objects merely rest at the bottom of the chamber during maceration until the cycle is complete.

Odor **control** is accomplished by sealing the bowl from the macerator with a flapper and **rubber** seal. The water spot in the bowl also prevents odor from leaking into the toilet compartment.

A logic control panel executes each function in order and can control multiple toilets. Since the complete cycle takes nearly one and a half minutes, the control unit will record a press of the flush button occurring during the cycle and upon completion of the **first** cycle initiate a second cycle. During this delay a light indicates to the user that action is forthcoming.

Each flush requires one liter of potable water. The anti-bacterial liquid solution is held in a tank on the wall next to the toilet. The tank capacity (5 gallons) is such that it needs to be refilled after every 1600 flushes.

As the system is currently configured, each toilet has its own retention tank, or two adjacent toilets could share a **tank**. The current tank capacity is enough for 99 flushes (approximately 50 gallons). The **modification** required to allow for full retention for **72** hours would merely be **tank** capacity. In addition, the discharge valve from the tank is an air-pressure operated pinch valve which opens at speed over 25 mph to allow gravity discharge from the tank. It is probable that this would be replaced by a valve not requiring train air to maintain its closed position.

Since the flapper, the macerator, and the pinch valves **are** aligned vertically, any clog can be cleared with the equivalent of a broom handle.

The flapper is *air* power open and close. The pinch valves **are** air power close only and will open in the absence of air pressure.

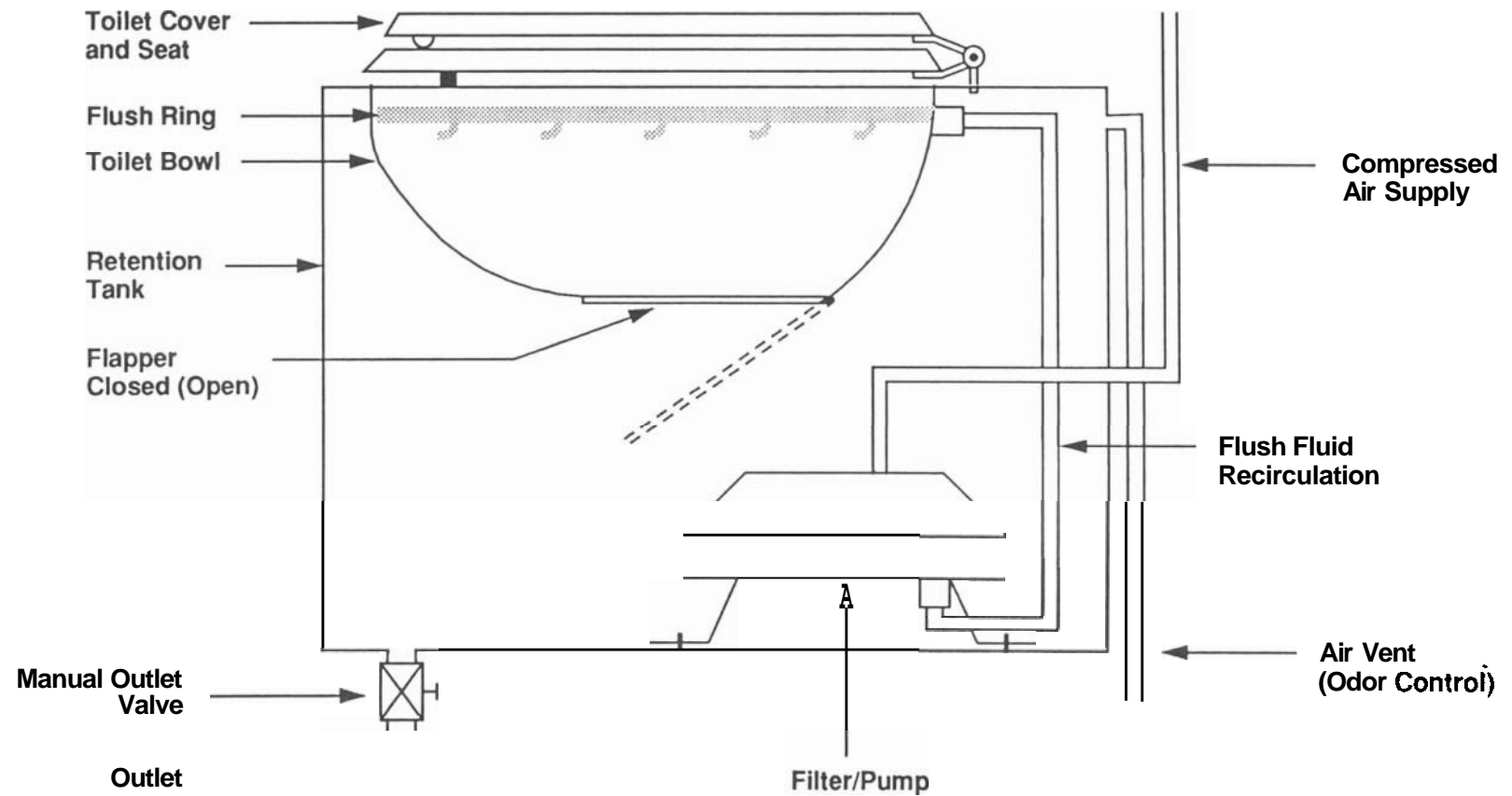
3.4 Recirculating Systems

Recirculating toilets accomplish bowl clearing, bowl washing, and transport through the pipes (when necessary) by **recirculating** the fluid from the retention tanks through the system (see Figure 3.7).

In general, 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.

Figure 3.7

Self Contained Recirculating Toilet



Several types of filters and pumps are used in recirculating toilet systems. Newer models use what is called a pin filter. This is 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 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 piece is positioned in the retention tank. Inside the container there is also a diaphragm which is used as the 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.

A second type of filter and pump, used more commonly on aircraft, is a metal screen filter and electric motor pump. The filter is a metal cylinder 3 to 4 inches in diameter and 7 to 9 inches tall. It is positioned vertically in the retention tank. The walls of the cylinder have holes approximately 3/16 inch in diameter. When the flush sequence is initiated, the electric motor pump pulls the waste through these holes into the cylinder and out to the flush ring. The filter is cleaned when the tank is emptied and water is sprayed from inside the filter against the walls of the cylinder. This reverse action clears the solid waste buildup from the filter holes.

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. Usually a pre-charge of 1 to 2 gallons of liquid is put in the retention tank. This fluid has both a deodorizer and coloring (usually blue).

This also means that multiple flushes per toilet use do not cause capacity problems. Since low flush fluid volumes (6 to 22 ounces) are less efficient at clearing and washing the bowl than a domestic high (5 to 7 gallon) volume flushes, multiple flushes per use may be likely.

The disadvantages of recirculating toilets are:

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

There **are** variations to the recirculating concept. They will be discussed below.

3.4.1 Monogram Self-Contained Recirculating System

The Monogram Self-Contained Recirculating System (see Figure 3.8) is currently used on Amtrak's **Amfleet** I cars.

In this system the retention tank is located beneath the toilet bowl and contains a filter pump for recirculating waste fluid during the flush cycle. Inside the filter pump is a diaphragm and pin filter. When air is injected above the diaphragm it pushes the effluent in the tank against the pin filter. The fluids pass through and through a tube to the flush ring. This fluid (64 ounces) is used to clear the bowl and wash the sides. When the pressure on the diaphragm is released, it relaxes and pulls effluent into the filter for the next flush cycle.

The flush cycle is initiated by pressing a mechanical button which activates a solenoid allowing compressed air into the filter pump. This forces liquid from the tank up into the flush ring, clearing the bowl allowing the waste to drop into the retention tank.

At the bottom of the bowl is a "sugar-scoop" shaped drain into the holding tank. While there is no odor seal between the bowl and the holding tank, there is a vent on the holding tank through which the odor passes due to higher pressure inside the tank car. This higher pressure results from the **train's** air conditioning system or simply from the effect of the **train's** movement

Since no new water is introduced to the system with each flush the toilet can be flushed repeatedly to ensure that the bowl is sufficiently cleaned without any impact on capacity.

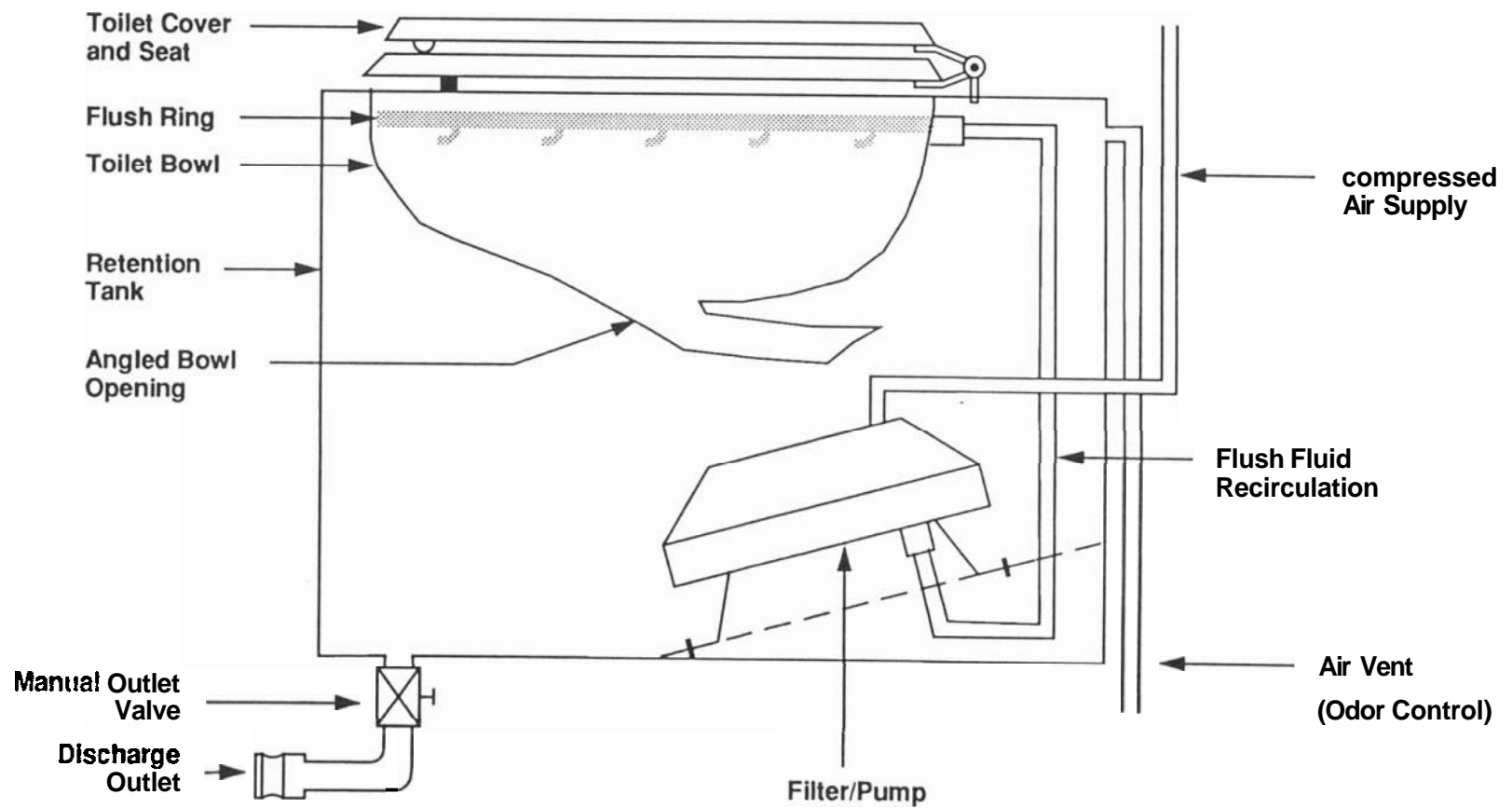
When the retention tank is full, a valve can be opened to discharge the waste into an appropriate waste collection device.

Monogram uses a Teflon coated, dry bowl. It has a tongue above the drain to prevent long objects from entering the tank or clogging the drain.

The retention tank has a 17 gallon capacity. **As** with all recirculating toilet systems, a pre-charge of potable train water, deodorant, and coloring must be added to the retention tank prior to use. This combination of fluids is intended to keep the recirculating fluid colored blue and to cover any odors from the waste material.

Figure 3.8

Monogram Self Contained Recirculating Toilet



Approximately 6 gallons of pre-charge are necessary leaving an effective **tank** capacity of 11 gallons for waste materials (new flush fluid is never introduced to the system).

3.4.2 Monogram "Modified" Recirculating System

The Monogram "Modified" Recirculating System (see Figure 3.9) is in use on **Amtrak** Heritage cars. It operates in the same way and with the same fluid volume per flush, 64 ounces, as the self-contained system with several exceptions:

- The bowl is **electro-polished** stainless steel.
- It uses a large, flat, round flapper at the bowl drain.
- The tank has a total capacity of 22 gallons as opposed to the 17 gallon capacity on the self-contained unit. Since the pre-charge requirement is the same, there is 6 more gallons of capacity.

3.4.3 Monogram Remote Recirculating System

The Monogram Remote Recirculating System (see Figure 3.10) is essentially the same as the Modified Self-contained Recirculating System except that the holding tank is not directly beneath the bowl. This enables the use of a much larger capacity holding tank mounted beneath the floor of the car, and possibly shared by more than one toilet.

The system uses a stainless steel bowl with a round flapper. When the flush button is pressed, compressed air is forced into the filter pump in the remote holding **tank**. Just as with the self-contained systems, the fluid is forced by the pump up to the flush ring in the toilet bowl as the flapper opens. The waste drops into a steeply graded pipe and flows by gravity to the holding **tank**.

The **tank** is emptied through a bottom outlet pipe and the waste flows out by gravity.

3.5 Vacuum Systems

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 3.11).

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

Figure 3.9

Monogram Modified Self Contained Recirculating Toilet

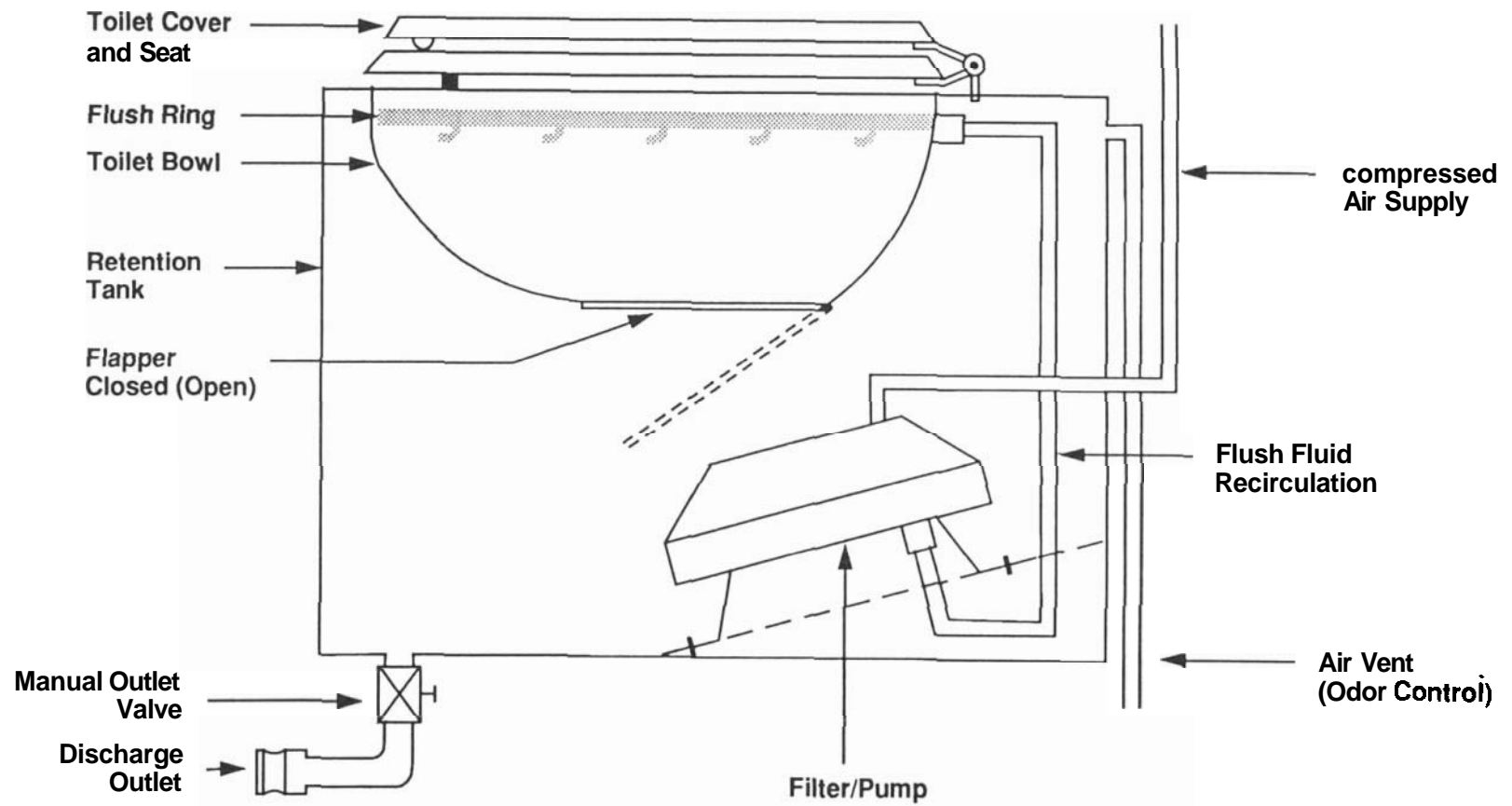


Figure 3.10

Monogram Remote Recirculating Toilet

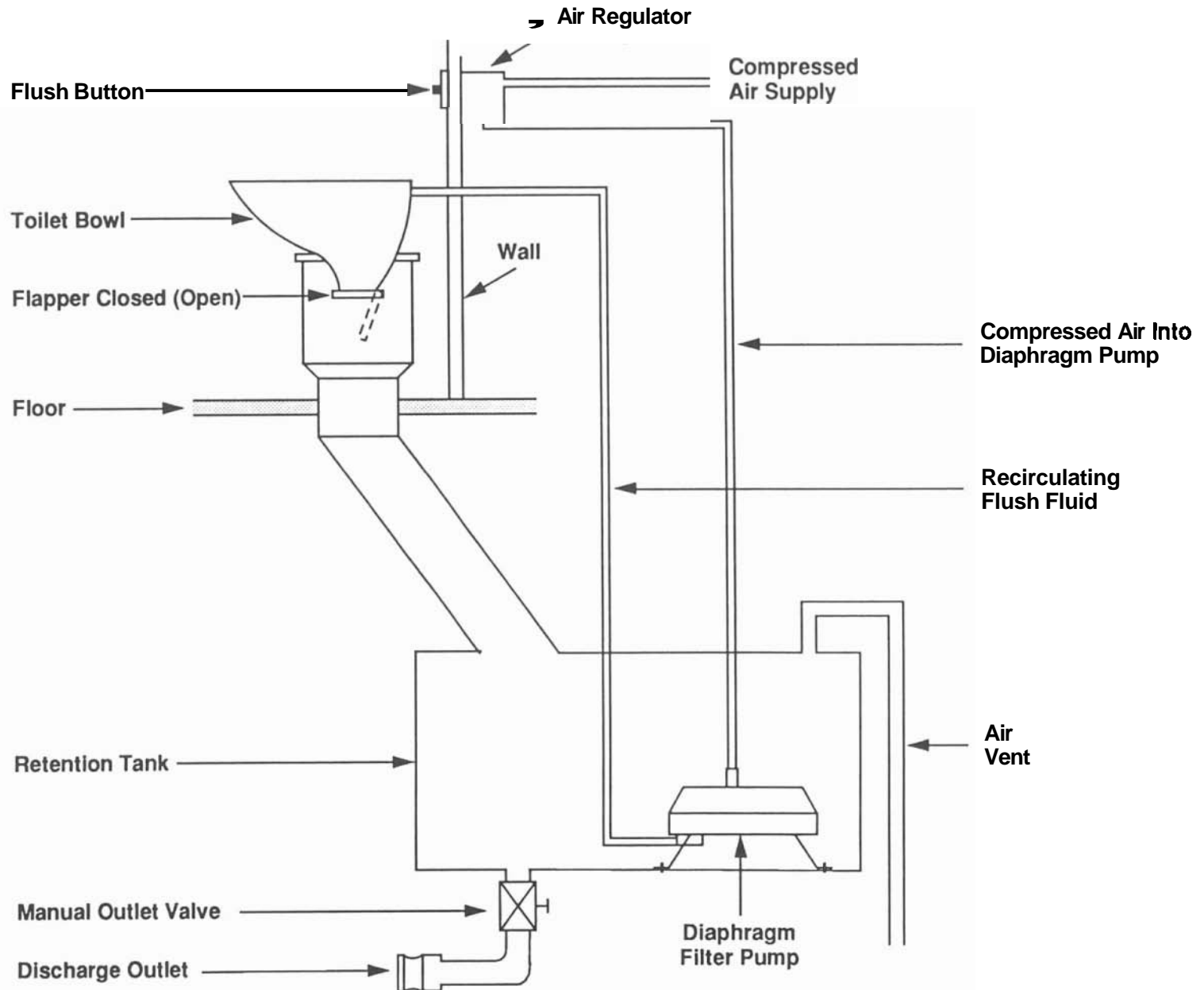
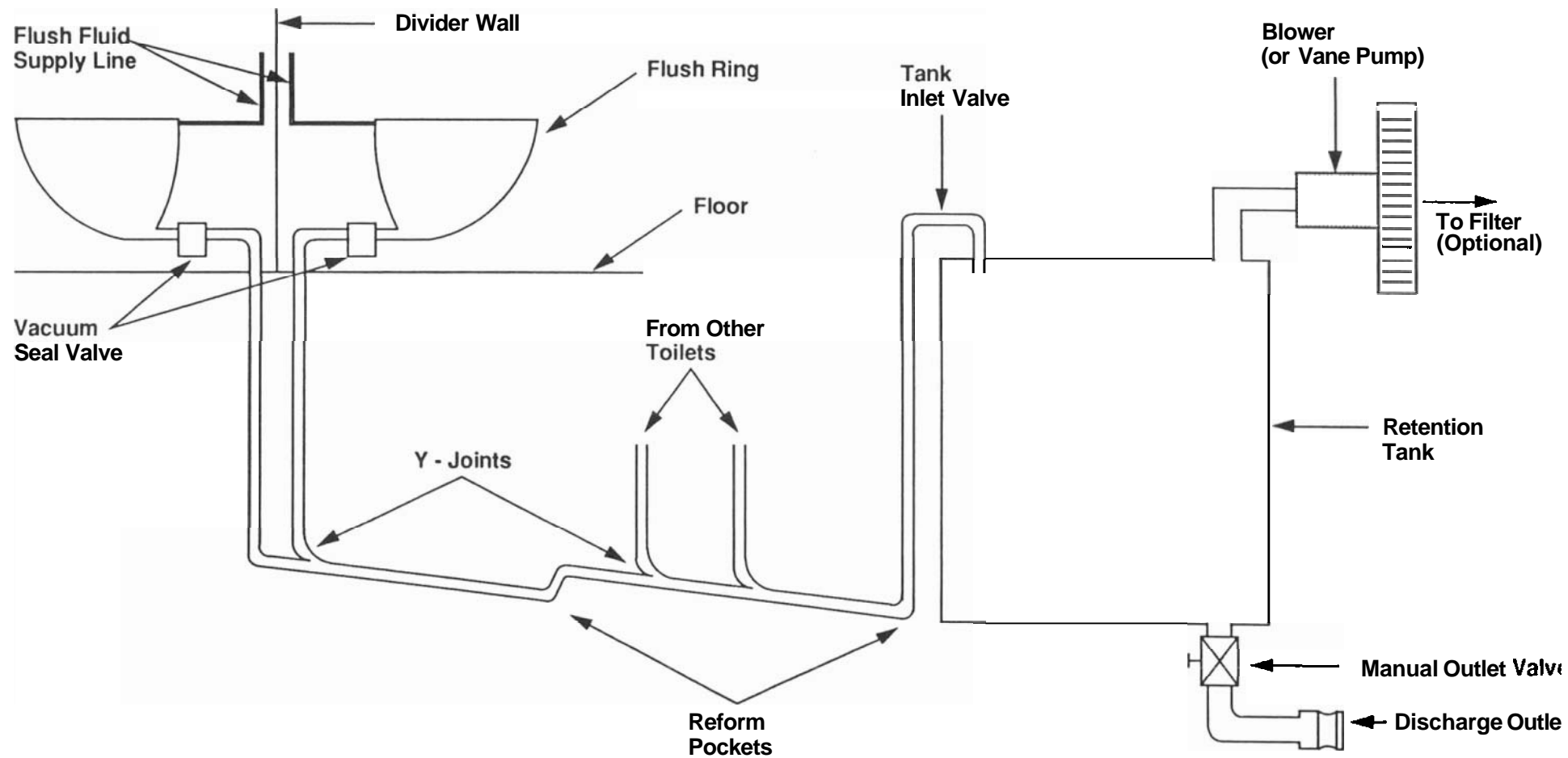


Figure 3.11
Vacuum System

3-22



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 but generally are not as efficient, reliable, or quiet. They will often be used in pairs where one blower would be used. They also generate a vacuum in the waste retention tank.
- 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 means of which the waste is drawn 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.

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.

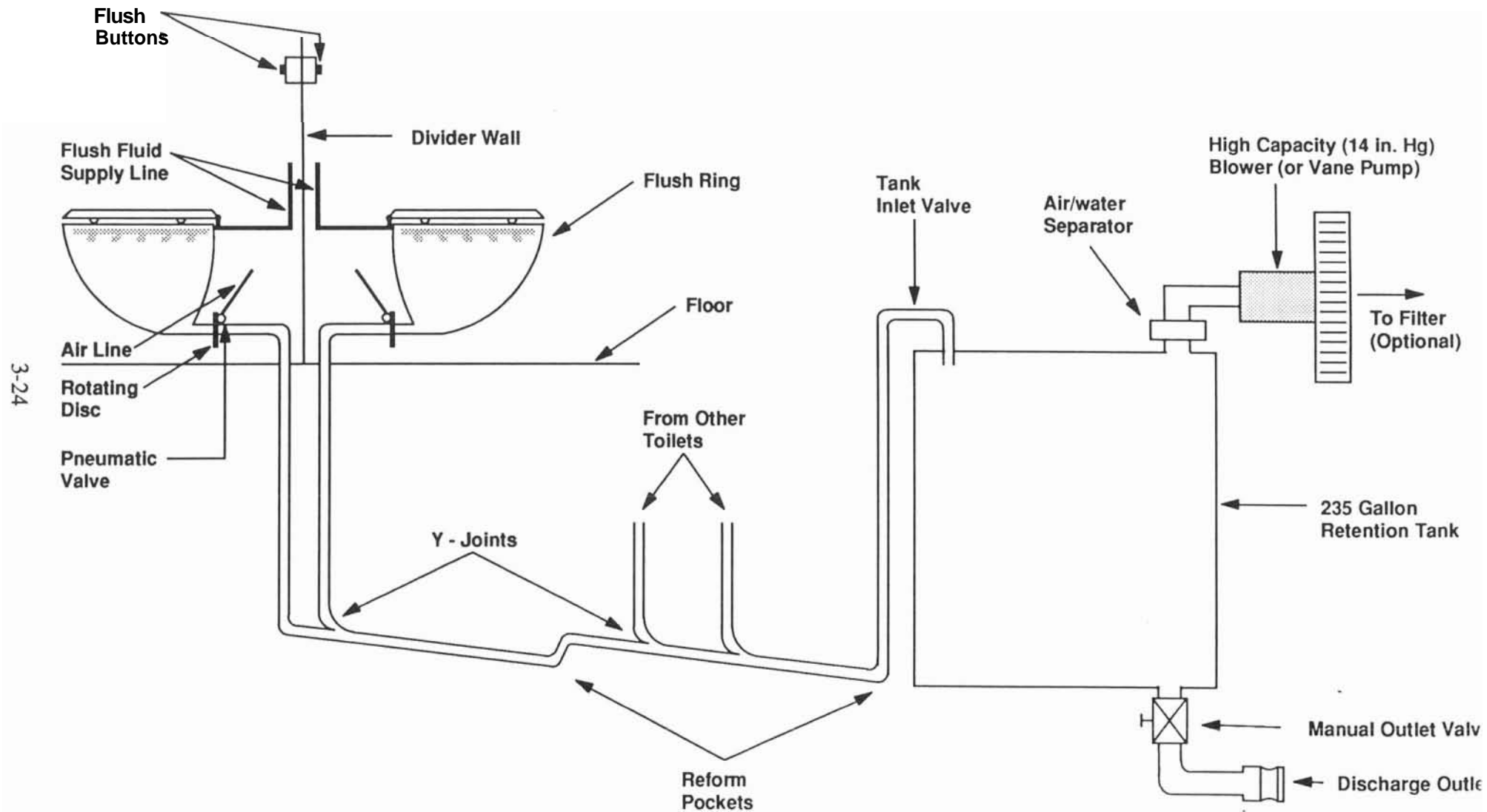
3.5.1 Evac 2000 Vacuum Toilet System

The Evac **2000** Vacuum Toilet System (see Figure **3.12**) is not currently in use on **Amtrak** with the exception of two units currently being tested on a Superliner car. It is currently installed on several hundred rail coaches in Europe.

The Evac system uses one vacuum collection system per car which is connected to all of the toilets on that car. The system generates and continuously maintains a vacuum in the retention **tank**. After a flush, or in the event of a vacuum leak in the

Figure 3.12

Evac 2000 Vacuum System



piping, the blowers will operate to renew the vacuum. Evac uses vane pumps to generate the vacuum on the test Superliner, but will be switching to blowers. Evac has installed conventional (carbon) filters to eliminate odors from the tank from escaping as the blower operates. An **air/water** separator is located upstream of the vacuum pumps to prevent liquid from entering the pumps.

The Evac 2000 toilet bowl has a teflon surface and steep sides. It is designed to be used dry. There is no flapper on the bowl, rather the drain is a round opening 1-1/2 inches in diameter leading out the back of the bowl. This opening is smaller than the piping in order to prevent clogs in the system.

The vacuum seal is a rotating disc in the piping (**2** inch diameter) just beyond the bowl drain. It is powered open and closed with air pressure (approx. 5 psi). In the closed position it is **hermetically** sealed by differential pressure when there is a vacuum in the tank. When there is no vacuum, the disc is spring loaded to prevent odors from escaping from the tank.

When the **electro-mechanical** flush button at any toilet is pressed, the rotating disc valve is **quickly** rotated until the cut-out portion of the disc is in place in the pipe. At the same time six ounces of potable train water is sprayed down the sides of the bowl through three nozzles in the flush ring. The combination of the water and the vacuum pressure clears the bowl and the water washes the sides of the bowl. After the flush cycle the disc valve rotates back to the closed position and is designed so that any waste on the disc is wiped off during this rotation. In the event that some waste material in the piping should prevent the rotating disc from closing completely, the system will recycle the close procedure three times in an attempt to allow the obstruction to be cleared. If it still remains open a light will be illuminated on the control panel to indicate which toilet is causing the problem.

The vacuum in the retention tank is sufficient for one or two flushes. During the flush cycle it draws approximately 133 liters of air through the piping. There is a control logic unit on each car which ensures that if toilets are flushed simultaneously they will flush sequentially. The system will delay each flush until the vacuum is regenerated. Evac expects the maximum delay to be ten seconds.

The retention **tank** has a capacity of 235 gallons. Of this, 35 gallons **are** used to draw the vacuum and the remaining 200 gallons to hold waste and flush fluid. The Evac system is maintained under a constant vacuum of 13 inches of mercury. This provides adequate velocity and lift in the systems. The toilets are prevented from flushing when the system vacuum drops to **7** inches mercury or less. This ensures proper **transport** of the waste and prevents clogging in the pipes. In case someone should be seated on the toilet and it accidentally flushes, the toilet seat is designed so that the air passes under the seat and above the shroud.

The piping on Evac installations is specifically profiled to enhance the vacuum transport. For example, at joints in the piping, the pipes form a "Y" joint rather than a "T" joint. There are also specially designed reform pockets. When the waste is travelling through the pipe it has a tendency to spread out. As this happens it loses velocity and there is increased risk that it won't make it to the tank. Reform pockets are places in the pipe where waste travelling at slower speed will stop and reform into a unit. The next time a flush is **initiated**, this reformed unit of waste will be pulled into the **tank** at high velocity.

The only moving part of the system which comes into contact with the waste material is the rotating disc valve. It is a carbon faced, spring-loaded, self regulating disc which has undergone cycle testing for 100k - 300k cycles.

3.5.2 Evac Ultimate Vacuum Toilet System

The Evac Ultimate Vacuum Toilet System (see Figure 3.13) is similar to the Evac 2000 in most respects but the few differences **are** important. The flush cycle is initiated by closing the cover of the toilet. This accomplishes three objectives:

- First, the flush cannot be initiated while anyone is seated on the toilet. Second, the cover must be closed for the system to operate most **efficiently**. A magnet in the cover triggers a reed switch under the shroud.

Second, a gasket on the underside of the cover makes a seal **with** the shroud (see Figure 3.14). When the rotating disc valve is opened the vacuum pulls the cover down on the closed bowl immediately removing the waste prior to introduction of water. After the waste is removed, 6 to 8 ounces of water is drawn in by the pull of the vacuum. Carefully placed holes between the top of the bowl and the underside of the shroud allow air into the system which scrubs the sides of the bowl with the water.

- Third, a low sound level. This is especially important in sleeping cars.

As with the Evac 2000, approximately 133 liters of air is drawn into the system during its one and a half second flush cycle.

The system uses gray water; water from the **sink**. A hose **from** the sink drain is attached to a 48 ounce stainless steel reservoir on the toilet. The hose has a filter to ensure that solids do not clog the flush ring. The reservoir holds enough water for six flushes, and needs only one use of the sink to fill. Any excess gray water is disposed of in the same way as gray water is **normally**.

Figure 3.13

Evac Ultimate Vacuum System

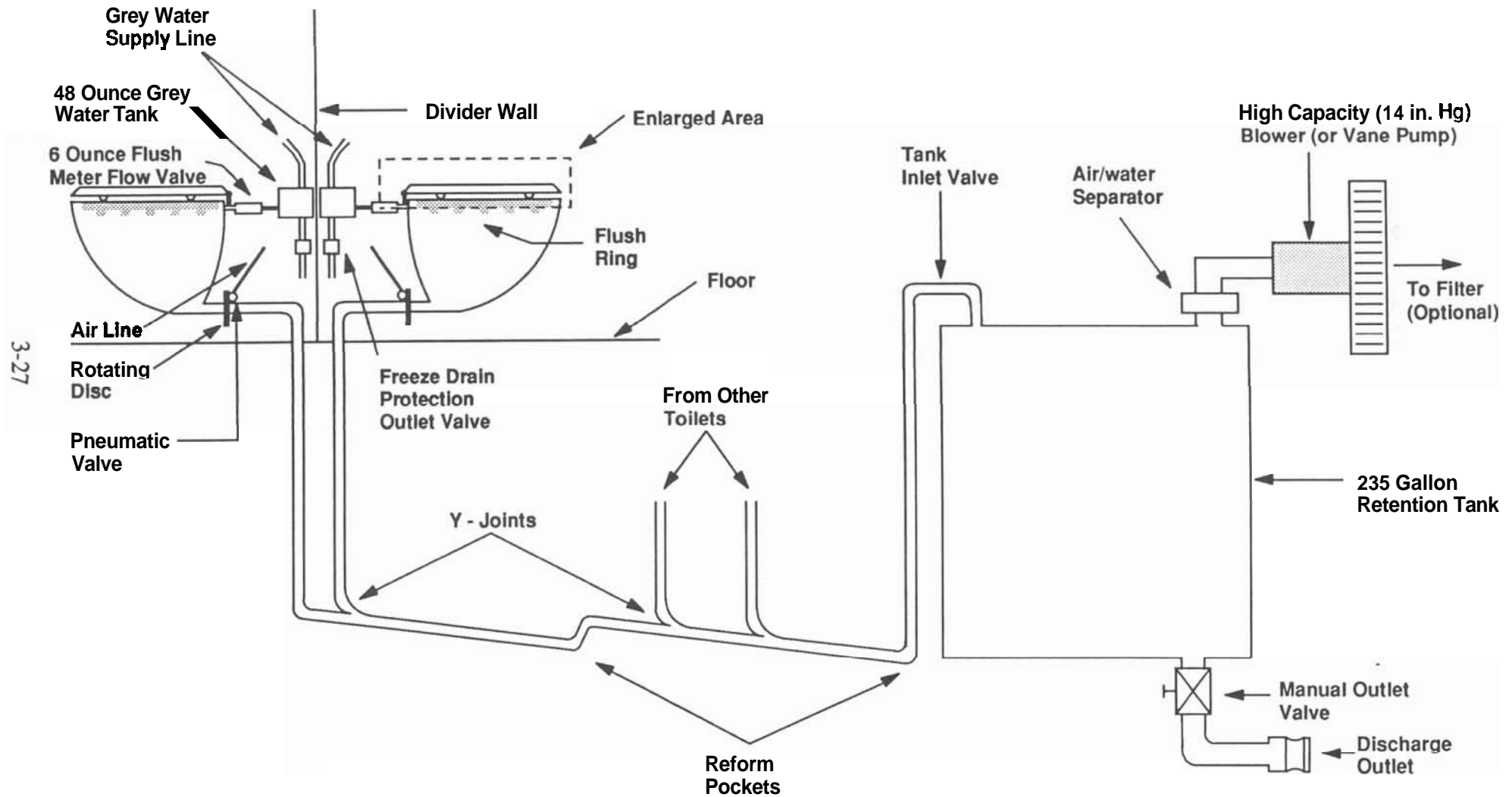
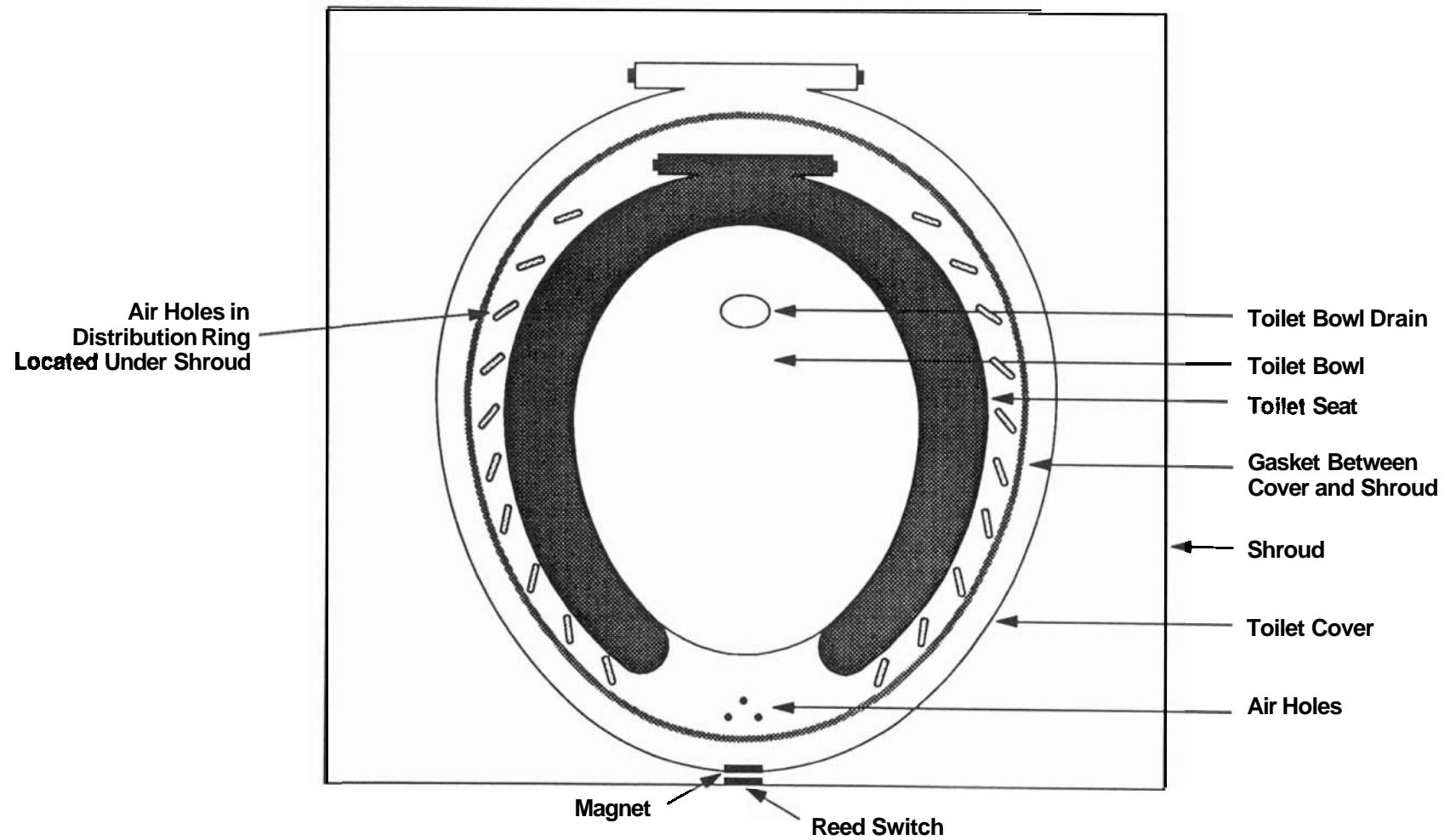


Figure 3.14

Evac Ultimate Top View (Cover Down)



The Ultimate's **control** system does not allow rapid re-flushing. A minimum of 15 seconds must pass between successive cover closings for the system to operate. This discourages children from playing with the system.

Evac expects that the Ultimate, which is not in regular passenger **service** yet but is being tested on the same **Amtrak** Superliner as the Evac 2000, will require less maintenance than the Evac 2000. This is because there are fewer moving parts. The only moving parts on the Ultimate are the blower, and the rotating disc. Since the gray water is drawn into the bowl by the vacuum, there is no need for a pump or a water solenoid valve. This eliminates the common problem of bowl-flooding caused by a sticking water solenoid valve.

3.5.3 GARD MkII Vacuum Toilet System

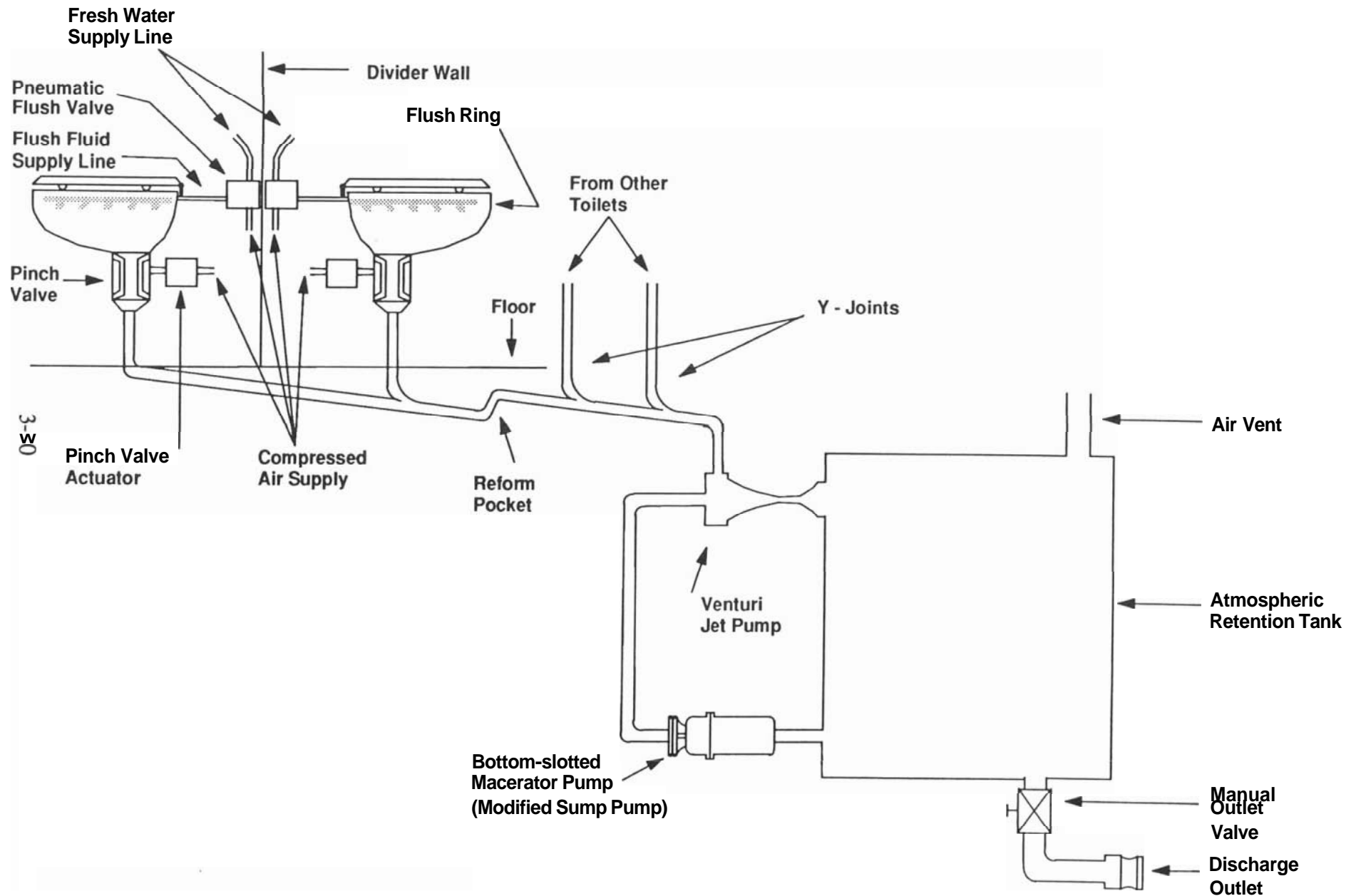
The GARD MkII Vacuum Toilet System (see Figure 3.15). currently in use on Viewliner cars, is different from most vacuum systems in the way it creates the vacuum. At the initiation of the flush cycle, a macerator pump pulls waste material and fluids out of the holding **tank**, grinds them and forces them through a **venturi** jet back into the holding tank. The piping from the toilets is connected to the venturi jet. The differential pressure created in the venturi jet creates a vacuum in the piping. By recirculating the waste to create the vacuum, an atmospheric tank can be used.

The GARD MkII system uses an **electro-polished** stainless steel bowl with a round, 1-1/2 inch drain over a pinch valve. The pinch valve is closed and has a small water spot to prevent odors from escaping from the holding **tank**. Compressed **air** is used to keep the pinch valve closed.

When the toilet is flushed the macerator pump begins to circulate the waste material through the **venturi** jet to create the vacuum. After four seconds the system has generated 15 inches of lift in the piping and an electric flush valve allows **32** to 48 ounces of potable **train** water into the bowl to clear the waste and to wash the bowl. Seven tenths of a second later the pinch valve opens to allow the waste to wash into the piping and be pulled by the vacuum to the holding **tank**. The pinch valve closes seven seconds after flush cycle initiation and the macerator continues to run for another three seconds. This allows **air** to be drawn in from the ends of the piping to clear the piping of any remaining waste material.

Multiple toilets can be used with one vacuum collection system. Up to three toilets can be flushed at the same time without degrading the performance of the pipe transport. **In** addition, to prevent clogging of the macerator, there is a pressure sensor which indicates insufficient pressure and reverses the flow through the macerator to **try** to clear the blockage.

Figure 3.15
GARD Mk II Vacuum For Viewliner



Since this system uses the waste in the holding **tank** to create the differential pressure, a pre-charge of fluid must be added to the holding tank after servicing before the system can be used again.

3.5.4 GARD MkII "Modified" Vacuum Toilet System

The GARD MkII "Modified" Vacuum Toilet System (see Figure 3.16) is the same as the system above in nearly all respects. There are two important differences:

- Rather than using up to 48 ounces of potable **train** water per flush, the modified version uses 8 ounces of water which is under pressure to at least 40 psi. This also reduces the holding **tank** capacity requirement and the pressurization enables better bowl clearing and bowl washing given the low fluid volume.
- A spring-loaded ball valve is used in place of a pinch valve to reduce maintenance and failure due to tears in the rubber on the pinch valve.

3.5.5 Monogram "Modified" Vacuum System

Monogram has **modified** its traditional rail vacuum system to enable total retention. The original system is described in Section 3.5.6.

The Monogram "Modified" Vacuum System (see Figure 3.17) is a low flush volume system using seven ounces of potable train water per flush. The water is sprayed through nozzles on the flush ring to clear and wash the bowl.

The bowl is designed to be used without a water spot and has steeper sides than the traditional Monogram bowl. It has a teflon coating to reduce friction. The vacuum seal is a ball valve which is powered open by compressed air, and is spring-loaded to close.

The flush is initiated by pressing an electro-mechanical **button**. A blower starts to pull a vacuum on the **first** holding **tank** generating a vacuum in this 20 gallon temporary holding tank. The blower is connected to a conventional (carbon) filter to remove odors. When there is sufficient vacuum in the tank the system opens the ball valve and sprays seven ounces of water into the bowl. The combination of vacuum pressure and water evacuates the waste from the bowl, through the piping into the temporary holding tank.

The **temporary** tank can hold up to **three** gallons of waste and flush water before the vacuum efficiency is reduced. In between flushes, a macerator grinds the waste in the smaller **tank** and pumps it to a 235 gallon **retention** tank. This large **tank** is kept at atmospheric pressure.

Figure 3.16

GARD Mk II Modified Vacuum For Viewliner

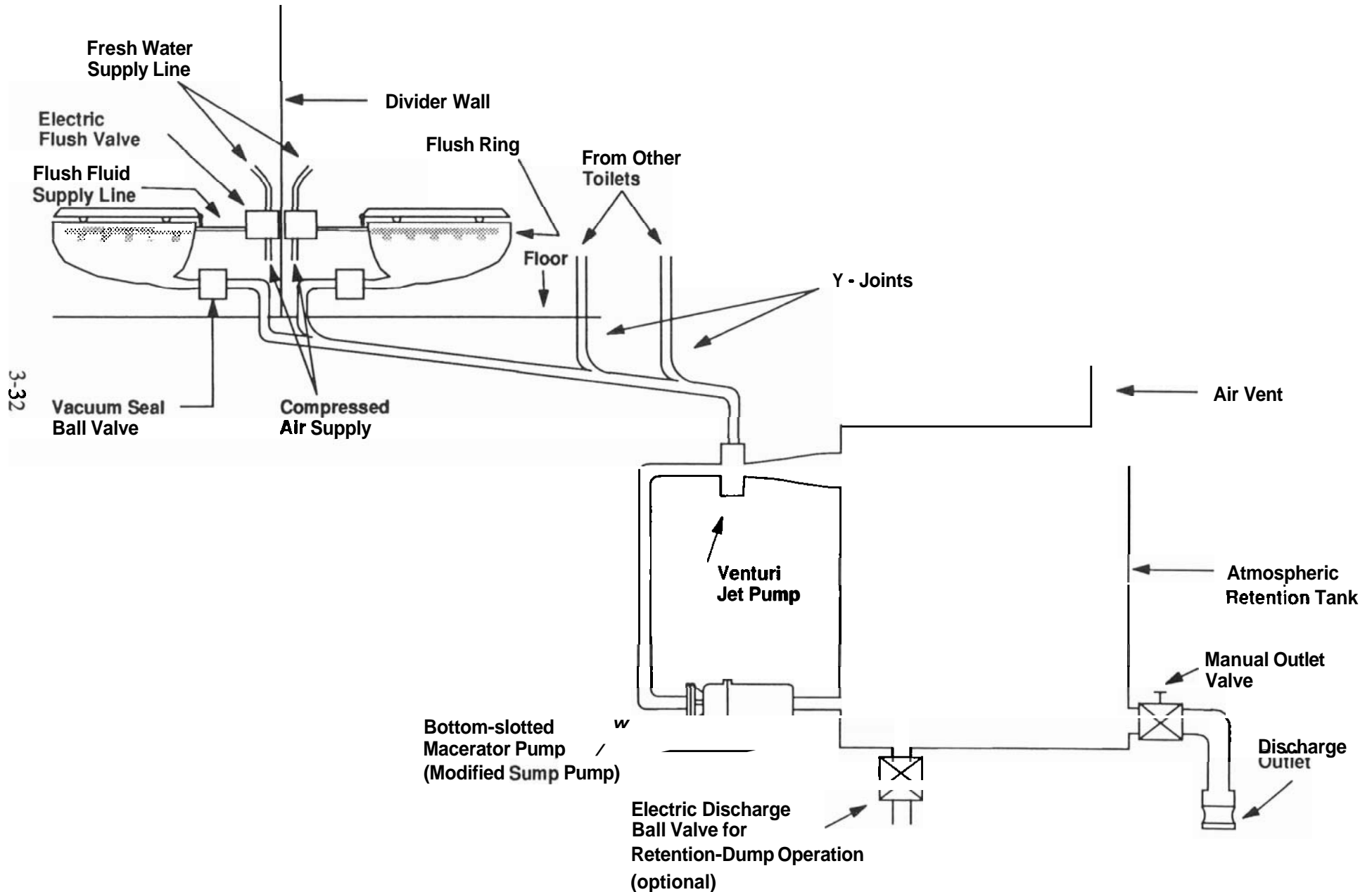


Figure 3.17

Monogram Modified Vacuum Toilet

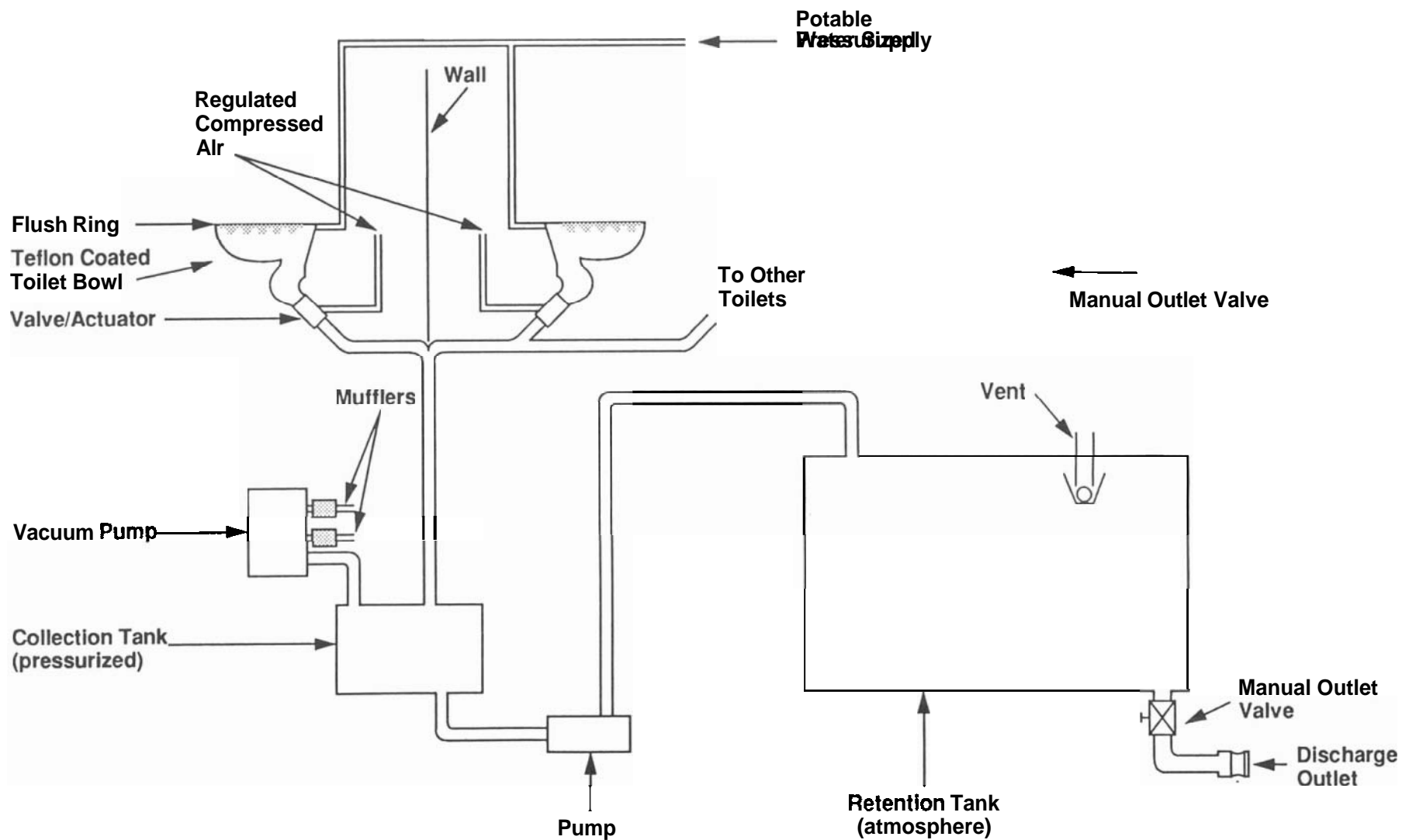


Figure 3.18

Monogram Vacuum Waste System

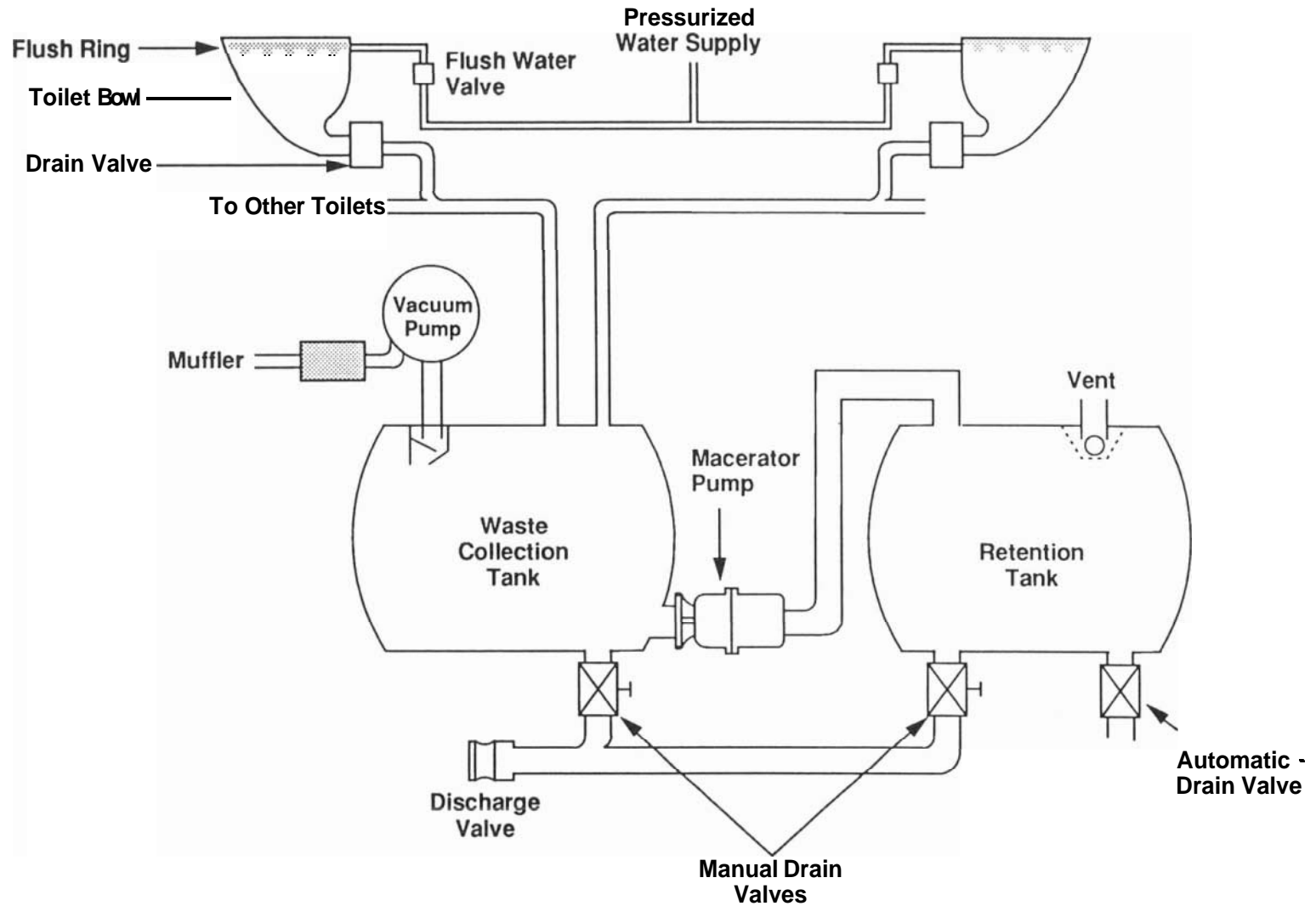


Figure 3.19

Monogram Vacuum Waste System

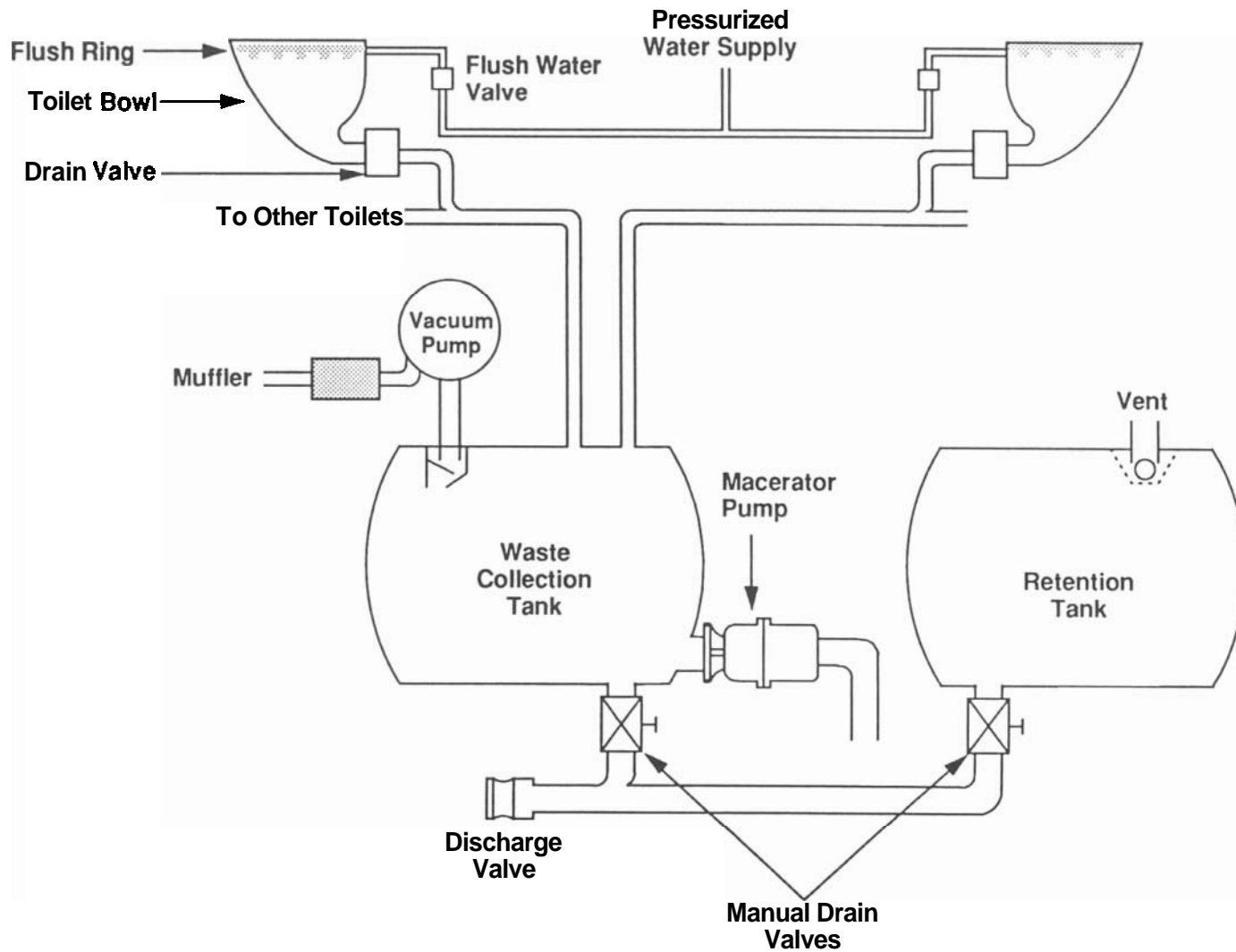
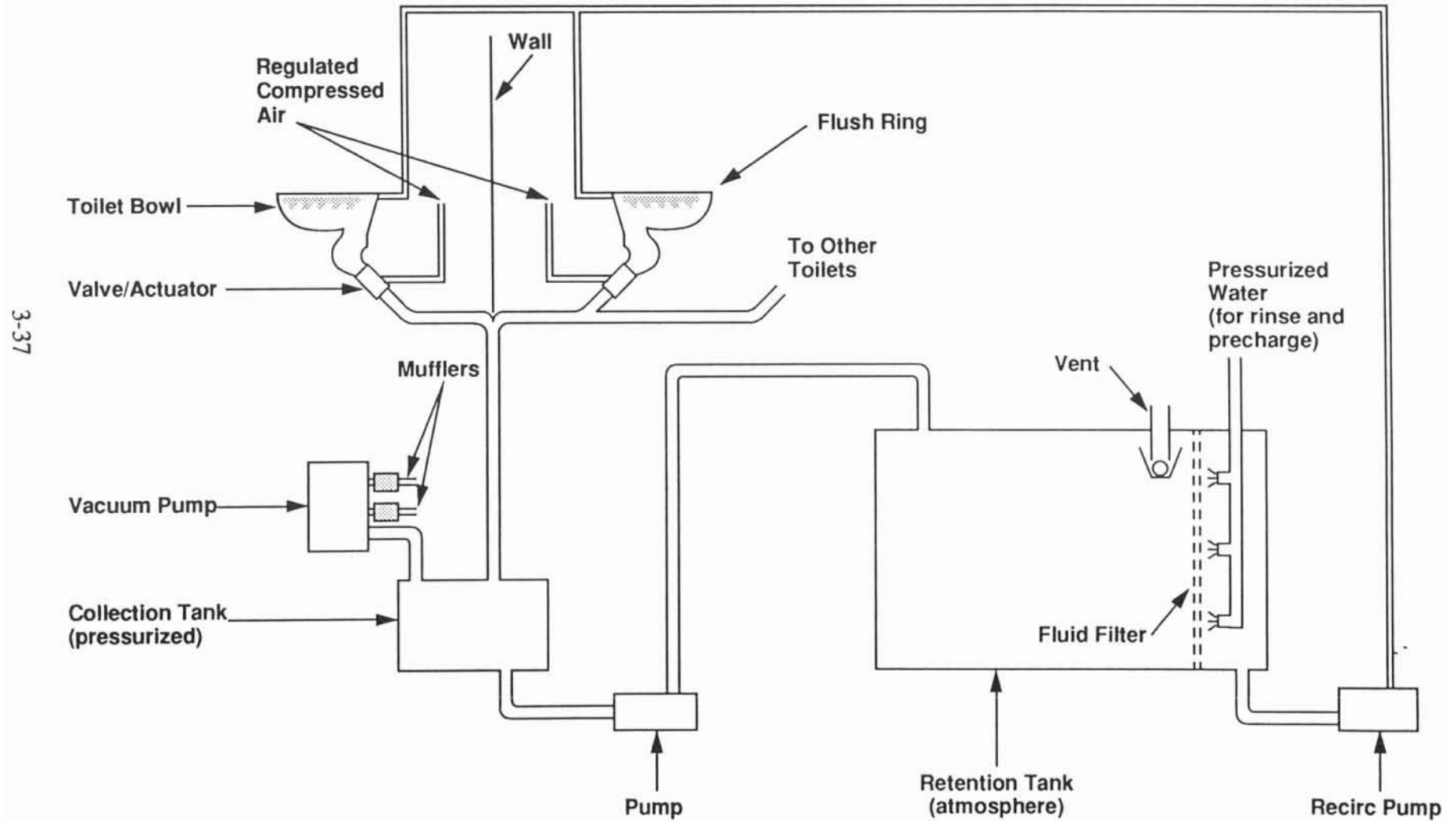


Figure 3.20

Monogram Vacuum Recirculating Toilet



When the flush is initiated, a pump draws fluid through a filter in the second holding tank and pumps it up to the toilet bowl. The system uses 64 ounces of fluid per flush as compared to the 8 ounces used by the modified, non-recirculating system described in Section 5.5. This allows for better bowl clearing and washing without creating a holding tank capacity burden.

As with the modified vacuum system, the vacuum is drawn on a small (20-gallon) temporary holding tank. As this tank fills with waste, a macerator pump pumps it to the larger atmospheric holding tank for final retention.

3.5.8 Monogram Prototype Limited Water Macerating Toilet

The Monogram Limited Water Flush Macerating (see Figure 3.21) is a different type of vacuum system from the other Monogram products. It combines the use of a vacuum for bowl clearing and transport to the macerator with a pump to transport the macerated waste to the holding tank.

The system uses a much steeper bowl than other Monogram systems. The bowl drain opening is just under two inches in diameter and has no flapper. Below the bowl drain is an S-trap which terminates in a vertical canister called the Waste Receiver. The system utilizes a wet bowl which forms a vapor seal in the S-trap .

At the initiation of the flush the pump is turned on and generates a low pressure differential on the bowl side of the pump. The pressure differential is **equal** to between **15** and **16** inches of mercury. A solenoid operates the flush valve letting 3 liters of potable train water into the bowl to clear the waste. As the waste leaves the bowl it is pulled by the pressure differential into the Waste Receiver.

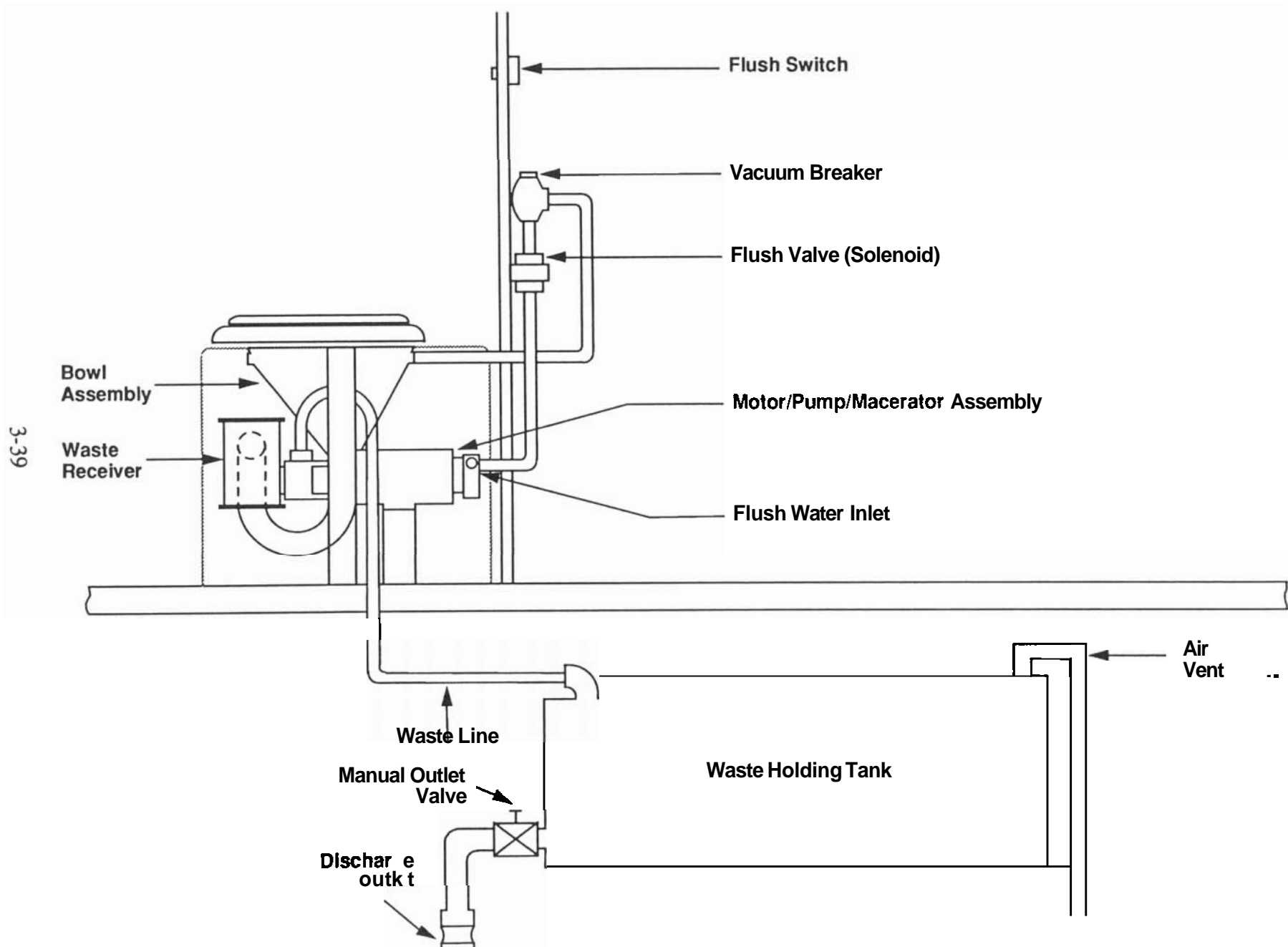
The Waste Receiver has an opening to the pump at the bottom side of the canister. In this opening is a cutter plate and a cutter blade. The plate has holes roughly **1/8th** inch in diameter similar to a meat grinder. When the pump is running the blade rotates across the plate as the waste material is pulled through. This action grinds the solids to less than **1/8th** inch in diameter.

The pump then pumps the ground waste through a pipe into the holding tank located beneath the floor of the car. In Monogram's tests, the pump had sufficient force to pump the waste up a 6 foot vertical hose into a floor mounted, top-loading tank, if necessary.

Monogram has designed the system based on the assumption that eighty percent of the flushes will not contain solid wastes. Therefore there will always be some liquid in the Waste Receiver. The solids will soak in the liquid prior to being pulled against the cutter plate for maceration. During each flush cycle the liquid in the Waste Receiver will be pumped to the holding tank and be replaced by new liquid. Some

Figure 3.21

Monogram Limited Water Flush Macerating Toilet



of the solid waste will be removed from the Receiver as well with each flush. Thus, one flush cycle is not necessarily designed to remove all of the waste from the Waste Receiver.

This system was configured originally for **trains** which were allowed to dump on the right-of-way. Should this system be used for total retention, Monogram indicated that it would reconfigure the flush ring to reduce the water volume per flush and increase the water pressure to ensure adequate bowl clearing.

Each time the large tank is emptied, water can be injected into the tank behind the filter to clean waste debris off the filter. The pre-charge of water, coloring, and deodorizer, necessary for a recirculating system, is added at this point.

3.5.9 Railtech Vacuum System

The **Railtech** Vacuum System is in pre-production stage as of the writing of this report (see Figure 3.22).

The system is the same as the **Railtech WTS 8300** system with the exception of pipe transport by vacuum from the macerator chamber to the retention **tank**.

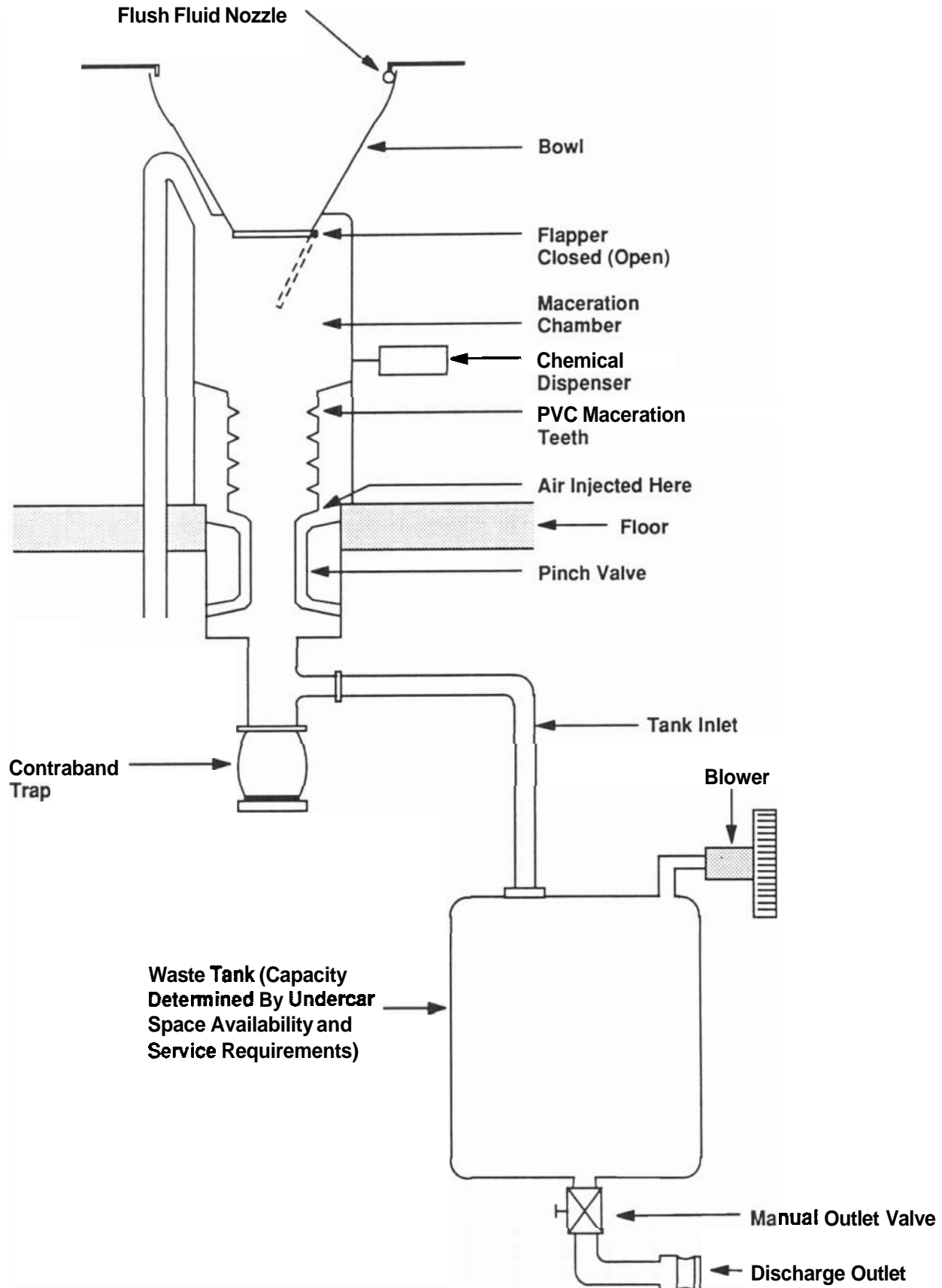
When the flush is initiated in this configuration, a blower is used to draw a vacuum on the retention **tank** in a manner similar to those described above. During this time, the flush fluid is **introduced** into the bowl through a single nozzle and the waste drops past the flapper into the maceration chamber. When the maceration cycle has been completed, the pinch valve opens and the waste is pulled through the piping to the **tank**.

Unlike other vacuum systems which do not maintain a constant vacuum on the entire system and consequently delay bowl clearing until such a vacuum is generated, the **Railtech** model allows immediate bowl clearing to the maceration chamber upon flush initiation. Since the maceration process requires more than eighty seconds to complete there is sufficient time for the blower to make the vacuum. In addition, any heavy objects which are not pulverized during maceration will drop into a contraband trap located below the pinch valve.

Since this system is in pre-production, the exact configuration of the system has not been determined to the extent that **further** description is possible.

Figure 3.22

Railtech Pre-Production Vacuum System



Chapter 4

WASTE DISPOSAL, HEALTH AND ENVIRONMENTAL ISSUES

4.1 Overview of Pump-out and Disposal Practices, and Options

Pump-out and disposal procedures are now in place at many Amtrak passenger car servicing and maintenance yards, but will have to be expanded to meet the increased workload if more retention toilets are put into service. In the Northeast Corridor where up to 90% of the train consists are **Amfleet I's**, maintenance facilities now have extensive ongoing retention toilet maintenance programs. At many other locations where **Amfleet I's** consists are not used and where the maintenance facilities have not been modernized, pump-out and disposal practices will have to be significantly expanded.

At Amtrak facilities that have recently been modernized, like the one in South Boston, Massachusetts, pump-out and disposal practices have been 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). Toilet dumping and cleaning typically proceeds in the following manner:

- Attach a lightweight hose via a "quick connect" to the outlet pipe from the toilet.
- Pull release cord and allow the toilet contents to flow by gravity through the hose to a pipe which directs it to a holding tank.
- Add five gallons of potable water, either through an outside connection or directly to the bowl, and rinse the bowl and retention tank.
- Discharge the rinse water through the same hose.
- Disconnect the hose.
- Add five gallons of potable water for the initial charge.
- Add two deodorizer tablets into the toilet bowl.

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 pump-out 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 same 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 (required by local waste treatment **authorities**—**see** below).
- Risk of unacceptable forms of waste being **introduced** into the local sewer system (e.g., fuel oil).
- Such facilities may contravene local or national regulations regarding the handling of and worker exposure to potentially hazardous materials.
- It is likely to be an undesirable **smelly** and unpleasant location to work, and thus be unacceptable to **Amtrak** workers.

A further alternative is to use mobile pump-out **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. Pump-out contractor services **are** readily available in most medium and larger sized communities. Mobile pump-out appears to be a suitable approach wherever cars **are** serviced in the open, and there is access for a road vehicle alongside the cars.

In conclusion, waste removal from the car can be accomplished in two acceptable ways:

1. Permanent pump-out manifold 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 pump-out by a waste-disposal contractor.
2. Mobile pump-out **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.

4.2 Waste Acceptance at Local Waste Treatment Facilities

In the Amtrak Report entitled "Waste Handling Improvement Program" and dated December 4, 1989, **Amtrak** proposed toilet maintenance facilities in 15 cities. In order to predict the willingness and ability of these municipalities to accept the sanitary waste from the trains, we performed phone interviews with the local municipalities in 6 of the 15 potential cities. A list of the cities and individuals interviewed and a summary of their comments are given in Table 4.1.

Each of the interviewed municipalities 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 (methods other than treatment by the local **POTW**). The municipalities 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 system because of these types of wastes.

The municipalities in each of the cities foresaw no 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 monitoring and billing purposes.

4.3 Chemical Usage

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.

Table 4.1: Summary of Comments from Municipalities


Location	Person Interviewed/ Title/Telephone #	POTW Type	Systems Similar to Amtraks Serviced	Opinion on QA Salts	Cost	Comments
Boston, MA	Janice Kearney/ (611)242-6000	Biological	Airlines and Chemical toilets	No problem	NA	<ul style="list-style-type: none"> Foresaw no difficulty permitting waste
Portland, OR	Gary Barnes/Industrial Waste Technician/ (503)796-7180	Biological	Airlines and Chemical toilets	QA chloride salts would be no problem. bromide salts may be	\$0.757/100cf up to 300 mg/LBOD and 350 mg/LTSS additional cons of \$0.117/lb excess BOD \$0.134/lb excess TSS	<ul style="list-style-type: none"> Foresaw no difficulty permitting waste Sampling & Monitoring Manhole would be required Volume would need to be monitored
 Salt Lake City, UT	Bill Farmer/Superin- tendant of Water Reclamation/ (801)799-4001 Vince Houtz/Office Manager of Public Utilities/ (801)483-6125	Biological	Airlines and Chemical toilets	No problem	NA	<ul style="list-style-type: none"> Foresaw no difficulty permitting waste Major problem will be monitor- ing the volume of waste Waste will need to be ground prior to discharge to sewer
San Antonio, TX	Robert Martinez/ Assistant Wastewater Compliance Manager/ (512)534-6400	Biological	Chemical toilets	No problem	NA	<ul style="list-style-type: none"> Foresaw no difficulty permitting waste Waste volume must be monitored if it's discharged to sewer it will have to be trucked

Table 4.1: Summary of Comments from Municipalities (Continued)

Location	Person Interviewed/ Title/Telephone #	POTW Type	Systems Similar to Amtraks Serviced	Opinion on QA Salts	Cost	Comments
Seattle, WA	Doug Hilderbran/ Industrial Waste Program Officer/ (206)684-2341	Biological	Airlines, Buses, and Chemical toilets	No problem	NA	<ul style="list-style-type: none"> Fonsaw no problem permitting waste stream Major concern was the buildup of solids in sewer line
Washington, DC	Russ Thomas/Waste- water Treatment Bureau Chief	Biological	Chemical toilets	No problem	NA	Fonsaw no problem permitting waste stream

NA = Not Available

Source: Arthur D. Little

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 their **Amfleet II** recirculating toilets: Hex Tab #2 and Celeste Sani-Pak. To date Amtrak has not had problems with either of these products except when the toilets are not emptied on a regular basis.

Both products are introduced into the tank of the recirculating toilet by adding two tablets or sachets along with five gallons of water (16 gallon total storage capacity), after they have been emptied and cleaned. Based on this usage, the final chemical concentration will be approximately 250 mg/L. In addition to the quaternary ammonium salts, the products have a blue dye to color the recirculated water and a floral perfume to mask any odors associated with the waste.

The manufacturers of both 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.

4.4 Health Risks and Safety Practices Associated with Toilet Maintenance

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. A more detailed discussion of the potential hazards associated with these agents is given in Appendix A.

The maintenance worker is 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 training program, a medical program and increased protective equipment (possibly face shields).

Chapter 5

EVALUATION OF WASTE RETENTION TECHNOLOGIES

5.1 Introduction

Chapters 2, 3, and 4 have provided detailed descriptions of toilet technologies and practices and of individual proprietary products currently available for railroad use. This discussion uses the available information on toilet design and operating principals as a starting point and provides an evaluation of how well each toilet system meets the requirements of a good **railroad** passenger car sanitation system.

The **first** step is to define the performance requirements of a "good" toilet system. This is based on established standards (where available) and our judgement of what performance is required of the system to fully satisfy Amtrak passengers. In some instances these performance requirements are not well defined, and some further research is wanted. Passenger acceptance criteria are a good example. We know that toilets are much complained about, but we do not know exactly what users would like to see in an ideal **toilet/washroom** installation.

The second step is to evaluate each of the systems described in Chapter 3. To do this we have developed a rating system somewhat similar to those used by *Consumer Reports*. Each system is rated against each performance criterion as to whether it:

- a) fully meets the criterion
- b) partially meets the criterion
- c) does not meet the criterion

Since there are many instances where information is lacking regarding whether an individual system would meet a specific criterion or not, there is a fourth rating:

- d) further information is required to provide a valid rating.

This is particularly **true** of reliability and user acceptance. Many of the technologies described in Chapter 3 are either at a prototype stage or have only been used in operating environments that differ substantially from those prevailing on Amtrak. Thus, the system performance can only be established through a properly designed test program.

This evaluation is presented as a rating chart, plus narrative comments on key issues in Section 5.3 below. Evaluations are based strictly on factual information, and judgments about the performance of individual proprietary systems are avoided.

In conclusion, it should be stated that the absence of any system **from** this evaluation does not imply anything about its suitability or otherwise in meeting the requirements of intercity and long-haul rail passenger services in the United States. **Our** policy in

this study has been to study those waste retention systems and technologies currently offered by the supply industry for this purpose. We **are** aware that other technologies and proprietary products are being used or **are** being developed for other purposes and may be adapted for railroad applications in the future.

5.2 Waste System Evaluation Criteria

The evaluation criteria are listed in Table 5.1. In setting these criteria, we have med to develop performance standards that are either quantitative or are readily checked by reference to system design information, or measurement either in service or with a suitably designed test installation. In our view, vague and qualitative standards are of limited use. They offer little guidance to the supplier as to what is required of the equipment, and determination of whether they are being met is judgmental and thus likely to be inconsistent.

The individual performance criteria are as follows:

Group 1: Passenger Acceptability

- Ergonomics. This relates primarily to the ease and **comfort** of use of the system for the average range of passengers. Much of this is concerned with the height and other dimensions of the toilet bowl and seat and has minimal influence on the waste retention function. References 10 and 11 are standards for domestic fixtures which can potentially be adapted to the railroad application. The questions that **are** relevant in this study are associated with toilet operation and waste removal:
 - Is the action to initiate flushing obvious to passengers that are not necessarily familiar with a given proprietary system?
 - Is the design such that the flushing lever or **button** can be located conveniently?
 - Does the toilet operate as expected? For example, systems that could have a substantial delay between pressing the flush lever and the actual flush could lead either to multiple flush **attempts** or an impression that the toilet is malfunctioning.
 - Is the design such that reasonable dimensional requirements can be met, including the accommodation of handicapped users? Although dimensional issues **are** not a primary subject of study in this report, the retention system design must **be** such that it does not prevent such standards being attained.
- Health Risks. Health risks may arise if the toilet is such that, in normal operation (not after a mechanical malfunction) users could be exposed to waste and thus the risk of infection. This criterion is not concerned with possible risks to servicing and maintenance personnel, which are discussed below. Of **course**, avoidance of this situation is a primary objective of toilet designers, and we would not normally expect a system to **be** deficient in this respect.

Table 5.1

List of Rating 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
- Waste Disposal

Car Configuration Acceptability

- System Weight
- Volume Requirements for Waste Storage
- Energy Requirements

- **Personal Injury Risks.** The toilet systems under review variously employ compressed air or vacuum to transport the waste, mechanical **macerators** to grind up waste prior to transport to a holding tank, and various electrically powered devices. The existence of such features brings with them the risk of injury. The questions that **are** asked are:
 - Are all mechanical valves, pumps, and macerators situated such that they cannot be reached by a user (for example, when **attempting** to remove a valuable object that has fallen into the bowl)?
 - Are vacuum systems so designed that either (a) the flush mechanism cannot be activated when a user is sitting on the toilet, or (b) cannot injure a user if the flush is so activated? This is an important issue, as there has been at least one case in the past of a serious injury being caused in this fashion.
 - Are all electrical systems properly installed and grounded?
- **Odor Exposure On-Train.** Odor control is normally achieved by ensuring that all waste is transported cleanly away from the toilet with an effective seal between any waste holding tank and the toilet itself. Systems are reviewed to determine whether these conditions exist, and if not, to review alternative approaches such as the use of deodorizing chemicals.
- **Odor Exposure Off-Train.** Many of the toilet systems under review use pneumatic means (compressed air or vacuum) to transport the waste from toilets to holding tanks. Such systems must necessarily exhaust air to the atmosphere. Since this air has been in contact with waste, it is likely to be malodorous. This could be offensive to passengers and other persons standing near the car in stations. Therefore, systems should be fitted with some means (such as chemical filters) to control such odors and be reviewed to determine whether this is the case.
- **Cleanliness of Toilet.** The primary issue under this heading is whether or not the flush mechanism used is capable of consistently and adequately cleaning the bowl and keeping it clean during normal **Amtrak** servicing and maintenance intervals. From our investigations, this ability **appears** to be a function of bowl geometry, bowl material, and coating (if any), and the volume, force, and direction of flush fluid (water or other). This performance criterion is important. Unclean toilets are offensive to users, and users will tend to use multiple flushes in an attempt to remove all waste and clean the bowl. This latter behavior defeats the purpose of low water volume flushing systems.

Generally toilet performance in this respect cannot be fully evaluated just by reviewing the design details. A suitably designed test program is required. This is discussed in Chapter 6.

- **Overall Aesthetics.** This criterion concerns general passenger impact to the design and functionality of the toilet, taking into account factors not considered in the other criteria above.

Group 2: Service Reliability

This group of issues is **concerned** with the reliability of the waste retention systems in service. Mechanical and electrical failures of various kinds are a major cause of toilet malfunction, leading to passenger dissatisfaction and high maintenance costs.

- Number of failure categories. This is a count of the number of **electrical** and mechanical failure modes to which the system is potentially vulnerable. Generally, complex systems with a large number of components will exhibit more failure modes than simple systems.
- Acceptable Mean Time Between Failure (MTBF). While it is unrealistic to expect that toilet and waste retention systems shall never fail, it is reasonable to expect high reliability. As a preliminary target, we suggest that **MTBF** should not be worse than the best "modem" toilet system currently in use on Amtrak for which there is sufficient service history to obtain a valid **MTBF** estimate. Table 5.2 shows toilet and waste retention system failures reported to **Amtrak's** maintenance information system for three car types that have seen several **years'** revenue service. These are the **Amfleet I** (Monogram recirculaang), **Amfleet II** (Microphor retentioddump) and Superliner (Monogram vacuum **retention/dump**).

Obviously it is not possible to evaluate system reliability in a study of this type and given the lack of extensive service data for each system evaluated. Thus, reliability information can only be obtained through a suitable test program.

- Failure Modes. Under this heading, each system has been reviewed for inadequate performance under normal operating conditions and for consequences of a failure of the principal mechanical, electrical, or pneumatic components. While all failures result in a lack of function, systems differ in the seriousness of the impact of a failure. Typical questions about the mechanical **arrangement** of a toilet system are:
 - To what extent does the system **retain** a limited **ability** to remove waste from a toilet bowl after failure?
 - If the defective component is at an individual toilet, is the impact confined to that toilet, or are **all** the toilet on the same car affected?
 - Is there provision for easy remedial action to clear the failure or contain its impact?

These questions are asked about each system reviewed to determine a performance rating.

- Dependence on other train systems. Almost **all** the toilet systems rely on **external** supplies of compressed air, elecmcgal power, or potable water for their operation. This reliance has been determined for each system but has not been categorized as good or bad. Many other on-train systems and services similarly rely on these "utility" supplies. However, this reliance may affect which systems are suitable

Table 5.2

Reported Toilet Repairs
Period 1/1/89-4/24/90 (1.31 years)

<u>Component</u>	<u>Amfleet I</u>	<u>Amfleet II</u>	<u>Superliner</u>
Toilet (unspecified)	97	89	226
Dump valve	28	5	5
Back-flow preventer	--	--	2
Toilet timer		2	1
Level sensor	--	1	1
Flush valve	2	--	--
Water transfer pump	7	10	1
Toilet motor		2	3
Macerator	--	45	6
TOTAL	134	154	244
Number cars in fleet	467	144	207
Number toilets in fleet	934	288	1602
Repairs/car/year	0.219	0.816	0.900
Repairs/toilet/year	0.110	0.408	0.116

Note: Although the **Amfleet II** toilet appears to have a worse record than the **Amfleet I** or **Superliner** on this basis, both these latter receive extensive preventative maintenance every four months, while the **Amfleet II** does not. Furthermore, many **Superliner** trains have a **mechanical/electrical** maintenance person riding with the train, and toilet repairs **are** his main activity. Thus, while these data can be used as a rough indicator of the kind of MTBF currently being achieved with retention and **retention/dump** toilets, they should not be used to compare the performance of different types of toilets.

for which **kinds** of operation. For example, electric power and compressed air are at least partially lost during a locomotive change. The acceptability of inoperable toilets at such times may be questionable. It may also be necessary to have toilets operable during routine cleaning and servicing (for example, to remove cleaning fluids). This means that cars must **be** connected to power and **air** during servicing if these **services** are relied on for toilet operation.

Group 3: Maintainability

This group of evaluation criteria are concerned with the ease with which retention toilet systems can be kept in good working order.

- **Ease of Periodic Servicing.** This criterion covers a system's needs for routine inspection, cleaning, testing, etc. to keep the equipment in good working order. **Amtrak** normally carries out such activities on a three or four month cycle, and the toilet systems should be compatible with this. Also, the amount of work to be performed should be reasonable and consistent with the need to maintain the system in good **working** order. The main factors which influenced the rating given to an individual system were system complexity, the nature of the maintenance-intensive items (pumps, blowers, valves, macerators, etc.) and their relative accessibility. In general, components should be easy to remove, clean, repair, and replace to receive a high rating.
- **Ability to Keep Clean.** This criterion refers to the ease with which the system can be kept clean during normal operations. Toilet design features that affect this **are** the geometry of the toilet bowl and shrouds, the nature of material surfaces and coatings and the general accessibility of these surfaces for cleaning.
- **Employee Health and Safety Risk.** This criterion is concerned with the exposure health and safety risks of railroad employees engaged in waste retention systems routine cleaning, **servicing**, and maintenance. These risks have two sources:
 - Risks from contact with waste. These are higher where cleaning and servicing lead to greater contact with waste because of the location and **arrangement** of the principal components.
 - Risk of mechanical injury from sharp or otherwise hazardous components. Macerators, in particular, are a potential hazard of this nature and should be arranged so that they can be serviced without unusual risk of injury.
- **Tolerance of Passenger Abuse.** This is a very important area. One of the major causes of toilet and waste retention system malfunctions is the presence of foreign objects in the toilet. The list of such objects mentioned to us is long and bizarre, including excessive quantities of toilet paper and paper towels, sneakers, pencils, false teeth, and **hypodermic** syringes. While it is not reasonable to expect a system to continue functioning regardless of abuse, we consider that a good system should have the following features:

- the ability to continue to function when subject to the milder forms of abuse (such as excessive quantities of toilet paper)
- arranged so that there is very little likelihood that abuse will cause serious mechanical damage
- arranged **so** that foreign objects **can** be removed easily to return the toilet to service
- arranged **so** that there is either little likelihood of abuse affecting all toilets in a car, or **so** that the defective toilet can easily be isolated

Group 4: Environmental Acceptability

- Waste Retention. Systems will be classified as acceptable if they meet the basic requirements of total retention with pump-out at properly equipped servicing locations. Some non-total retention systems have been included in the evaluation because they exhibit some interesting technical features which could potentially be incorporated into a full retention system.
- Waste Disposal. This addresses the issue of whether the waste generated by the system can be easily disposed of to a public sewer or a public waste treatment facility. If there are any identifiable problems with this (such as extra charges or disposal constraints), then a system does not fully meet requirements.

Group 5: Car Configuration Ability

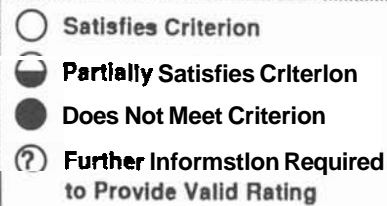
The waste retention system has to fit into a typical passenger car along with all the other equipment required by the buyers specification, and within overall weight and spacial constraints. Other things being equal, it will be easier to accommodate small rather than large quantities of waste. Under this heading we evaluated:

- System overall weight
- Volume requirement for waste retention
- Energy measurement

5.3 Evaluation of Waste Retention Systems

Each waste retention system described in Chapter 3 has been evaluated according to the criteria established in Section 5.2 above. The results **are** presented in the rating chart Table 5.3. In many cases, individual toilet systems were deemed to meet minimum acceptability requirements for a specific criterion. **All** exceptions to meeting the minimum acceptability level **are** discussed below. The comments on the exceptions to the criteria **are organized** into the five groups referred to above.

Table 5.3 Ratings of Toilet Systems



	Gard Amfleet II Prototype	Microphor Redwood Fiber H-Series	Microphor Gravity	Microphor Gravity w/Modified Macerator	Railtech WTS 8300	Monogram Self-Contained Recirculating	Monogram Modified Recirculating	Monogram Remote Recirculating	Evac 2000 Vacuum	Evac Ultimate Vacuum	Gard Mk II Vacuum	Gard Mk II Modified Vacuum	Monogram Modified Vacuum	Monogram Modified Vacuum	Monogram Vacuum Waste	Monogram Vacuum Recirculating	Railtech Pre-Production Vacuum
Passenger Acceptability																	
Ergonomics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>
Public Health Risk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Personal Injury Risk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>
Odor Exposure-on train	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>
Odor Exposure-wayside	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>
Cleanliness of Toilet	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall Aesthetics	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Service Reliability																	
Number of Failure Categories	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>
Acceptable Mean Time Between Failures	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>
Failure Modes Benign	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Dependence on Other Train Systems ¹	w/a/e	w/a/	w/a/e	w/a/e	w/a/e	/a/	/a/	/a/	w/a/e	/a/e	w/a/e	w/a/e	w/a/e	w/a/e	/a/e	w/ /e	w/a/e
Maintainability																	
Ease of Periodic Servicing	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Ability to Keep Clean	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>
Employee Health & Safety Risk	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>
Tolerance to Passenger Abuse	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Environmental Acceptability																	
Waste Retention	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>
Waste Disposal	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>
Car Configuration Acceptability																	
System Weight	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Volume Requirements for Waste Storage	<input type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input checked="" type="radio"/>	<input type="radio"/>
Energy Requirements	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Note 1: W=water A=Air E=Electricity

5.3.1 Passenger Acceptability

Ergonomics

Fourteen of the seventeen toilets evaluated met the ergonomics criterion. However, Railtech's two toilets, the WTS 8300 and the Pre-production Vacuum, did not meet the criterion. These toilets failed the criterion because of their flush cycle delay. A passenger can experience a delay of up to eighty seconds after pushing the flush button before a flush is initiated. This was deemed sufficiently different from a conventional flush process **control** as to be unacceptable to most passengers. At the same time, it should be noted that the bowl shape and seat of each of these same toilets were particularly well-designed, as compared to the other toilets, to **accommodate** male passengers.

The other model which did not receive an acceptable ergonomics rating, the EVAC Ultimate Vacuum, cannot be rated at this time. This model has a unique feature which may face some difficulty in gaining passenger acceptance. The toilet has no flush button. The flush cycle can be **triggered** only by closing the toilet seat cover. Further information on passenger acceptance of the design is needed before a valid rating can be provided.

Public Health Risk

For thirteen of the toilets studied, there does not appear to be any public health risk for passengers. This criterion is not clearly met for the four recirculating models produced by Monogram:

- the Self-Contained Recirculating Toilet,
- the Self-Contained Modified Recirculating Toilet,
- the Remote Recirculating Toilet, and
- the hybrid Vacuum Recirculating Toilet.

While recirculating toilets have long been in public use, notably in the aircraft environment, their safety in the railroad operating environment is a concern. Servicing intervals are notably different between rail and air travel modes. The efficiency of sanitizing agents may be considerably lower near the end of a rail journey, potentially exposing passengers to health hazards. This may be more of a factor for applications of recirculating technology to sleeper compartments. Therefore, these four **recirculating** models **are** not rated.

Personal Injury Risk

Seven toilet models received an acceptable **rating**:

- GARD Amfleet II prototype
- Microphor Redwood Fiber H-Series
- Microphor Gravity
- Microphor Gravity with Modified Macerator
- Monogram Self-Contained Recirculating Toilet
- Monogram Self-Contained Modified Recirculating Toilet
- Monogram Remote Recirculating

Two other toilets failed our criterion for personal **injury** risk. Railtech's two toilets, the WTS 8300 and the **Pre-production** Vacuum models both allow passenger access to a chamber below the bowl lined with extremely sharp macerator teeth. If a passenger were to try and remove an object accidentally dropped into the toilet such as a pair of eyeglasses, they could easily receive lacerations and possible simultaneous exposure to waste.

Additional information is required before we can rate any of the eight vacuum toilets:

- EVAC 2000 Vacuum
- EVAC Ultimate Vacuum
- GARD Mk II Vacuum
- GARD Mk II Modified Vacuum
- Monogram Modified Vacuum
- Monogram Vacuum Waste
- Monogram Vacuum Recirculating

There have been reported instances of personal injury to overweight individuals who have intentionally or accidentally **triggered** the vacuum flush sequence while they have remained seated on a vacuum toilet. In those instances where their body effectively sealed off much of the air intake path to the toilet, significant injury has been reported, in at least one case required hospitalization. Of the eight toilets above, the EVAC Ultimate Vacuum may be least susceptible to causing such injuries. The flush cycle on this toilet is normally triggered only by closing the seat cover. However, we do not have sufficient data on the operational safety of this seat flush trigger to provide an acceptable rating at this time. The other seven vacuum toilets may require **modification** to meet this criterion.

Odor Exposure—On Train

Ten toilet models satisfied this criterion:

- GARD **Amfleet** II prototype
- GARD Mk II Modified Vacuum
- Monogram Modified Vacuum
- Monogram Vacuum Waste
- Monogram Limited Water Flush Macerating
- All three **Microphor** models
- Both EVAC models

Five other models received only partially acceptable ratings.

Two Monogram models, the Remote Recirculating and the Vacuum Recirculating toilets, were downgraded to partially acceptable because of the inherent nature of operation of recirculating toilets. [The Self-Contained Recirculating and Self-Contained **Modified** Recirculating models would have been similarly downgraded, but received the lower rating noted below due to their waste storage shortcomings]. These toilets continually recirculate raw sewage into the passenger compartment and can introduce unacceptable odors. In normal operation, **Amtrak's** service intervals often result in a high ratio of raw sewage to perfumed pre-charge. The result is unappealing odor exposure. The acceptability of **strong** odors from the perfumed pre-charge may also be questioned.

Three other toilets, the GARD Mk II Vacuum and both **Railtech** models, the **WTS** 8300 and **Pre-production** Vacuum, are equipped with pinch valves on the waste pipe to the storage tank. If the passenger rail car is stored temporarily between trips without locomotive- or yard-supplied air line pressure, a direct air path to the waste **tank** is opened. When these cars are initially placed into service, odor levels can be unacceptable. These **three** toilets received a **partially** acceptable rating for this reason.

Two toilets did not meet this criterion. The Monogram Self-Contained Recirculating and Self-Contained **Modified** Recirculating models failed the criterion because of the waste storage design of these toilets. These toilets do not remove the sewage from the passenger compartment area. The sewage, mixed with a perfumed pre-charge **remains** in a holding tank inside the passenger **compartment**, just below the toilet drain. Odor is prevented from drifting upward into the passenger compartment by a tank vent that is effective only while the **train** is in motion.

Odor Exposure — Wayside

Thirteen of the systems studied passed this criterion.

Three vacuum systems failed.

The waste storage tanks of all of the non-vacuum type toilet systems require passive venting. The volume of the air flow through the **tank** and its release into air at passenger stations is minimal and **unlikely** to be detected. The air flow across the less

diluted waste in a recirculating toilet storage tank may be slightly more noticeable, but remains insignificant. Vacuum systems present another situation. In such systems a large volume of air is passing **across** the waste in the holding **tank** and released into the atmosphere at wayside at every flush of the toilet or continuously in some systems. Of the three manufacturers offering vacuum systems, two provide filters on the air exhaust from the waste tanks. **GARD** has developed a two-stage catalytic filter, while EVAC uses a somewhat more conventional **charcoal-type** filter. Monogram's exhaust air is unfiltered and so received an unacceptable rating for its three vacuum models:

- Monogram Modified Vacuum
- Monogram Vacuum Waste
- Monogram Vacuum Recirculating

This is a relatively easily rectified shortcoming.

There is insufficient data to rate the seventeenth system, the **Railtech** Pre-production Vacuum.

Cleanliness of the Toilet

Nine of the seventeen models studied received an acceptable rating regarding cleanliness of the toilet and bowl:

Microphor Redwood Fiber H-Series
Microphor Gravity
Microphor Gravity with Modified Macerator
Railtech WTS 8300
EVAC 2000 Vacuum
Monogram Modified Vacuum
Monogram Vacuum Waste
Monogram Limited Water Flush Macerating
Railtech Pre-production Vacuum

The apparent cleanliness of the toilet to the passenger is achieved by different combinations of features among the models studied. All of the Microphor models use a high water flush volume to ensure cleanliness. The **Railtech WTS 8300** has a **steep-sided** bowl and also uses a high flush water volume. The EVAC 2000 Vacuum, the Monogram Modified Vacuum and the Monogram Vacuum Waste models all have steep-sided Teflon-coated bowls that are likely to ensure adequate bowl cleaning. The Monogram Limited Water Flush Macerating Toilet uses high flush water volume with a steep-sided bowl and a water spot. And the **Railtech Pre-production** Vacuum model has a steep-sided bowl.

None of these nine designs had any other feature that impaired the overall toilet cleanliness rating. However, the EVAC Ultimate Vacuum, may be impaired in this manner. While equipped with a steep-sided Teflon-coated bowl, this model has a unique toilet seat cover gasket that could affect cleanliness. This seat cover with gasket, when lowered to flush the toilet, may come into contact with urine residue on the toilet enclosure. When the next passenger raises the toilet seat cover, urine could drip off the gasket onto the toilet seat. No data exists at present regarding the impact of this design feature on toilet cleanliness. Therefore, we have not rated the EVAC Ultimate Vacuum on this parameter.

All three GARD systems were given ratings of partially acceptable:

- **Amfleet II** prototype
- Mk II Vacuum
- Mk II Modified Vacuum

All of these models use gradually sloping stainless steel bowls that are in fact prone to staining in this application.

The four Monogram recirculating toilets were rated not acceptable:

- Self-Contained Recirculating Toilet
- Self-Contained Modified Recirculating Toilet
- Remote Recirculating Toilet
- Vacuum Recirculating Toilet

Our rating in this instance is attributable to the **combination** of the recirculating design and the use of gradually sloped stainless steel bowls, that are in fact highly prone to staining in this application.

Overall Aesthetics

Thirteen of the seventeen toilets evaluated met the aesthetics criterion. Four systems were not rated, due to insufficient **information** regarding passenger preference. The systems not rated consist of **all** four of the recirculating toilet designs manufactured by Monogram:

- Self-Contained Recirculating Toilet
- Self-Contained Modified Recirculating Toilet
- Remote Recirculating
- Vacuum Recirculating

In general our informal inquiries appear to indicate that the public at large is unaware of how recirculating toilets work in either the rail or air environments. If the public

were more knowledgeable in this area, recirculating toilets may be perceived as less **attractive** by the public and **transportation** service operators. Further information is required to test true passenger acceptance, given alternatives now in the marketplace.

5.3.2 Service Reliability

Number of Failure Categories

This rating category does not assess total reliability, but defines the number of ways in which specific systems can fail. Four basic toilet designs, consisting of seven specific toilet models, received an acceptable rating because of their relatively few possible failure modes:

- Microphor Redwood Fiber H-Series
- **Railtech WTS 8300**
- Monogram's conventional **recirculating** toilets
- EVAC's vacuum toilets

The first two toilets are quite simple gravity flush systems with a minimum of complicating hardware. Monogram's conventional **recirculating** toilets have a relatively small number of parts (though critical components are normally immersed in sewage). **EVAC's** two vacuum designs, while representative of state-of-the-art features, actually incorporate few failure-prone components as compared to other vacuum systems.

Nine systems received partially acceptable ratings. Included in this group were two gravity flush systems:

- GARD **Amfleet II** prototype
- **Microphor Gravity**

Each of these systems incorporated a macerator, the frequent cause of toilet system failure.

Four conventional vacuum systems offered by GARD and Monogram incorporate macerator pumps and more complicated flush mechanisms than the EVAC designs and were also given partially acceptable ratings.

Three hybrid designs were given partially acceptable ratings:

- Monogram Vacuum **Recirculating**
Monogram Limited Water Rush
- **Railtech Pre-production Vacuum**

These systems tend to be more complex than are single technology type models. In general, they have a longer list of components subject to failure.

The Monogram Vacuum Recirculating model, combining recirculating and vacuum technology, is essentially similar to its Modified Vacuum System with another pump added. This system requires the proper operation of a vacuum blower, macerator and recirculating pump and related components, yielding a fairly long list of potential failure modes.

The Monogram Limited Water Flush Macerating system, uses many of the same components as Monogram's more conventional Modified Vacuum System, but in a very different configuration. This hybrid configuration is likely to have at least the same number of failure modes as the more conventional vacuum system.

The **Railtech** Pre-production Vacuum, another hybrid **combining** gravity flush, maceration without a grinder pump and vacuum equipment, has fewer components subject to failure than do the other hybrid systems, but still more than the seven systems that earned acceptable ratings.

One other **gravity** system, the Microphor Gravity with Modified Macerator was not rated because of insufficient data regarding the durability of its improved non-bottom sloned macerator.

Acceptable Mean Time Between Failure (MTBF)

This is one of two categories in which all seventeen models received the same rating. In this instance all seventeen models remain **unrated**. Insufficient data exists to compare the designs. For those models already in service, **Amtrak** simply does not maintain records that would indicate both the failure rate *and the specific cause of failure by component or subsystem*. The failure rate data is also obscured by service programs. For example, **Amfleet I recirculating** toilets receive complete overhauls on a three month interval. **Components** at or near failure detected in these comprehensive **servicings** are not well documented. Comparing the MTBF of **recirculating** models receiving this form of preventive maintenance to **Microphor gravity systems** which do **not** benefit from a similar maintenance program **would** only produce skewed results.

Many other designs are simply too new, or exist in only prototype **form**, thereby making any MTBF estimate not meaningful. Further information is needed to adequately and fairly rate this criterion across the various toilet manufacturers' products.

Failure Modes Benign

Five systems received an acceptable rating against this criterion:

- Microphor Redwood Fiber H-Series
- Railtech WTS 8300
- Railtech Pre-production Vacuum
- EVAC 2000 Vacuum
- EVAC Ultimate Vacuum

The **first** three systems all allow for a quite easy recovery method. A simple plunger or broom handle can easily unclog any of these systems. Therefore, failure of any of them is unlikely to expose passengers to waste or odor from waste. The impact of a failure by either of the EVAC toilet models on other toilets on a car and on the passengers themselves can be fairly easily contained. These toilets are easier than other vacuum toilets to isolate from the rest of the system on a train, with plugging options both in the bowl and just below the waste valve at a special fitting for that purpose.

Nine other toilets received a partially acceptable rating. Four of these toilet designs simply do not offer any easy recovery mode:

- GARD **Amfleet** II prototype
- Microphor Gravity
Microphor Gravity with Modified Macerator
- Monogram Remote Recirculating

Five other vacuum systems do not offer adequate capability to isolate the toilet from the rest of the vacuum toilets on a **car**:

- GARD Mk II Vacuum
- GARD Mk II **Modified** Vacuum
- Monogram Modified Vacuum
- Monogram Vacuum Waste
- Monogram Vacuum Recirculating

Three systems failed this criterion:

- Monogram Self-Contained Recirculating Toilet
- Monogram Self-Contained Modified Recirculating Toilet
- Monogram Limited Water Flush Macerating

The first two systems above can reach the limit of their storage capacity without warning to passengers. The waste deposited by the last passenger to use the toilet would then overflow the storage tank. As a result, after this last user flushed the

toilet, a mixture of pre-charge and waste would then remain in the bowl. As a result, a strong odor of human waste and pre-charge would permeate the passenger compartment. This unpleasant condition would persist until the car is serviced. It should be noted that no mechanical failures are required for this to occur. All that is required is higher than anticipated use of a particular toilet in a particular car, due to placement in the train with respect to the location of other **duty** or unkempt toilets, or simply proximity to a food service car.

In the worst possible result, a recirculating waste **tank** reaching capacity en route can lead to waste sloshing out of the toilet, overflowing into the passenger compartment. **Amtrak** currently does experience this failure mode. This is clearly unacceptable.

The third system relies on the functioning of a macerator to generate a vacuum and pull the toilet bowl waste over a trap and into a canister below the bowl. Every flush of the toilet should clear the bowl, though the canister area may contain solid waste for five or six flushes before clearing. The design assumes that one in every five or six toilet uses will consist primarily of urine. If several consecutive uses result in deposition of solid waste in the toilet, the macerator may fail to generate sufficient vacuum to clear the bowl or the canister area, resulting in a flush failure. Again, at best an odor problem results. At worst, human waste could spill into the car. This failure mode is instigated not by a mechanical failure, but by a passenger usage **pattern** that does not reflect the average, but is plausible nonetheless. This result is deemed not acceptable.

Dependence on Other Train Systems

Most of the toilet systems rely on three car systems, in addition to their own equipment:

- train's potable **fresh** water supply (used for flushing)
- train **line air** pressure (for pneumatically **actuated** valves)
- hotel power (for electrically actuated valves, microprocessor **controls**, pumps and fans)

Three systems rely only on train line air:

- Monogram Self-Contained Recirculating Toilet
- Monogram Self-Contained Modified Recirculating Toilet
- Monogram Remote Recirculating

Two systems rely only on ~~train~~ line air and electricity (hotel power):

- EVAC Ultimate Vacuum
- Monogram Vacuum Recirculating

The Microphor Redwood Fiber H-Series requires both water and train line air. The Monogram Limited Water Rush Macerating requires both water and **electricity**. The remaining ten systems require all three car support systems.

5.3.3 Maintainability

Ease of Periodic Servicing

Five systems were given acceptable ratings. The Microphor Redwood Fiber H-Series simply has very few elements requiring periodic maintenance. The two **Railtech** models, the **WTS 8300** and the Pre-production Vacuum have relatively few moving parts and are generally quite accessible for servicing. The two EVAC models are similarly rated for the same reasons, with the EVAC Ultimate Vacuum system having notably few moving parts (only the waste valve and the vacuum fan).

Eight other systems were given **partially** acceptable ratings, in large part due to the presence of a macerator in the toilet system, a frequent failure component, which often requires disconnection and removal of other equipment:

GARD **Amfleet II** prototype
Microphor Gravity
Microphor Gravity with Modified Macerator
GARD Mk II Vacuum
GARD Mk II Modified Vacuum
Monogram Modified Vacuum
Monogram Vacuum Waste
Monogram **Limited** Water Flush Macerating

All four recirculating toilet models failed to satisfy this criterion:

- Monogram Self-Contained Recirculating Toilet
- Monogram Self-Contained Modified Recirculating Toilet
- Monogram Remote Recirculating
- Monogram Vacuum **Recirculating**

The first two of these toilet systems require removal of all major system components for cleaning and sanitizing prior to servicing. The third and fourth systems require removal of significant components for cleaning and sanitizing prior to servicing. Essentially all components in these systems are exposed to recirculated human waste, complicating **service** tasks.

Ability to Keep Clean

Five of the toilets equipped with steep-sided Teflon-coated bowls were given acceptable ratings:

- EVAC 2000 Vacuum
- EVAC Ultimate Vacuum
- Monogram Modified Vacuum
Monogram Vacuum Waste
- Monogram Vacuum Recirculating

When maintained with appropriate cleaning agents, these models ought to require the least effort to keep clean.

Nine other units were given partially acceptable ratings against this criterion, due to the use of stainless steel bowls, that under normal use and maintenance would require more effort to keep clean:

- GARD **Amfleet** II prototype
- **Railtech** WTS 8300
- Microphor Redwood Fiber H-Series
- **Microphor** Gravity
- Microphor Gravity with Modified Macerator
- GARD Mk II Vacuum
- GARD Mk II Modified Vacuum
- Monogram Limited Water Flush Macerating
- **Railtech** Re-production Vacuum

These ratings assume that **Amtrak** can gain effective control over field maintenance practices. Lack of compliance with manufacturer recommended cleaning procedures was cited by **Amtrak** in reducing the benefits of Teflon-coated bowls. We presume this is a surmountable difficulty with potential passenger and reduced maintenance cost benefits.

All three of the conventional Monogram **recirculating** toilets were rated not acceptable:

- the Self-Contained Recirculating Toilet
- the Self-Contained Modified Recirculating Toilet
- the Remote Recirculating Toilet

Our rating is attributable to the combination of the recirculating design and the use of gradually sloped stainless steel bowls, that are in fact highly prone to staining in this application.

Employee Health & Safety Risk

Eleven of the systems received an acceptable rating.

All four of the recirculating units received a partially acceptable rating, due to the increased likelihood that workers servicing these toilets could come in contact with human waste.

The two **Railtech** units received a failing grade due to the same hazard described in section 5.3.1 above. The macerator spikes could injure maintenance workers. Special care would be required to service these units.

Tolerance to Passenger Abuse

Only five units received acceptable ratings against this criterion.

The Microphor Gravity with Modified Macerator is particularly well-designed so as to keep foreign objects out of the waste system, unless they can easily pass unobstructed to the waste tank. This is accomplished through a particular shaping of the toilet drain. This Microphor model **also** utilizes a non-bottom **slotted** macerator that is less susceptible to jamming due to deposition of bottle caps, coins and other similar objects into the toilet.

The **Railtech** WTS 8300 is extremely easy to clear. The other **Railtech** model is designed with a contraband trap to prevent damage to the rest of the toilet system.

Both of the EVAC units stand up well against this criterion. They have three features that help minimize the effect of passenger abuse:

- Narrow drain opening relative to waste transport size
- Use of a rotating disc valve that can act as a guillotine to chop up foreign matter and eliminate obstructions.
- Profiling of the waste transport pipe to reduce blockages from foreign matter

Eight other units received partially acceptable ratings. Seven of these systems include macerators that are susceptible to jamming due to the introduction of foreign matter:

- GARD **Amfleet** II prototype
- Microphor Gravity
- GARD Mk II Vacuum
- GARD Mk II Modified Vacuum
- Monogram Modified Vacuum
- Monogram Vacuum Waste
- Monogram Limited Water Flush Macerating

The eighth system, the Microphor Redwood Fiber H-Series, has a toilet nap design that may be susceptible to clogging if subjected to significant **passenger abuse**.

The four **recirculating** systems all failed this criterion. Each of these units is susceptible to clogging with the mere introduction of recyclable paper towels into the toilet bowl.

5.3.4 Environmental Acceptability

Waste Retention Meets Statutory Requirement

All but three of the seventeen models received an acceptable rating regarding retention. The three models that did not attain that rating are:

- **Railtech WTS 8300**
- **Railtech Re-production Vacuum**
- **Microphor Redwood Fiber H-Series**

The **Railtech WTS 8300** received a partially acceptable grade. In normal operation, this model would meet legal requirements. However, the WTS 8300 uses a pinch valve on the waste tank drain. This valve could open due to loss of train line air pressure and allow the waste tank to be emptied at an inappropriate time. The **Railtech** Pre-production Vacuum was not rated due to lack of information on its waste ~~tank~~ valve arrangement.

The Microphor Redwood Fiber H-Series received a failing grade. This model treats the waste en route and effectively dumps grey water on the track.

Waste Disposal

Thirteen of the systems received an acceptable rating regarding waste disposal. The four recirculating systems received partially acceptable grades. While public sewer authorities do accept waste from such systems, **there** is a cost penalty associated with treated waste of this **type**. The highly concentrated, perfumed, colored and mated waste generated by a **recirculating** toilet system is considered less desirable by most sewer authorities.

5.3.5 Car Configuration Acceptability

System Weight

All but one of the systems studied received an acceptable rating for this criterion. The Microphor Redwood Fiber H-Series failed this criterion due to the inordinate size of the waste storage and **treatment** tank for an eighty passenger rail car. The required storage tank would be nearly as large as the passenger car itself to meet the 72-hour **Amtrak service** requirement. Much of the size problem pertains not to the storage of waste, but to the treatment capacity.

Volume Requirements for Waste Storage

Ten systems satisfied this criterion, while seven others received partial or failing grades.

Six systems received a partially acceptable rating:

- **Microphor Gravity**
- Microphor Gravity with Modified Macerator
- **Railtech WTS 8300**
- Monogram Limited Water Flush Macerating
- Monogram Self-Contained Recirculating Toilet
- Monogram Self-Contained Modified Recirculating Toilet

The two Microphor systems, the **Railtech WTS 8300** and the Monogram Limited Water Flush Macerating systems though feasible, use a higher volume flush, requiring a larger waste storage **tank** than competing systems. More lengthy refills of potable train water are also required en route.

The two recirculating units included in this group cannot accommodate a waste tank large enough to support a 72 hour trip. These units were not given failing grades since they might still satisfy service requirements in a segment of the fleet dedicated to short-haul service.

The Microphor Redwood Fiber H-Series received a failing grade because of the size of the waste tank as described above.

Energy Requirements

All of the systems received an acceptable rating on this criterion.

It should be noted that other systems do exist that treat waste en route, but consume large amounts of **electricity**. GARD currently makes such units for maritime applications, though they are not offered for rail passenger installations. Amtrak tested similar technology in the **1970s** but rejected it due to lack of effectiveness and system energy requirements.

Chapter 6

SYSTEM COST ANALYSIS

6.1 Introduction to System Cost Analysis

The cost analysis of on-board waste retention toilet systems was **carried** out under three scenarios and according to two different approaches. The three scenarios were used to capture the effects of variability in operating characteristics between systems and to accommodate any inaccuracies in the estimation of costs.

The three scenarios are:

- **Expected.** The input values encompassed the manufacturers', **Amtrak's**, and Arthur D. Little 's best guesses on operating characteristics, user behavior, and costs.
- **Favorable.** The input values to this model were designed to generate a best case scenario in terms of costs. Fewer flushes per day, lower maintenance costs, and a more conservative fleet utilization factor were used to calculate a lower bound on costs.
- **Unfavorable.** These input values generate a worse case scenario. More uses per day, higher car availability and more frequent servicing were used to approximate an upper bound on costs.

The two modelling approaches were as follows:

- The **first** model generates costs according to eight typical **Amtrak** routes. The specific cars in each consist were used in the analysis. It is assumed that these are representative routes and that the costs generated from this model could be exnapolated across the entire fleet and route system.
- The second model generates costs by car on three different length hypothetical routes. This model gives costs according to service hour and length of route. It is used to demonstrate how costs are affected by length of trip and by number of service hours per day. These costs **are** also calculated under each of the three scenarios described above.

These models **are** more fully described in Section 6.6 and Appendix E. The output of the models is found in Appendices C and D.

6.1.1 Data Gathering

The input data came from three sources: the manufacturers, **Amtrak**, and Arthur D. Little estimations. During the course of the study, team members conducted on-site interviews and tours with five retention toilet system manufacturers. The manufacturers visited were:

- Chamberlain GARD Niles, IL
- Envirovac, Inc. (EVAC) Rockford, IL
- Microphor, Inc. Willits, CA
- Monogram Sanitation Compton, CA
- Railtech, Ltd. Baie d'Urfe, Quebec

During these visits, data was gathered with regard to:

- Toilet systems currently in service on railroads, aircraft, or marine installations
- Toilet systems currently available for total retention operation
- he-production or prototype toilet systems for total retention operation

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

Microphor	Gravity System
Monogram	"M ed 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 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 used in the analysis because we were unable to obtain sufficient cost data during the time frame of the study.

The manufacturers supplied us with 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 meant to be firm.

From Amtrak we obtained 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.

Arthur D. Little estimated waste disposal costs, pump-out time requirements, and installation time requirements.

6.1.2 Estimation Issues

This cost analysis is limited by a variety of factors:

- **Tank Capacity** Since Amtrak has not yet issued a specification for an on-board total retention waste system the tank capacities supplied by the manufacturers were for standard tanks on an 'average' car. In addition, they **are** for current car designs and are meant to fit in the existing space. Since our study is for new cars, these capacities **are** not necessarily relevant. We assume tank sizes would be matched to the seating capacity of the car.
- **Flush Fluids Used per Flush** While this quantity is not expected to vary from that which the manufacturer supplied to us, it is of critical importance to the operating cost of a total retention toilet system. This is because of the cost of waste disposal and the time required to pump-out the holding tanks. It is no less expensive to dispose of potable flush fluids than human waste.

This volume is also important because it amplifies **variability** in the number of uses per person per day as well as the number of flushes per use.

- **Flushes per Person per Day** This value was the subject of much debate between the various manufacturers. Studies of toilet usage provide inconsistent results. The issue is complicated by the fact that some people may flush before using a public toilet (some studies cite this on up to 60% of all uses), and the fact that with low flush volume toilets it may be necessary to flush several times to adequately clear the bowl. This impacts capacity requirements, disposal cost and pump-out labor cost.
- **Cost of Major Servicing** Amtrak currently experiences large differences in the maintenance requirements of different toilets. For example, during a major overhaul Amtrak removes the recirculating toilets from the car and cleans them

completely prior to servicing them. At a labor cost of near \$36 per hour, these extra maintenance hours can add tens of thousands of dollars to the **annual** operating cost of a car.

6.2 Estimated Capital and Installation Costs

The capital costs associated with each toilet system were provided to Arthur D. Little by the manufacturers. They **are** rough costs intended to provide an indication of the order of magnitude costs of a system. They **are** not necessarily the actual cost of the system as that would be dependent on **Amtrak's** particular specifications and the quantity ordered.

Installation costs are calculated according to the cost of installing the toilets and the cost of installing the collection system. They were derived by multiplying the number of hours for installation by the number of toilets and collection systems per car (**e.g.** **Railtech** systems require multiple holding tanks per car where other systems use only one).

The installation time requirement for each system is an **Arthur D. Little** estimate based upon the relative complexity of the toilet systems. For instance, it is assumed that vacuum toilet systems will require more installation time for the on-board collection system than will the **Railtech** collection system which does not require piping.

The estimation of time required for the installation of the toilets themselves does not vary by toilet system type. It was assumed that no one toilet fixture was any more complicated than any other with regard to installation time.

The exact calculations **are** described in Appendix C.

6.3 Estimated Operating Costs

Operating costs were calculated according to 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 servicing 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, Arthur D. Little made estimates of the costs. It

is hoped that the testing program outlined in Chapter 7 of this report will provide much of the data necessary to project these costs more accurately.

All labor costs associated with operating and maintaining the toilet systems were calculated at the standard Amtrak rate of **\$36** hour. It was assumed that it would take approximately 10 minutes to clean each toilet bowl at the end of the service day or the end of the **trip**, whichever is longer.

Waste disposal costs were calculated at \$0.017 per gallon for sewage which did not contain chemicals for recirculation and \$0.022 per gallon for sewage which contained these chemicals.

We further assumed that on average it would take **3** minutes to connect and disconnect the discharge hoses to the holding tanks when the tanks were to be emptied, and that the pump-out of the sewage would require one second per gallon of sewage. These times were used to calculate the labor cost of sewage disposal. These are costs not currently experienced on most **Amtrak** routes.

Holding **tank** capacity was an important factor with regard to pump-out because systems which had insufficient capacity on the long routes were assessed an en route pump-out which required more total **connect/disconnect** time per hip than a system with sufficient capacity. (There is not any additional pump-out time required because the amount of sewage generated, and consequently pumped out during the period, is a constant.)

6.4 Estimated Annual Long-term Maintenance

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 **train**. 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. These numbers are **Arthur D. Little** estimates.

The frequency of servicing is currently three times per year. We ran the model using this as a base case but also used semi-annually and quarterly servicing to evaluate the effect of a change in the maintenance policy.

Since none of these toilet systems has a history of use in this environment (full retention), 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.

6.5 Capital and Maintenance Costs of Fixed/Mobile Waste Pump-out Systems

Estimates of the capital costs of **constructing** a suitable **pumpout** facility (a multi-car manifold connected to the municipal sewer system) were requested from appropriate Amtrak officials, toilet system manufacturers, and **architect/engineering** companies. This resulted in estimates that ranged between **\$150,000** to **\$300,000** per installation, depending on local factors. Such factors include the extent of site clearance required, distance to the sewer system tie-in, etc.

Amtrak's "Waste Handling Improvement Program" (**Dec.** 1989) identified a need for 12 new such manifold **pumpout** facilities to fully meet national needs, resulting in a total investment of between \$1.8 and **\$3.6** million. Since there is relatively little mechanical equipment associated with these installations, we estimate annual maintenance costs (labor and materials) to be approximately 2% of capital cost. This results in an annual national maintenance cost for the new installations of between **\$360,000** and **\$720,000**.

Note that the above estimates assume that some **Amtrak origin/destination** points with a limited need for **pumpout** will be served by a contractor's tank truck. Examples include San Antonio and Portland, OR. The cost of a permanent installation cannot be justified at such locations, which may need to service only one or two short **trains** daily.

Mobile pump-out of the holding tanks can cost much more than pump-out at Amtrak's terminal locations. While we did not include these excess charges in the model they can be significant. In the event that a train requires emergency pump-out en route, the disposal costs can be as high as \$0.10 per gallon as compared to \$0.017 to \$0.022 per gallon as discussed above.

In addition, the waste collection company that provides the collection truck will likely charge an hourly rate to provide the service. This can range from \$100 to \$175 per hour depending on the geographic area and the time of day. This charge will be based not only on the time spent draining the tanks, but also on the travel time to and from the train yard and the disposal time.

Finally, there are usually community restrictions governing what can and cannot be discharged into the local sewers. It is not uncommon for communities to refuse waste material **from** other communities or jurisdictions. In the case of a train which by definition belongs to no one community, this may present a problem.

6.6 Description of Cost Analysis Models

The **first** of the two cost models calculates operating and capital costs for each toilet system type by car type and route (Appendix C). 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 described in section 6.1.

Eight Amtrak routes were selected which were representative of the various lengths of trips available. The car types used in each consist, when taken together, represent **ninety** percent of all Amtrak car types. This is important for generating costs for as many different seating and toilet configurations as possible.

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 mp 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 calculated per one-way mp when the car completes one or more trips per day. In this case pump-out, cleaning and servicing are assumed to be performed daily. On longer mps, of over **24** hours, pump-out, cleaning and servicing are assumed to be performed at the end of each **trip**.

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 total operating cost per year per car is calculated as well as the total operating cost per year for all cars of that car **type**.

The output of the first cost model is summarized in the front of Appendix C. It shows the annual operating cost and the capital cost (including installation) under each scenario for each car type on each route on which that car type is used. When a car type is used on more than one route, a weighted average is used to determine how many of that car type are used on each route.

The operating and capital costs are totalled for the **27** car types used in the model. As these car types represent 1,239 of the 1,367 toilet-equipped cars in the fleet, the totals are scaled up to derive a total fleet cost for all car types. Note that a number of Amtrak passenger cars are not equipped with toilets.

6.7 Model Inputs and Results of Analysis

Two cost models were generated for analyzing the various retention toilet systems. The first (Appendix C) models the costs according to current Amtrak routes and consists. This is useful in **evaluating** the costs for actual routes which are currently operated.

The second (Appendix D) models the costs by car type and three probable types of **service** for that car. This model allows comparison of per hour operating costs for each car type under differing levels of utilization. For instance, a given car type may be used on a 24 hour route every other day or on a 48 hour route two out of three days. In the latter case the car will be **carrying** passengers for 75 percent fewer hours than the former. The annual operating cost will therefore be different.

Since the two cost models generated as a part of this study differed only in calculation and presentation parameters, the inputs to the two cost analysis models were essentially the same. The inputs included but were not limited to:

- 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
- Rush 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, Favorable, and Unfavorable) 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 cost levels generated in the costing model by Amtrak route account for those **car** types which represent about 90% of the fleet. Twelve hundred and **thirty** nine cars are accounted for out of a possible 1,367. We projected the costs for the entire fleet

on the assumption that the 90% used in the sample are representative in terms of operating characteristics and number of passengers and toilets per car.

In the Expected scenario the capital costs range from a low of \$21.5 million for the Monogram Self-Contained Recirculating Toilet to \$47.6 million for the Monogram "Modified" Vacuum Toilet. These estimates are based on 1,367 toilet-equipped cars, and the same numbers of toilets per car as in the present fleet. The total number of toilets in the Amtrak fleet is 6,090.

Capital Cost

Monogram Self-Contained Recirculating	\$21,539,555
Railtech WTS 8300	\$37,418,120
Evac Ultimate	\$37,781,214
Microphor Gravity	\$46,651,052
Monogram "Modified" Vacuum	\$47,648,991

The annual operating costs varied from a low of \$8.95 million for the Evac Ultimate Toilet to \$12.7 million for the Monogram Self-Contained Recirculating Toilet.

Annual Operating Cost

Evac Ultimate	\$ 8,954,049
Monogram "Modified" Vacuum	\$ 9,345,007
Microphor Gravity	\$10,013,645
Railtech WTS 8300	\$10,898,080
Monogram Self-Contained Recirculating	\$12,694,163

The net present value for the systems over ten years discounted at ten percent ranges from a low of \$89,365,314 for the Evac Ultimate to \$103,939,563 for the Microphor Gravity Toilet.

Net Present Value (10 years, 10%)

	Net Present <u>Value</u>	As Percent <u>of Evac</u>
Evac Ultimate	\$89,365,314	100.0%
Monogram Self-contained Recirculating	\$97,581,549	109.2%
Monogram "Modified" Vacuum	\$100,738,285	112.7%
Railtech WTS 8300	\$100,980,455	113.0%
Microphor Gravity	\$103,939,563	116.3%

The ten-year period was chosen at random, a longer period would tend to amplify the differences in annual operating costs. Using a twenty year term changes the relative ranking of the systems. The Monogram **Recirculating** system drops from second to

fourth due to its higher annual operating costs. In addition, the relative differences between the systems **contracts** with the exception of the Evac Ultimate, which is still significantly lower.

Net Present Value (20 years, 10%)

	Net Present <u>Value</u>	As Percent <u>of Evac</u>
Evac Ultimate	\$110,577,426	100.0%
Monogram "Modified" Vacuum	\$122,876,574	111.1%
Railtech WTS 8300	\$126,797,970	114.7%
Monogram Self-contained Recirculating	\$127,653,978	115.4%
Microphor Gravity	\$127,661,855	115.5%

Tables **6.1** and **6.2** list the annual operating costs, capital costs and net present value over ten years for the five systems under the Favorable and Unfavorable scenarios. Systems with a high flush volume generally rank higher under the "favorable" scenario than under the other scenarios. This is because the favorable scenario assumes a lower number of flushes per use, leading to lower waste disposal charges. The benefit of this is more pronounced in the case of the higher flush systems.

Figure **6.1** demonstrates the difference in waste generated by the different systems. It shows how much of the total waste is human waste, on average, and how much is flush fluid.

Favorable			Net Present			
Manufacturer	Model		Number of Cars	Value 10yrs. - 10%	Operating Cost	Capital Cost
Microphor	Gravity	Sample:	1,239	\$79,870,518	\$6,742,796	\$42,282,848
		Entire Fleet:	1,367	\$87,857,570	\$7,439,389	\$46,651,052
Monogram	Modified Vacuum	Sample:	1,239	\$78,237,442	\$6,343,200	\$43,187,344
		Entire Fleet:	1,367	\$86,061,187	\$6,998,511	\$47,648,991
Monogram	Self-Cont'd Recirc	Sample:	1,239	\$71,033,401	\$8,671,971	\$19,522,684
		Entire Fleet:	1,367	\$78,136,741	\$9,567,864	\$21,539,555
Evac	Ultimate	Sample:	1,239	\$69,204,067	\$6,196,299	\$34,243,544
		Entire Fleet:	1,367	\$76,124,474	\$6,836,433	\$37,781,214
Railtech	WTS 8300	Sample:	1,239	\$76,798,361	\$7,480,925	\$33,914,448
		Entire Fleet:	1,367	\$84,478,198	\$8,253,773	\$37,418,120

Table 6.1
Amtrak Systemwide Waste System Costs—Favorable Scenario

Unfavorable			Net Present			
Manufacturer	Model		Number of Cars	Value 10yrs. - 10%	Operating Cost	Capital Cost
Microphor	Gravity	Sample:	1,239	\$109,426,630	\$11,552,918	\$42,282,848
		Entire Fleet:	1,367	\$120,369,293	\$12,746,439	\$46,651,052
Monogram	Modified Vacuum	Sample:	1,239	\$104,690,405	\$10,648,298	\$43,187,344
		Entire Fleet:	1,367	\$115,159,446	\$11,748,365	\$47,648,991
Monogram	Self-Cont'd Recirc	Sample:	1,239	\$105,855,465	\$14,339,101	\$19,522,684
		Entire Fleet:	1,367	\$116,441,011	\$15,820,461	\$21,539,555
Evac	Ultimate	Sample:	1,239	\$93,027,245	\$10,073,411	\$34,243,544
		Entire Fleet:	1,367	\$102,329,970	\$11,114,086	\$37,781,214
Railtech	WTS 8300	Sample:	1,239	\$110,487,064	\$12,963,606	\$33,914,448
		Entire Fleet:	1,367	\$121,535,771	\$14,302,865	\$37,418,120

Table 6.2
Amtrak Systemwide Waste System Costs—Favorable Scenario

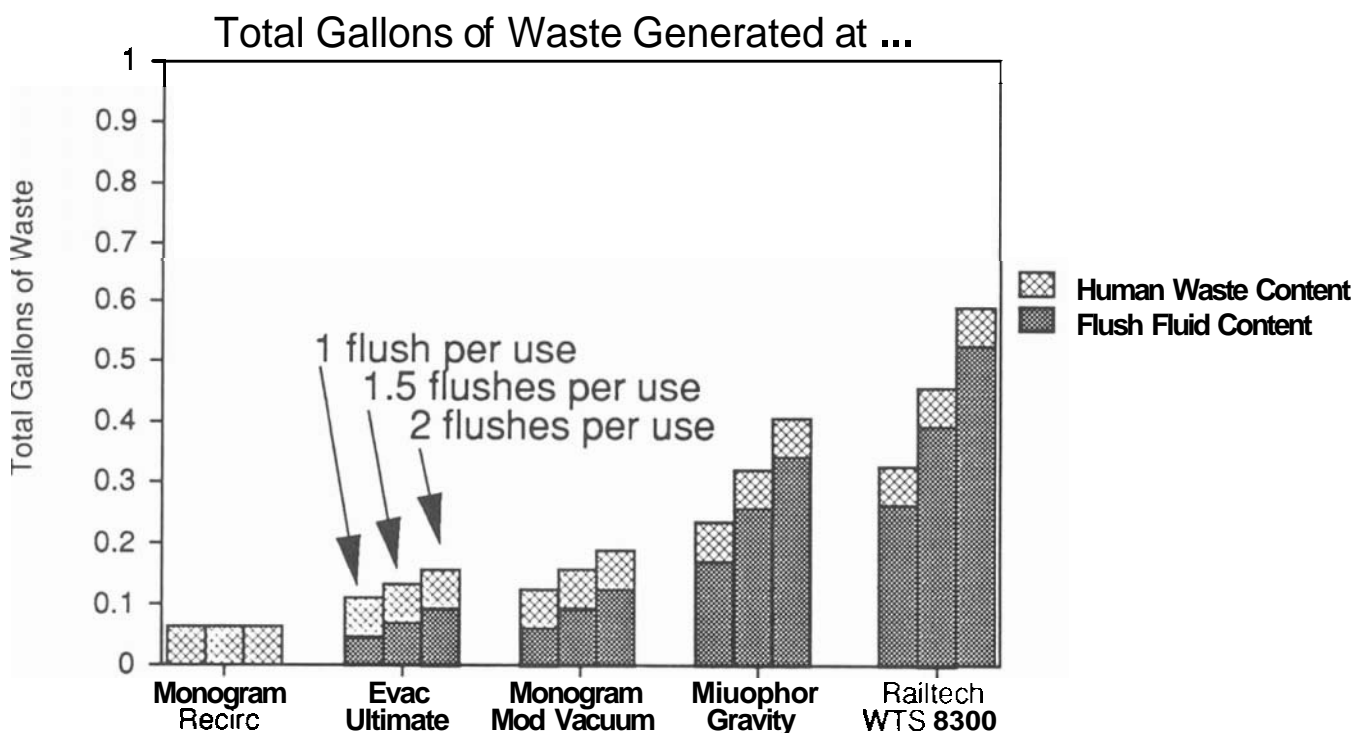


Figure 6.1
Volume of Waste Generated Per Use

The figure has three bars per toilet system to show total waste generated for flush to use ratios of 1:1, 1.5:1, and 2:1. The average number of flushes per visit, to a toilet is certain to exceed 1. A figure between 1.5 and 2.0 is thought to be reasonable, although hard data is not available. There are two reasons for this:

- a) Some users always flush a public toilet before use.
- b) One flush may not be adequate to properly clean the bowl.

Maintenance costs have a large impact on the operating costs of these systems. The fact that Amtrak **currently** removes recirculating toilets from the car, washes them, and then **performs** maintenance leads to higher non-trip related operating costs than those toilet types which can be serviced in the car. Because of this practice, the cost models assume that recirculating toilets require six more **hours** of labor per major servicing than do non-recirculating toilets.

We estimate that there are currently about 6,090 toilets on Amtrak passenger cars. Each extra hour of maintenance required per service, at three services per year, at **\$36/hour**, costs Amtrak nearly \$650,000 per year. If removing and replacing a recirculating toilet actually requires four to six hours, the annual labor cost to Amtrak will be from \$2.6 million to \$3.95 million.

Chapter 7

WASTE RETENTION SYSTEM EVALUATION PROGRAMS

7.1 Introduction

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

Based on the work documented in this report, it is clear that

- A number of proprietary retention toilet systems have been developed by the supply industry that can potentially meet Amtrak's requirements
- No supplier has yet developed a system for the retention of all waste (including grey water from washing and dining car activities as well as "black" water from toilets).

Therefore, 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 should be addressed later, should this be necessary. In either case, the evaluation procedure will be very similar to that discussed below.

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, we consider that 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:

- Frequent failures in service leading to costly repair and loss of use of cars
- Costly modifications and retrofits to correct troublesome installations
- Passenger dissatisfaction, leading to a loss of revenue

As toilet systems are one of the major causes of customer dissatisfaction with Amtrak service, this latter point should be particularly emphasized.

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
- Compatibility with car configuration and Amtrak operations (volume capacity, weight, bulk, power requirements, etc.)

- Acceptability to the user
- Reasonable maintenance and servicing requirements
- Adequate reliability in service

Once these have been defined, then evaluation procedures **are** developed for each performance criterion. In general, these will include a design review based on the documented design of the system and past experience with the system or any of its components, a bench test to determine that the system functions as designed, at least in its "as new" condition, and a service test to determine maintainability, reliability and passenger acceptance.

In this chapter, we will describe Amtrak's test program as it is presently structured, and then describe enhancements to the program to make it more comprehensive and useful.

7.2 Amtrak's Test Program

This test program is described in Amtrak's document "Waste Handling Improvement Program" (Reference 13). This document describes the background to the program, and identifies the systems to be tested. Choice of system was based on the response of the supply industry to an invitation issued in the summer of 1989. This led to the choice of equipment for test as listed in Table 7.1. Table 7.1 also gives the status of each installation as of June 1, 1990. Each installation was or is being carried out under the supervision of supplier representatives, and in accordance with Amtrak's normal practice with regard to water, air and electric power supplies, and such matters as protection against freezing in cold weather.

We have not seen any plans regarding which trains or routes the systems will be operated over, or for gathering operating, servicing and maintenance data. Some suppliers **are** fitting some data acquisition systems, for example, to count the number of times the system is flushed. However, we understand that the general intent is to monitor the reliability, maintainability and servicing requirements of each system. We also assume Amtrak and the supplier will perform **normal** functional tests on each system prior to putting the car into service.

7.3 Recommended Evaluation Program

7.3.1 Overview

This section provides our recommendation for an enhanced retention toilet evaluation program, which we believe will improve the utility of Amtrak's present program, and of any program in the future to test proprietary waste retention systems. This program has four main steps:

Table 7.1**Summary of Amtrak Test Program Status**

<u>Tollet Svstem</u>	<u>Amtrak Car on Which Installed</u>	<u>Status as of 6/1/90</u>
GARD Amfleet II Prototype (gravity flush)	Amfleet II	Installed
Microphor gravity w/Modified Macerator (22-ounce flush)	Amfleet II	Awaiting installation
Monogram Modified Self-contained Recirculating	Heritage Sleeper	Awaiting designated car for installation
EVAC 2000 Vacuum	Superliner	In process of being installed
EVAC Ultimate Vacuum	Superliner	In process of being installed
GARD MkII Vacuum	Viewliner	Installed
GARD MkII Modified Vacuum	Viewliner	GARD MkII Vacuum should be converted to Modified Vacuum model by mid-June
Monogram Modified Vacuum installation	Superliner	Awaiting designated car for

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

Our main concerns about the present **Amtrak** approach are that it focuses mainly on step 4, while steps 1, 2 and 3 are receiving insufficient attention, and that detailed data acquisition plans are lacking.

7.3.2 Evaluation Criteria

Section 5.2 of Chapter 5 is an initial attempt to develop a set of evaluation criteria, based on our observation of the past history of retention and **retention/dump** toilet systems on Amtrak, and discussions with, and information from, Amtrak and the suppliers. We recommend that Amtrak take this as a starting point, and convene a group of experienced managers to improve on the list. This should include people concerned with:

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

Particular issues that should be addressed by this group are:

- Define good installation practice (independent of individual system technology), including:
 - routing and detail design of pipe work for **accessibility**, maintainability, freedom from freezing problems in cold weather
 - arrangements for **power/air** supplies, necessity for backups if **train** power and air supply is not available
- 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 the high level of dissatisfaction (see Chapter 2) indicates a clear unmet need. Is this mainly due to a lack of cleanliness and reliability, or **are** there other concerns which could influence system choice? A **survey** of passenger reactions to the existing systems in use on **Amtrak** would provide very useful inputs for this effort.
- **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 MTBF for major components and the overall system,

annual hours per car for routine maintenance, etc. This is not a trivial issue—several million dollars per year are spent by **Amtrak** in toilet maintenance.

- Determine what variations of requirements apply to specific car types. For example a "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, adequate retention capacity would probably be an "essential requirement," reliability "highly desirable," and ease of cleaning "nice to have." The **rankings** could be defined 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 **rankings** in this manner would take some work, but we believe it would pay dividends to Amtrak.

- 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 preparing a test installation and service testing.
- Amtrak would have a significantly improved chance of eventually getting waste retention systems that fully meet requirements.

7.3.3 Design Evaluation

The design evaluation is **carried** out on a generic technology, or after an installation has been engineered to apply a particular retention system to a particular car. This can apply to either a new car or in a **retrofit** situation. It is essentially similar to the evaluation carried out on the retention toilet technologies in Section 5.3. The possible outcomes of such a review 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.

7.3.4 Functional Tests

These tests should be **carried** out on *all* car installations. In addition, it is desirable to **carry** out some kinds of tests with a bench test set up, **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 fittings and **trim**.

Our suggestions regarding the functional tests are as follows:

Test set-up. This 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**. Elaborate instrumentation is not necessary, but it may be desirable to measure or monitor key pressures in pneumatic systems, and when components such as valves and blowers operate, so that the supplier and **Amtrak** can verify that the system operates as intended.

- Normal operational tests. These tests should be **carried** out on both the 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. Tests of this type are specified in the American National Standards Institute standard for domestic toilets (Reference **10**) and the equivalent British Standard (Reference **11**). The issue of testing was further discussed in *Consumer Reports* (Reference **12**), in the Context of performance testing domestic low-flush toilets. Based on a review of these test procedures (which tend to be undemanding, especially as measures of the system's **ability** to clean the bowl), we suggest the following procedures:

- Liquid waste removal. The standard tests **are** devised for the domestic water closet, and the issue is dilution of the standing water in the bowl. Most transportation toilets **are dry** bowl and those tests **are** inappropriate. We suggest the following:

Dye 8 oz. of water a distinctive color and pour into the bowl, making sure to sluice around the sides of the bowl in the process. Flush. Observe and record any residue. If there is any residue, repeat the flush once and observe and record again. Repeat the test five times for each toilet, including each individual toilet of multi-toilet systems.

- Solid waste removal test. The standard tests are either undemanding or inappropriate. They **are** listed in Table **7.2**. In particular, the various ball and cylinder tests are inappropriate for use in any system with a macerator. A more appropriate but messier alternative commonly used in the transportation industry is canned dog food. **12** oz. of dog food is dumped in the bowl. A single flush should remove all waste and leave a clean bowl. This test can be made more severe by deliberately smearing the dog food around the bowl.

Table 7.2

Standard Toilet Tests

1. ANSI A112.19.2M - 1982

- a) Ball Test. 100 polypropylene balls, 3/4" diameter, having a total weight of 0.31 - 0.33 kg. Toilet must remove an average minimum of 75 balls per flush in a test repeated five times.
- b) Granule Test. Approximately 2500, 2-3 mm diameter disc-shaped polyethylene granules are placed in the bowl. One flush shall remove 95% of the granules.
- c) Cylinder Test. Four latex cylinders, 1" diameter by 4 3/8" long with rounded ends are used. Toilet must remove an average of three out of four cylinders at each initial flush.
- d) Paper Test. Six 6-sheet strips of single-ply toilet paper **are** crumpled into loose balls, 2-3 inches diameter, and placed in bowl. Toilet is flushed immediately, and all paper must be removed.

2. British Standard 5503 Part 2 - 1977

- a) Ball Test **A** single ball of 43 mm diameter, relative density 1.075-1.080 is used. Toilet must remove ball at a single flush. Four out of five tests must be successful.
- b) Sawdust Test. 20 g of fine sawdust is sprinkled on bowl surfaces above water level as completely and evenly as possible. Flush system passes test if less than 5000 mm² (8 in²) of surface remains unwashed. This test is carried out once.
- c) Paper Test. 12 individual sheets of twin-ply toilet paper shall each **be** crumpled loosely, and individually dropped into the bowl. Toilet shall remove all paper four times out of five repeat tests.

These tests should be repeated five times to ensure consistency of performance. If the toilet is in a multi-toilet installation, then each toilet in the system shall be tested, and tests shall also be performed with simultaneous flushing of any two toilets.

- Paper removal test. An adaptation of the ANSI test is suggested, with the modification that a small amount of water is added prior to flush (say 2 to 4 oz.)
- Abuse Test. One of the major causes of toilet malfunction is abuse by users, primarily the induction of foreign objects into the toilet deliberately or by accident. Toilets should be designed such that abuse cannot cause severe mechanical damage, and **obstructions** are easily removed. Amtrak should devise an abuse test as follows:
 1. Develop a list of test objects based on service experience. Many candidates are mentioned in Chapter 2 of this report.
 2. In a bench test only, 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 maintenance effort was required to return toilet to use

7.3.5 Service Test

Systems that successfully pass all 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 start with a functional test (**as** described in 7.3.4, excluding the Abuse Test), and the vehicle put into service. Ideally the toilet test cars should not be involved with any other equipment test program, as this is likely to reduce the amount of **service** running the cars will experience.

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. We recommend that data acquisition for a service test should comprise the following:

- A count of flushes of each toilet in the car by mp
- Measurement of the volume of waste removed from the car at each pump-out
- 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 short period (say, 1 month), 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 1 year's normal service) should be sufficient. The test should be terminated earlier if repeated problems arise. Note that a service test will not yield a meaningful MTBF figure for long term maintenance cost estimates. The sample of one car is simply too small.

Chapter 8

SUMMARY OF RESULTS AND CONCLUSIONS

8.1 Summary of Results

This study has been performed to review and summarize the "state of the art" in waste retention systems for intercity railroad passenger cars, and to review the available technologies capable of potentially meeting service needs on all types of Amtrak cars. The technologies have been reviewed regarding their suitability for fitting into new-build passenger cars. Issues relating to retrofitting waste retention systems to existing cars have not been specifically addressed, although much of the information in this **report** will be of relevance to a retrofit program. In summary, the results of the study are as follows:

Existing Practice and Experience (Chapter 2)

All existing practice applies to toilet waste retention systems. We found no experience with waste retention systems designed for "grey water."

Amtrak. As well as old "straight through" systems, **Amtrak** currently operates three types of retention or partial retention toilet systems:

- The Monogram recirculating, full-retention toilet on the **Amfleet I**
- A Monogram vacuum **retention/dump** toilet on the Superliner cars
- A **Microphor** gravity **retention/dump** toilet on the **Amfleet II** and Horizon cars

Service experience with these systems has not been good, especially the **first** two types for which substantial preventative maintenance programs are required. 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 defective toilet systems.

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. However, the **service** environment, with typically only four hours intensive use daily, and daily pump-out is clearly much less demanding than for an intercity passenger car.

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 purpose appears to be to seal the car for climate control, and 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. At least the British, German and Danish national rail systems (BR, DB and DSB) are known to have adopted such a policy. 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 odor and waste disposal problems. On the other hand, France (SNCF) so far has exclusively used recirculating toilets.

The conclusion from this review is that while there are pockets of experience with full-retention toilets around the world, none of it provides a long enough history of good service in a comparable environment to enable Amtrak to select a system for immediate application.

Description of Technologies and Their Performance

A total of 17 makes and models of retention toilet have been described in detail in Chapter 3. All these models except two are full-retention systems. The other two were included because of their potential adaptability for full-retention, and because they included design features of interest. All these models have been developed by the supply industry and are offered in a rail car version, but some are at the prototype stage only. Three operating principles are represented:

- **Gravity/compressed** air systems
- Recirculating systems
- Vacuum systems

The technologies have been evaluated against a set of performance criteria in Chapter 5. This showed that almost all the technologies had the potential to meet the performance criteria. The differences between technologies lay mainly in estimated reliability and maintainability. In general, the vacuum systems scored highest in this evaluation and the recirculating systems lowest. The performance of the systems against some key criteria could not be evaluated because of the lack of service experience.

We **are** aware that there are other systems, some with different operating principles, which have been developed for non-rail applications. These have not been described because less information was available and the technology has not been adapted for rail use.

Waste Disposal Issues. Generally we found that there were few problems associated with waste disposal. The waste generated by both recirculating toilets (with chemicals) and that from non-chemical systems is generally acceptable to municipal sewer and waste treatment facilities. However, waste containing chemicals is charged for at a higher rate than non-chemical waste.

Costs. Detailed capital, operating and maintenance cost estimates are provided in Chapter 6. We determined that the capital cost to equip all Amtrak's fleet with retention toilets varied between \$21 and \$48 million, and annual costs for waste disposal and maintenance varied between \$9 and \$13 million. There **are** two points to be emphasized in connection with these costs:

1. The capital costs **are** for toilets installed in a new-built car. The cost of a **retrofit** program for existing cars would be different.
2. These **are** total, operating, and maintenance costs, not incremental costs over the current situation on **Amtrak**. The existing retention and retention-dump toilets in cars built for Amtrak since 1970 have many similarities with the systems investigated in this study, including similar costs.

Waste System Evaluation. Evaluation programs **are** reviewed in Chapter 7. We recommend a four-step process for the proper evaluation of any system to be applied to an **Amtrak** car:

- Develop essential and desirable performance criteria.
Perform "desk" evaluation of proposed systems and car installations.
- **Perform** functional tests "on the bench" and of the final car installation. The bench tests should particularly include tests for resistance to damage from abuse.
- Carry out a service evaluation. This should particularly include an evaluation of passenger acceptance of the system.

8.2 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 4 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 is 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 under development for the full retention of "grey water" (**from** washing activities and dining car kitchens)

as well as "black water" from toilets. If Amtrak was required to fit such systems, it would have to start from scratch, and invite the supply industry to develop suitable products.

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, leading to lower 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 disposal cost advantage. The waste disposal estimates are independent of whether the on-car waste system was installed at the time of car construction or is a retrofit.

There appears to be no significant environmental or engineering problems associated with toilet waste pump-out 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 realistic 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.

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- Ref 6 R.F. Hill and C.H. Garratt, "The Mark 111 Sleeping Car," *Railway Engineer*, Issue 2, 1982. Institution of Mechanical Engineers, London.
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Note: These reports are now substantially out of date as they include discussion of technologies available only to about 1981. Many developments have occurred since then.

Appendix A

HEALTH RISK ASSESSMENT AND RISK MANAGEMENT FOR SEWAGE DISPOSAL FROM AMTRAK TRAINS

Amtrak collects human waste from on-board toilet facilities in holding tanks which are emptied at waste stations into municipal sewage systems. Employees who transfer the waste material may be exposed to infectious agents or other harmful material. Therefore, it is appropriate to characterize the nature and degree of risk and to recommend appropriate protective measures.

The following discussion is an assessment of the risks posed by the waste handling operations. The **structure** of the discussion is divided into four sections: hazard identification, hazard assessment, exposure assessment, and risk characterization.

This risk assessment is followed by a discussion of risk management, focusing on prevention of exposure and its **adverse** consequences.

Hazard Identification

The holding tanks will contain human sewage which may incorporate pathogenic biological agents. The tanks may also contain toxic chemicals and physically harmful materials such as hypodermic needles. While the focus of this assessment will be biological agents, we are concerned about the potential accumulation of toxic or asphyxiating gases (**e.g.**, hydrogen sulphide or ammonia) in the tank or in sumps and subsequent exposure during the unloading process and recommend that the potential for such exposure be evaluated.

The infectious agents could include bacteria, viruses, protozoa, and fungi. These organisms would be derived primarily from the gastrointestinal **tract**, but bloodborne pathogens may also be present in the sewage. Among the enteric viruses, hepatitis A is a principal concern. **There are** a variety of infectious **and/or** endotoxin producing bacteria including leptospira **interrogans**, legionella pneumophila, Salmonella, Aeromonas **hydrophila**, and Mycobacterium xenopi. Aspergillus **fumigatus** is an allergenic fungus that has been associated with sewage and compost operations. There are two parasitic protozoa, **Entamoeba** histolytica and **Giardia lamblia**, that are potential hazards. Finally, Hepatitis B (HVB) and the Human Immunodeficiency Virus (HIV) are **bloodborne** pathogens that could be present in the waste material.

Hazard Assessment

The pathogenicity of microorganisms and their by-products depends upon the susceptibility of the person being exposed, the mode of transmission, the portal of **entry**, and the infectivity or toxicity of the organism.

Human resistance to disease and responsiveness to biologic toxins and allergens varies considerably from individual to individual and, even for a particular individual, depends upon factors such as age, immune status, and preexisting illnesses.

Many **microorganisms** which **are** common in the environment and are **normally** considered to be benign can cause serious, and even fatal, illnesses in susceptible people. On the other hand, there are other microorganisms which can represent a more constant and serious hazard. HVB and **HIV** are threats to healthy workers. Also, there **are** exotic viruses such as Acute Hemorrhagic Fever Viruses, which have occasionally caused outbreaks of illness in the United States.

Hepatitis B or serum hepatitis is a bloodborne virus which represents a major occupational hazard for healthcare workers. The virus is spread through breaks in the skin, mucous, membranes, sexually, or from mother to infant at birth. It is highly infectious. One milliliter of blood from an infected individual may contain up to 100 million infectious doses of virus. The virus has been shown to survive on dry surfaces for up to a week at room temperature; however, it does not survive well in feces.

The Human Immunodeficiency **Virus (HIV)** is associated with the Acquired Immunodeficiency Syndrome (AIDS). Transmission has been shown to occur through sexual contact and parenteral exposure to blood. The virus has been identified in a wide variety of biologic media including urine, but in epidemiologic studies has only been shown to transmit AIDS through blood, semen, vaginal secretions, and possibly breast milk. There is no evidence of transmission by insects. The **HIV** virus is much less resistant than the Hepatitis B virus to environmental conditions, and it will not survive for very long outside of the body.

The other enteric viruses, the protozoa, and fungi can cause a variety of respiratory, gastrointestinal, and dermatologic illnesses, and in some cases, can survive for long periods of time in hostile environments. Generally, they are less infectious than HVB. For example, in an experiment, 14 volunteers were exposed to *Salmonella typhi*. No one was affected by exposure to 10^3 organisms while one person was resistant to 10^9 organisms.

Exposure Assessment

There **are** four main routes of transmission for infectious diseases: (1) contact, (2) vehicle, (3) **airborne**, and (4) vectorborne. Contact transmission could be, for example, direct transmission from a contaminated hand to the mouth. Vehicle transmission involves exposure through contamination of objects such as food or water. Airborne transmission involves the dispersion of biologic material on dust particles or droplets. Vectorborne transmission involves transfer of biologic material by insects or animals.

The culmination of these transmission routes is the portal of entry or exposure which may be the respiratory tract by inhalation, the gastrointestinal tract by ingestion, the skin and mucous membranes by penetration or through breaks in the tissue, and the blood by direct inoculation or systematic spread.

In the specific case of sewage holding tanks, Amtrak employees may be exposed to small amounts of residual waste material which is retained in the transfer pipe or spilled in the surrounding area. Large exposures may occur during spills resulting from failures in the pipe or its connectors. The portals of entry could include inhalation, ingestion, and skin absorption. Less direct exposure via vehicles or vectors are also possible, particularly if hygiene is poor.

Risk Characterization

Risk Characterization involves combining the assessment of potential exposure with the hazard assessment to estimate the nature and severity of the risk. In the case of cancer risk assessment, this usually involves an expression of the probability that extra cases over background will occur over a year or **lifetime**. For chronic disease, risk is expressed in terms of a threshold of exposure which, if exceeded, can result in disease. The degree of risk is expressed in terms of the extent to which the threshold is exceeded. For biological material, dose-response data are limited and thresholds vary depending upon individual susceptibilities, the infectivity of the organisms, and the dose. It is appropriate to state that the risk for Amtrak employees is real and potentially severe. It is also possible to eliminate or substantially reduce the risk by implementing preventive measures.

The literature on the occupational health risks associated with municipal waste water and solid waste operations includes environmental monitoring and epidemiologic studies and suggests that the risks are real and controllable. In a review of this literature, Herbert R. **Pahren** of the **U.S.** Environmental Protection Agency states that:

"Persons exposed to relatively low densities of **microorganisms** in the air near wastewater operations showed no significant adverse health effects, but infections were sometimes found at high densities. Also, when operations were conducted indoors, to microbial densities tended to be much higher than outdoors, resulting in illnesses to a number of workers."

Recommendations for Risk Management

Preventive measures may be primary, in terms of preventing exposure, secondary, in terms of preventing infections when exposure occurs, and tertiary, in terms of

'CRC Critical Reviews in Environmental **Control** Vol. 17, Issue **3**; 187-228, 1987.

effective diagnosis and treatment. All three approaches have relevance for Amtrak employees.

Primary prevention involves establishing safe and hygienic work practices which will reduce the risk of exposure. Employees should be trained to recognize the hazards and their consequences and to take protective measures. Compliance with preventive programs should be monitored. Employees should also be supplied with and trained in the use of protective equipment including work clothes and gloves. If possible, face shields would provide an extra level of protection in the case of leaks or spills.

Secondary prevention also involves good hygiene including training in and facilities for cleaning up spills. It also involves vaccination. Healthcare workers are routinely vaccinated against HVB, and when exposure is likely to involve HVB post-exposure prophylaxis with Hepatitis B immune globulin may also be provided. Medical personnel should encourage routine vaccination for polio and tetanus and should not place individuals with immune system deficiencies in this occupation. In order to understand the likelihood of the risk, we recommend that Amtrak test the sewage material to characterize the microbial population. Amtrak should also survey medical operations in other sewage handling occupations to understand the state of the art.

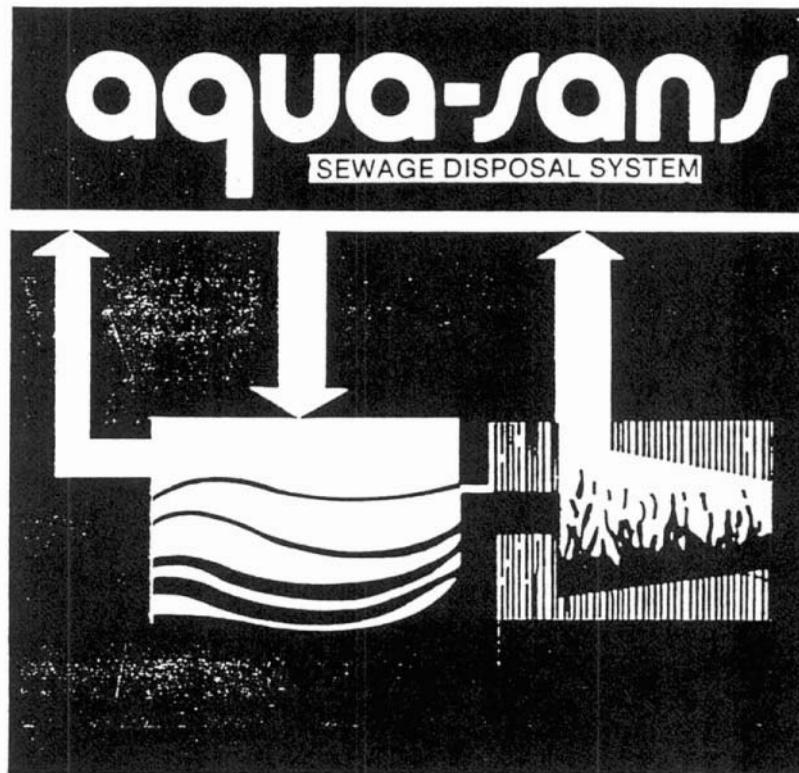
Finally, Amtrak medical personnel should be trained to diagnose and treat illnesses that may result from exposure and employees should be encouraged to report illnesses that might result from sewage exposure.

Aqua-sans

Introducing

THE PERFECT FLUSH™

qua-Sans® Zero-Discharge
Sewage Disposal System

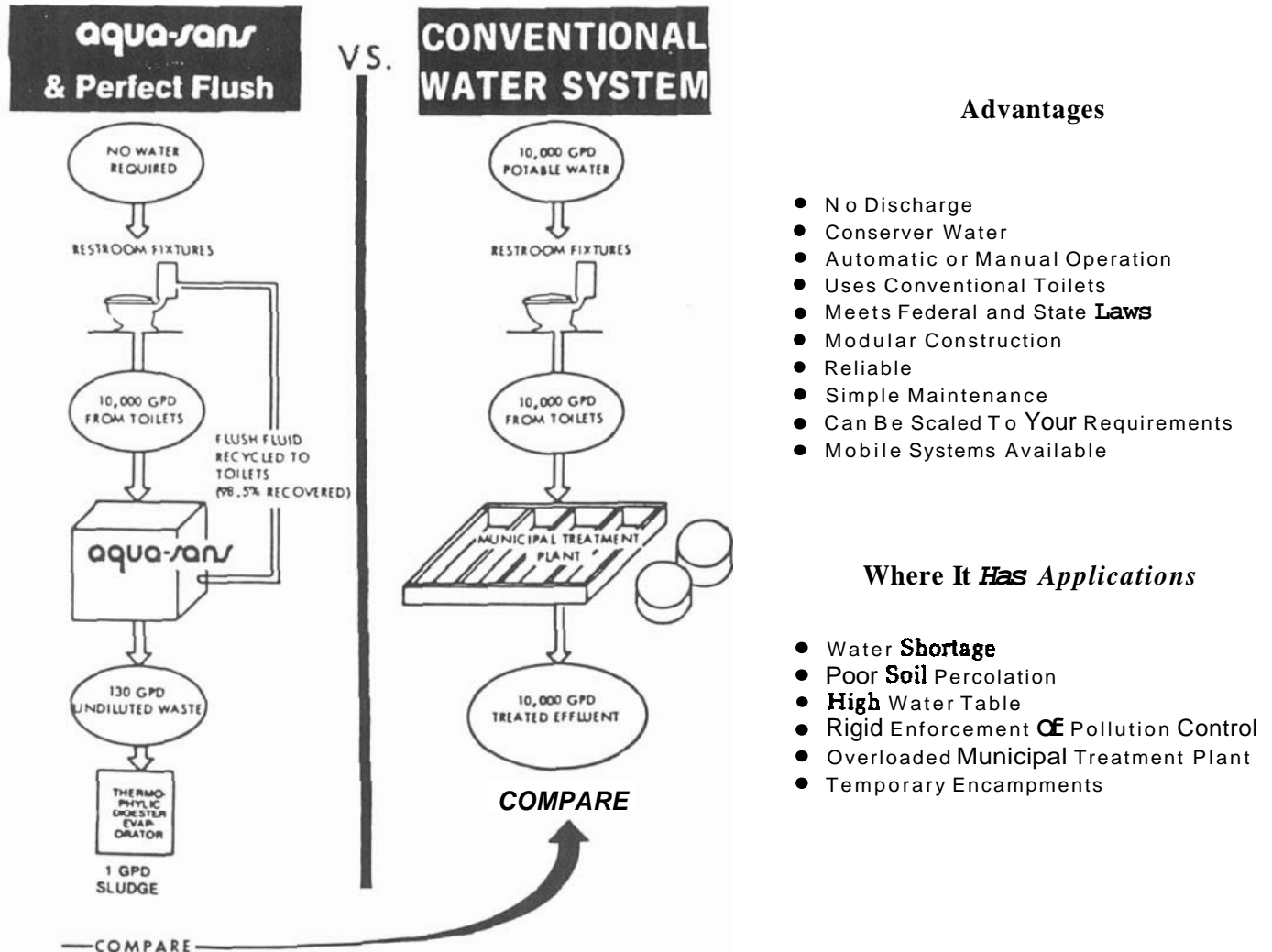


- ☐ PARKS AND RECREATIONS AREAS
- ☐ OFFICE BUILDINGS AND FACTORIES
- ☐ RESIDENTIAL
- ☐ HIGHWAY COMFORT STATIONS
- ☐ CONSTRUCTION SITES
- ☐ MARINE AND OFFSHORE

After many years of research, development and field-testing, the Aqua-Sans technology has evolved into a revolutionary sanitation system designed for today's pressing environmental needs. The Aqua-Sans toilets utilize a clear, odorless, non-reactive fluid for flushing. This fluid looks exactly like water; but, unlike water, it is used over and over again continuously in each system to carry wastes to a special tank where the wastes are separated from the flush fluid. The flush fluid is conditioned and returned to the toilets for flushing. The wastes are transferred to our recently developed "digestor-evaporator" where the wastes are mineralized by bacteria and the associated water (96 to 98% of normal wastes) is evaporated. The resulting sludge, approximately 3 gallons per person per year, is easily removed about once or twice a year and can be disposed of in several convenient methods.

What does "AQUA-SANS" really mean? It means that waste problems are over in areas where conventional sewer lines and centralized treatment plants are inadequate, impractical, or economically unfeasible. It means that areas may now be developed where septic tanks are either prohibited outright, operate poorly, or where fresh water is too valuable to waste flushing ordinary toilets. It means that modern sanitation facilities can be provided wherever needed. It means that we do not have to depend upon sewers!

HYDRAULIC FLOW COMPARISON



STOP USING DRINKING WATER TO TRANSPORT BODY WASTES.

The benefits for public sanitation are enormous.

First, 80 to 90% of the water used for public sanitation (as compared to up to 50% of the water used in the home) is utilized to flush toilets. THUS, 80 TO 90% OF THE WATER PRESENTLY USED FOR PUBLIC SANITATION WOULD BE SAVED! No more costly flushing away of our constantly diminishing reserves of drinkable water — a gigantic benefit to individuals and society as a whole.

Secondly, highly contaminated toilet wastes would no longer pollute our lakes, rivers and oceans. No more harmful bacteria breeding where pure lakes and rivers used to be.

Finally, the need for complex and expensive sewage treatment plants or troublesome septic tanks would be greatly reduced. No more cries that remoteness has made proper treatment of sewage impossible.

But how can all of this be accomplished and still provide the kind of flushing toilet services to which modern society has become accustomed? AQUA-SANS!

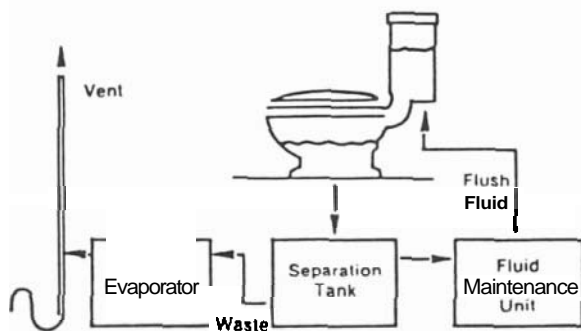
WITH "AQUA-SANS" THE *t u i l e t* IS SEWERLESS!

For nearly a century, one of the world's most inefficient inventions has been playing a major role in the ever-increasing pollution of the earth's dwindling supply of pure fresh water. That invention — the water flush toilet.

Each and every one of us, whether served at home, work or play by public sewers or septic tanks, uses an average of 13,000 gallons of drinking-quality water EACH YEAR just to flush toilets — pure water that carries off our individual annual production of a mere 165 gallons or less of body waste. In the case of sanitary sewers, this 165 gallons annual body waste is carried to complex and costly centralized treatment plants. There, depending on the level and type of treatment system, only 40 to 90 Percent of the harmful matter we introduce into otherwise perfectly drinkable water is removed. Ordinary septic tanks do even less.

The remainder of the contaminants — including pathogenic viruses not always eliminated by conventional sewage treatment — may find their way back into the environment. The result — further degradation of our invaluable pure water supplies. Government sources cite the bacteria from human digestive waste — fecal coliform bacteria — as the single largest contaminant in the waters of the United States and the world.

Each year about 50% of our personal wastes are deposited in some form of public sanitation facility away from home (i.e. factories, offices, schools, restaurants, gas stations, parks, etc.). Aqua-Sans can eliminate the waste discharge, including hand washing water, from these facilities.



AQUA-SANS FLUSH FLUID

The flushing fluid is a clear, water white, very low freeze point, mineral-derived liquid. It is not harmful if accidentally ingested or if it comes in contact with the skin. It lasts indefinitely. In normal operation, a small amount of the fluid may be lost each year. A 20 person system contains less than 100 gallons of fluid while a 600 person system contains only 1000 gallons of fluid.

AQUA-SANS WET-BOWL TOILETS

The wet-bowl toilet fixture is visibly similar to a conventional water flush toilet and differs only by a coating of * TEFLON® on the inside of the bowl. Flushing and refill is even quieter than with a water flush toilet. Waste instantaneously sinks to the bottom of the bowl beneath the flush fluid sealing off obnoxious odors so common in ordinary toilets. Thus, the Aqua-Sans toilet is far more pleasant to use than a standard water flush toilet. *Optional* Aqua-Sans urinal fixtures are also available.

* TEFLON is a registered trademark of E. I. DuPont de Nemours & Co.

HYGIENE

No discernible bacteria of any type are found in the toilet and urinal bowl fluid or on the sides of the bowl, making the Aqua-Sans toilet and urinal much more hygienic than a water flush system. (Test reports from independent laboratories are available.)

SEPARATION TANK

This tank receives flush fluid plus black waste by gravitational flow from toilets and/or urinals. The tank is usually located below the toilets; however, a small lift station may be used where this is not possible. The flush fluid and waste separate upon entering the tank. The flush fluid flows to a separate compartment where it accumulates until needed to resupply the flush cycle. A small pump moves the fluid from the compartment back to the toilets/urinals for flushing automatically on demand.

FLUID MAINTENANCE UNIT

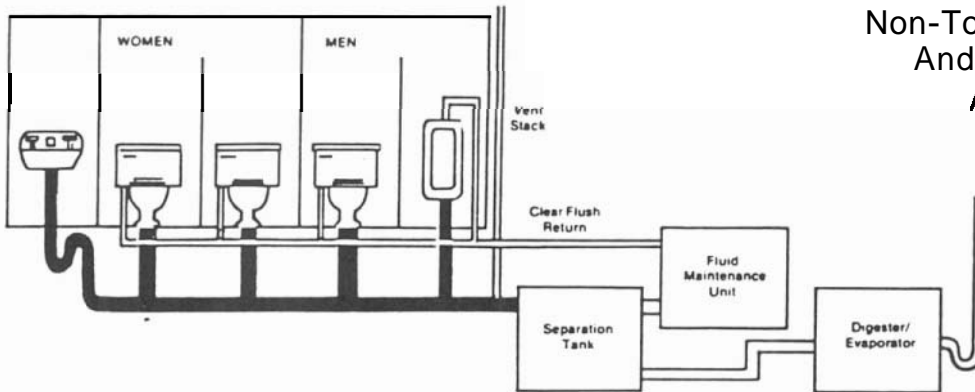
The fluid maintenance unit consists of a small pump that continuously moves a small amount of the fluid from the separation tank through a series of purification elements and returns it to the separation tank. These elements are replaced every few months during a routine servicing cycle. They keep the fluid in a like new condition for trouble-free service.

DIGESTER/EVAPORATOR

The waste is moved from the separation tank to the digester/evaporator by a unique air-lift pump which serves the dual function of liquefying the waste and moving it to the digester/evaporator on a continuous basis, minimizing the waste in the separation tank. The digester/evaporator is an aerated/heated tank that heats the waste to about 140 degrees F where disease-causing bacteria and viruses are killed. A special, non-harmful bacteria naturally present in our waste thrive at this temperature and digest the waste material. Air is supplied to the tank for the bacteria to live and this air carries away the water by evaporation. Less than one percent of the waste remains in the form of a harmless sludge requiring removal about once or twice a year.

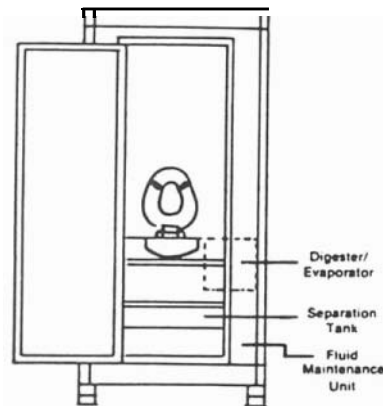
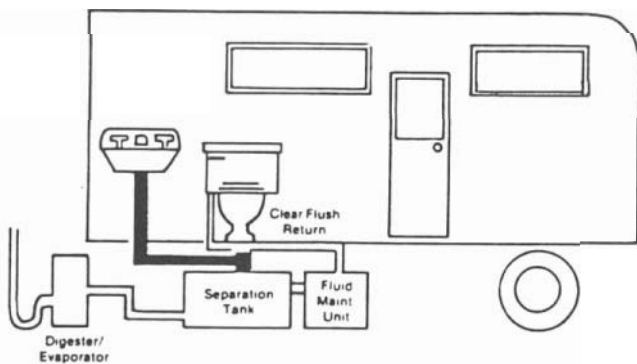
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Systems Available In All Sizes
And Configurations.
Non-Toilet Water Treatment
And Recycle Systems
Also Available



Semi-permanent

Portable Installations



OWNER/USER RESPONSIBILITY

The user/owner can have no responsibility whatsoever in normal daily operation of an Aqua-Sans system if a maintenance contractor is available. All periodic maintenance can be performed by the user or a qualified servicing company.

Housekeeping chores normally associated with water flush toilets have been all but eliminated. There is no mineral or fecal matter buildup on the toilet bowl. The combination of the TEFLON coating and Aqua-Sans fluid prevent these conventional water flush toilet and urinal problems from occurring.

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REPRESENTED BY:

(415) 348-0748



L. Murdock, P.E.
Civil Engineer

Railroad Specialist

B-b

110 Park Road
Burlingame, CA. 94010

REPRESENTATIVE LIST OF INSTALLATIONS

MODEL	LOCATION	OPERATIONAL	REMARKS
	RICHMOND, VA.	MAY 1977	FOUR UNITS ON I-64 IN NEW KENT COUNTY, VA. FOR VIRGINIA HIGHWAY DEPT.
A	LITTLE ROCK, ARKANSAS	MARCH 1977	CORPS OF ENGINEERS MOTOR VESSEL, 'SHORTY BAIRD'
	ROSYTH, SCOTLAND	1978	ONE UNIT FOR BRITISH ROYAL NAVY ON HMS LONDONDERRY
	CHARLOTTESVILLE, VIRGINIA	SUMMER 1978	FOUR UNITS ON I-65 NEAR CHARLOTTESVILLE, VA. FOR VIRGINIA HIGHWAY DEPT.
AB-2	COOK INLET, AK	JUNE 1977	ONE UNIT FOR ARCO OFFSHORE PLATFORM WITH INCINERATOR
B	CMK INLET, AK	JUNE 1977	ONE UNIT FOR ARCO OFFSHORE PLATFORM WITH INCINERATOR
B	COOK INLET, AK	JUNE 1977	ONE UNIT FOR MARATHON OIL OFFSHORE PLATFORM
B	C K INLET, AK	JUNE 1977	TWO UNITS FOR UNION OIL OFFSHORE PLATFORMS
D	OLYMPIC VALLEY, CALIFORNIA	AUGUST 1977	ONE UNIT AT MOUNTAIN TOP RESTAURANT SQUARE VALLEY SKI CORP. <i>HARDY HERDER</i>
A	POOLE, DORSET, ENGLAND	DECEMBER 1977	ONE UNIT AT HAMMURBY PUMP AND COMPRESSOR DIV. FACTORY
D	MONROE, MICHIGAN	MARCH 1978	ONE UNIT AT CARLTON REST STOP ON I-275 NEAR YPSILANTI, MICH FOR MICHIGAN HIGHWAY DEPT.
N	BARROW, AK	APRIL 1978	ONE UNIT AT ARCTIC SLOPE REGIONAL HEADQUARTERS OFFICE BUILDING
B	KENAI, AK	JULY 1978	ONE UNIT AT SALAMATOF SEAFOODS, INC. FACTORY
AB-2	Barrow, AK	October 1980	One unit at Barrow Regional Service Center (police station).
N	Barrow, AK	September 1981	One unit at North Slope Borough Administration Building.

7-78



REPRESENTATIVE LIST OF INSTALLATIONS

MODEL	LOCATION	OPERATIONAL	REMARKS
A	CHRYSLER FACILITY NEW ORLEANS, LA.	FEBRUARY 1974	UNIT AT NASA'S MICHAUD ASSEMBLY FACILITY
C	ANNAPOLIS, MARYLAND	NOVEMBER 1973	U.S. NAVY RESEARCH AND DEVELOPMENT CENTER BARRACKS SERVING 150 PERSONNEL, SUCCESSFULLY COMPLETED.
A	NEW YORK HARBOR AREA	MARCH 1972	DUNBAR & SULLIVAN DREDGING CO. TUGBOAT "R.H. GOODE" WITH A CREW OF 6 TO 10
A	FORT BELVOIR, VIRGINIA	OCTOBER 1972	U.S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER. EQUIPMENT TO BE RELOCATED TO ANOTHER SITE.
B	ALBANY, NEW YORK	APRIL 1973	LOCATED AT THE FIVE-RIVER ENVIRONMENT EDUCATION CENTER
B	WICHITA FALLS, TEXAS	DECEMBER 1973	TWO UNITS ON TEXAS HIGHWAY U.S. 281 AT BURKBURNETT, TEXAS
	TAMPA, FLORIDA	JULY: 1973	TRAILERIZED LATRINE FOR CONSTRUCTION SITE
A	MOBILE, ALABAMA	APRIL 1974	CCRPS OF ENGINEERS SNAGBOAT "ROS", 28-MAN CREW
B	BUTTE, MONTANA	JUNE 1975	TWO UNITS ON INTERSTATE HIGHWAY 90, HOMESTAKE REST AREA
A	NEW ORLEANS, LOUISIANA	1974	FOUR UNITS ON THERICT, INC. OCEAN-GOING TUGS (12-MAN CREWS) BUILT BY MAIN IRON WORKS
A	NEW ORLEANS, LOUISIANA	STARTING IN 1974	SEVEN UNITS ON THERICT, INC. OCEAN-GOING TUGS (12-MAN CREWS) BUILT BY ECUITABLE EQUIPMENT CO.
B & C	NEWCOMB, NEW YORK	DECEMBER 1974	THREE UNITS AT LAKE HARRIS PUBLIC CAMPSITE IN THE ADIRONDACK MOUNTAINS.
A	FORT BELVOIR, VIRGINIA	JANUARY 1975	ARMY LCU
B	TACOMA, WASHINGTON	JANUARY 1975	BRINKERHOFF MARINE DRILLING OFFSHORE PWTFCRM
	STARKVILLE, MISSISSIPPI	SUMMER 1975	ONE UNIT ON U.S. 82 SPECIFIED BY MISSISSIPPI HIGHWAY DEPARTMENT
S-20	BAY ST. LOUIS, MISSISSIPPI	APRIL 1975	ST. STANISLAUS BOYS CAMP
S-20	CASCADE DAM, IDAHO	FALL 1976	THREE UNITS AT RECREATION AREA
S-50	TETON DAM, NEWDALE, IDAHO		TWO UNITS AT RECREATION AREA
S-20 S-50	PALISADES DAM, IDAHO	SUMMER 1976	ONE OF EACH SIZE AT RECREATION AREA
A	LA ROCHE, LOUISIANA	APRIL 1976	ONE UNIT ON AMERICAN GULF SHIP BUILDING TUG





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Fax (504) 392-5946

PROPOSAL TO PROVIDE A ZERO DISCHARGE TOILET WASTE TREATMENT SYSTEM FOR RAILROADS AND OTHER TRANSPORTATION VEHICLES

BACKGROUND:

The Aqua-Sans Oil Flush Toilet System development began over twenty years ago at Chrysler Corporation under a contract sponsored by The United States Navy. The system was designed to provide zero toilet discharge into the sea when ships were near shore.

This system has been thoroughly tested to meet the requirements of safety and human factors aboard ships, offshore oil rigs, in homes, offices and public rest rooms. The commercial development of this concept was discontinued by Chrysler after ten years because of the lack of enforcement of environmental regulations by the Federal and State agencies and public apathy to environmental problems. These factors eroded the market for such a system.

During this period several systems were built and installed nationwide and some of these early systems still exist. Aqua-Sans, now under the direction of the original inventor, has improved and begun manufacturing and installing the new oil flush toilet systems. The most recent installations have been for the Virginia Department of Transportation at rest stops on Interstate Highway 64. These installations are significant because they replaced Aqua-Sans systems installed by Chrysler Corporation some thirteen years ago. The new larger systems were necessary due to increased usage. The new systems are designed to accommodate 10,600 uses per day, and are housed in the same buildings even though they have been updated with new innovations.

To supplement these large units, Aqua-Sans technology is now being incorporated into small units. Units to accommodate six live in persons with average use of 6.5 flushes per person per day or with expanded storage for as many people that could use a commode.

Description:

The Aqua-Sans Oil Flush Toilet utilizes mineral oil as the flush fluid instead of water. In a standard toilet 98% of what goes down the sewer is potable water before being used to flush. Only 2% is human waste (urine, feces, toilet paper and other flushable materials). By using mineral oil, there is no reduction in flushing quality and waste transport. At the same time there has been a 98% reduction in sewage volume requiring treatment. In the smaller systems, such as those for use on trains, Aqua-Sans uses a specially designed toilet fixture to reduce the volume required for flushing due to their compact size.

In the standard configuration the toilet waste is transported by pipes to the separation tank where the mineral oil and the waste separates due to the difference in their specific gravities. Because oil and water are immiscible, the two fluids remain separate. Human waste consists of urine (98% water) and feces (86% water) along with the toilet paper which tends to remain in the water phase.

The oil being lighter than water (specific gravity 0.83), rises to the top and overflows a weir into a storage reservoir. The oil is continuously filtered and cleaned to remain like new. Chlorine is added to the oil in a form that will not enter the water phase and prevents the oil from being biodegraded. The oil from the reservoir is then returned for use in flushing the toilet. Very little oil is lost from this system, therefore, the initial filling can last for years needing only minor replenishment. The mineral oil is classified as a technical grade, the same type used in cosmetics and baby oil. It is water clear and has a viscosity near that of water.

The waste material sinks to the bottom of the separation tank where it is broken up and constantly mixed with air in a patented configuration that biodegrades the wastes aerobically. No chemicals or biological inhibitors are added, therefore, accumulations of waste in the system may be discharged into any sanitary sewer system. The waste remains in an aerobic condition which reduces noxious odors from the system. Aerobic digestion tends to destroy pathogenic organisms and with the digester evaporator, which may be added to the system, further reduces the waste volume. The elevated temperature in the digester with time destroys both viruses and pathogenic organisms. There is no addition of waste volume from this toilet system due to the flush fluid and the digester can reduce the already low volume of waste by an additional 95%.

Summary:

The Aqua-Sans Flush Toilet system has been in development and use for over twenty years. Although this concept is cost competitive in many situations it has not been widely marketed. The small size, minimum volume of waste and the simplicity of the system makes it ideally suited for installation aboard trains, buses, ferries and boats.

The experience gained over the twenty years of use make this a proven technology. The oil flush toilet concept can be configured to fit almost any space and energy requirements are minimal. The Aqua-Sans Systems are cost competitive where pollution abatement and or water conservation are truly desired and enforced.

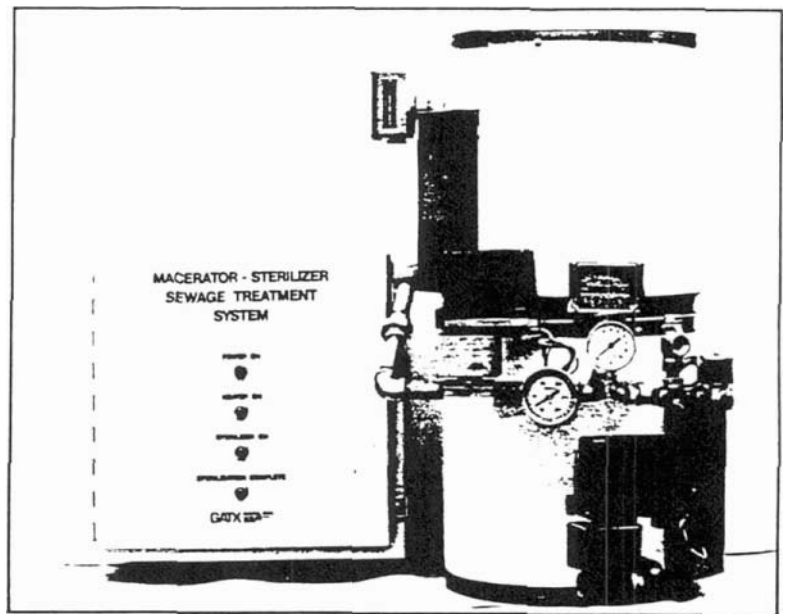
GARD

MACERATOR STERILIZER SEWAGE TREATMENT SYSTEM

The GARD/GATX Macerator Sterilizer Sewage Treatment System (MSS)* is a flow-through system that treats the sewage by heating to 250°F for 15 minutes to effect a complete sterilization, i.e., no viable organisms present in the wastes to be discharged. This system, designated as Model MSS-I is certified by the U.S. Coast Guard as a Type I MSD, USCG Certification No. 159.15110121211.

The essential criterion of the performance of the MSS is meeting the USCG and EPA discharge standards for treated effluent. Current regulations require that the effluent will not have a fecal coliform bacterial count of greater than 1000/100 ml, nor visible floating solids. Field tests showed that the effluent from the MSS results in a fecal coliform count of zero; this more than meets the current regulations. The MSS is being upgraded to meet Type II regulations, which state that the effluent will not have a coliform count greater than 200/100 ml, nor total suspended solids greater than 150 mg/l.

Macerator Sterilizer Systems are currently in operation on U.S. Army Corps of Engineers' Dredges "Harding" and "Pacific," and on American Steamship Company's MV "Belle River."



GARD's MSS:

- Meets the current USCG and EPA discharge regulations.
- Operates automatically with no servicing requirements.
- Requires no additives; thus, no stocking and handling of chemicals are necessary, and no materials other than sterilized human sewage will be discharged with the effluent.

SYSTEM OPERATION

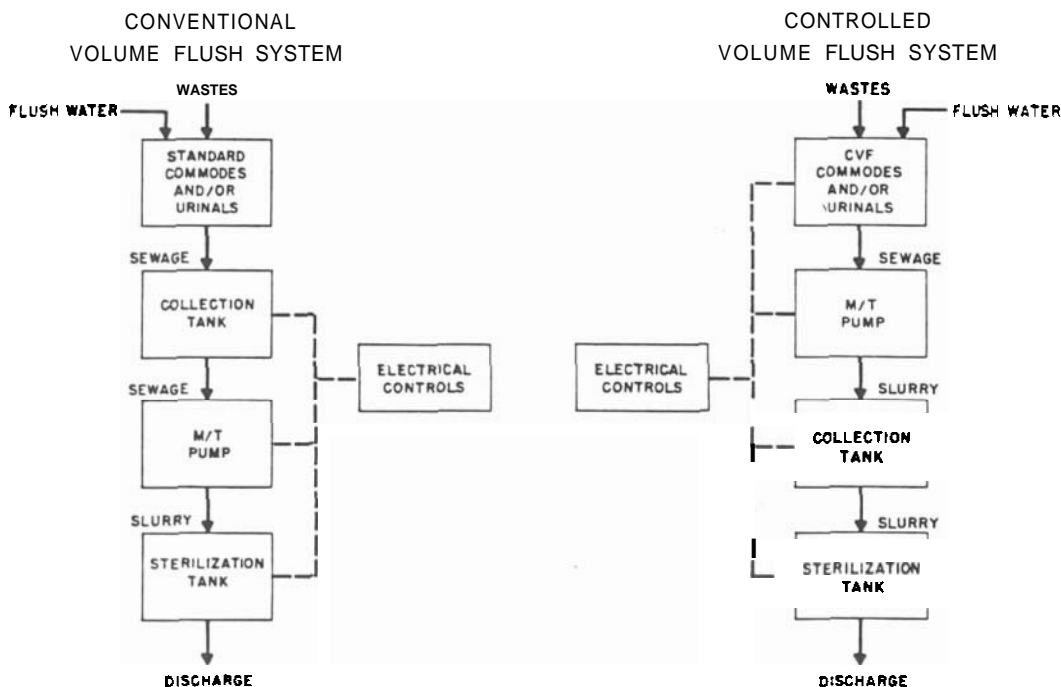
The Macerator Sterilizer System operates on repetitive automatic cycles. A batch of wastes is ground up by a **macerator/transfer (MIT)** pump and directed to the sterilizer tank. Electric heaters in the sterilizer tank raise the temperature of the sewage to 250°F under 15 psig steam pressure. After holding at 250°F for 15 minutes, sterilization is completed and the sewage is discharged overboard when the vessel is operating in waters where discharge of sterilized wastes is permitted. A lockout switch in the control circuit prevents discharge of wastes in restricted waters. The MSS can be used with either Controlled Volume Flush (CVF) commodes or standard flushing commodes (see schematic diagrams), but in order to limit power consumption GVF commodes are preferred.

POWER REQUIREMENTS

An average of 0.8 KWH is required per man-day to heat sterilize the sewage from controlled or low volume flush toilets; with conventional flush toilets, the power required is approximately 16 KWH per man-day. The M/T pump requires 2 KW during a short duty cycle, and controls including motorized valves require 500 watts. The pumps and sterilizer heaters operate from 460 volt, 3 phase, 60 Hz; control voltage is 120 volt, 1 phase, 60 Hz.

SPACE REQUIREMENTS

Sterilizer sizes vary from 10 to 120 gallons with processing rates up to 1800 gallons per day, depending upon individual requirements. The largest component of the system, the 120-gallon sterilizer tank, is 36 inches in diameter and 72 inches high. Pumps are approximately 10 inches in diameter and 15 inches long. Controls are housed in a 20-inch by 20-inch by 6-inch deep NEMA 12 splashproof box. The system is modular, thus each component can be mounted in its most convenient location.

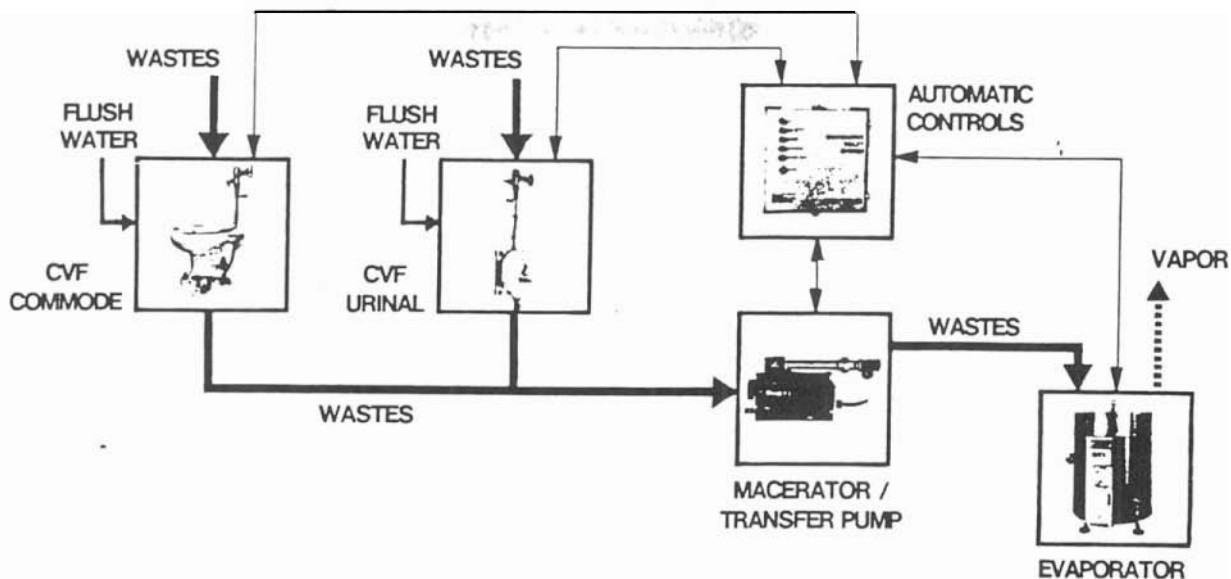


ETS

EVAPORATIVE LOSS

GARD, INC.

A SUBSIDIARY OF
GATX CORPORATION



BACKGROUND:

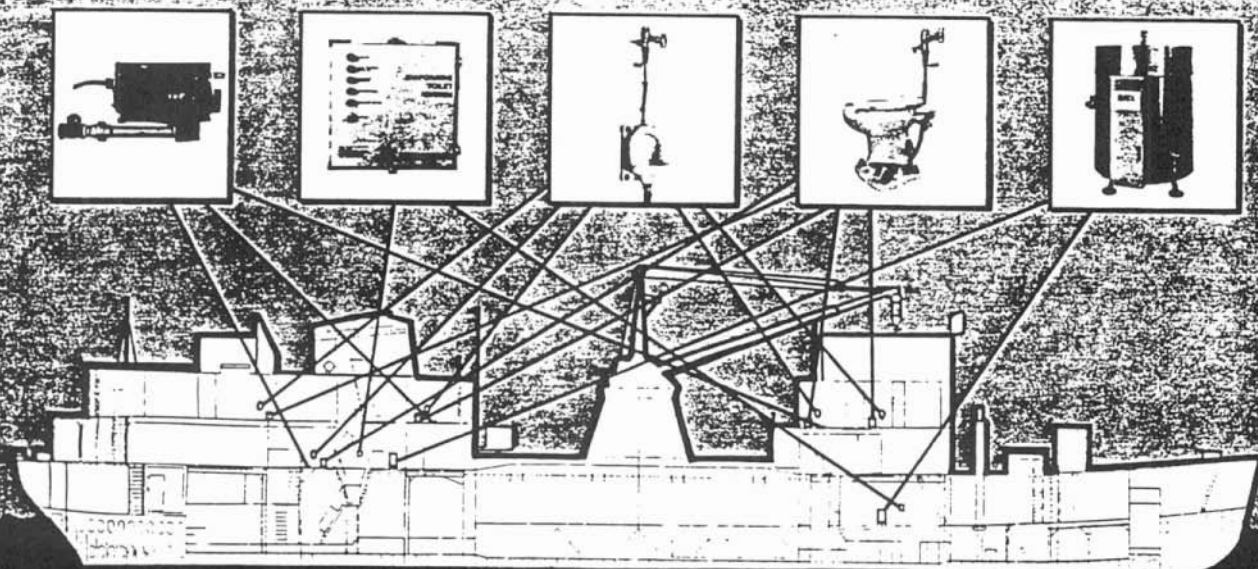
GARD, Inc. began development of the Evaporative Toilet System (ETS) concept several years ago to fill the need for a simple, reliable, and extended capacity system on board aircraft. A flight test program of an ETS for aircraft was entered into and coordinated with United Airlines, Boeing Aircraft Company, the Federal Aviation Administration, and the U.S. Public Health Service. With the advent of America's ecological awareness,

the concept was extended to marine, land-based, and other mobile applications.

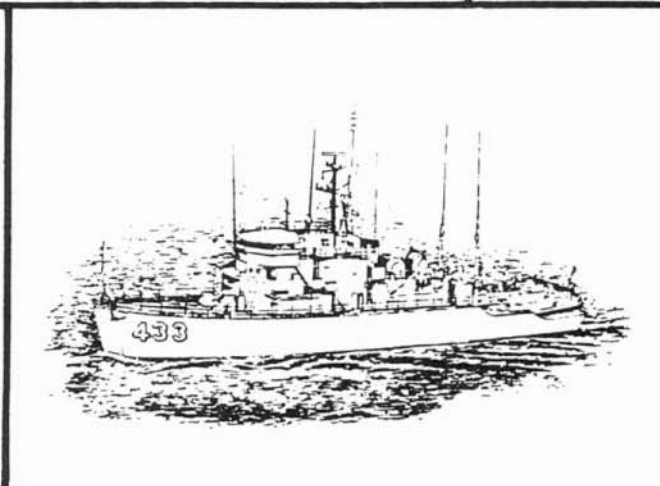
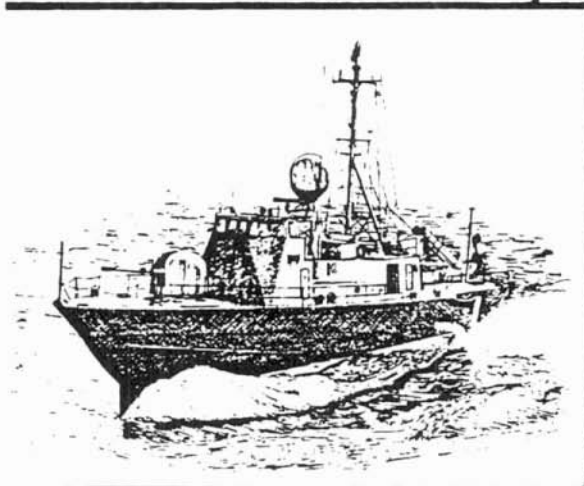
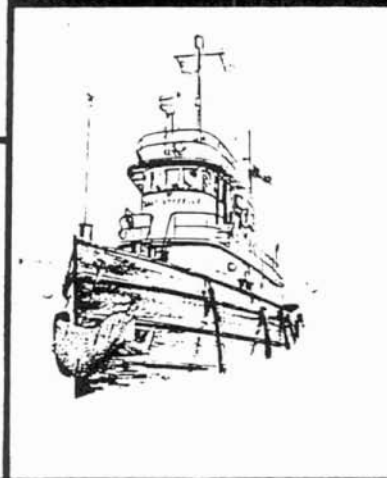
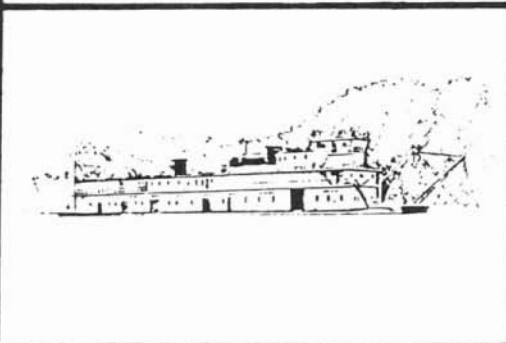
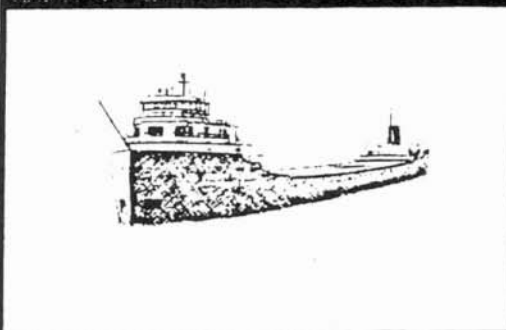
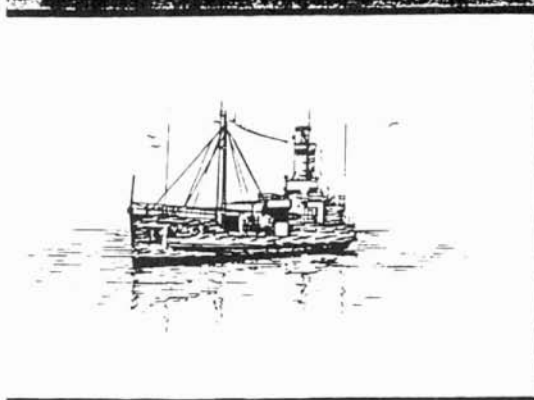
The ETS features extended retention by volume reduction of toilet wastes through controlled evaporation of flush and waste water. This approach is feasible because the mixture of flush water and waste is primarily water, which can be vaporized to steam and vented to the atmosphere. The effluent steam is treated by a floor

treatment system to remove objectionable odors. The evaporator retains the remaining solid wastes in the form of a sludge. When the solids in the sludge reach a predetermined concentration, automatic controls signal the operator that the system will soon require servicing. Servicing consists of pumping the retained sludge to approved facilities for disposal.

U.S. Patent Nos. 3,797,491 and 3,797,473.



TYPICAL INSTALLATIONS



GENERAL INFORMATION:

- **STANDARD SIZES:**
75-man system, or equivalent loadings for **around-the-clock** use. 16 days of operation before **pump-out**.
- **SERVICE HOURS REQUIRED (Average Monthly):**
Tank Pump-Out and **Cleaning—4** hours.
During Normal Operation—None, fully automatic.
- **REQUIREMENTS FOR SYSTEM SUPPORT:**
AC power for pumps and controls.
AC or DC power for evaporator.
Fresh or salt water at minimum of 30 psig for flushing.
- **CERTIFICATION:**
Approved under U.S. Coast Guard standards for marine installation —
Model ETS-II: #159.15/1012/1/III.

TECHNICAL SPECIFICATIONS:

SYSTEM PARAMETERS (based on 25-man crew)

- Electrical Demand:
Evaporator — 8 KW (approximately 24 hours per day)
Macerator/Transfer (MIT) Pumps — 1.4 KW each (approximately 15 seconds per flush)
Controls — 03 KW each (continuous)
Sewage Volume Per Day: 48 gallons (average)
- Rate of Evaporation: 2 gallons per hour
- Service **Interval**: 16 days

SYSTEM COMPONENTS

- Evaporator:
Size — 80 gallon capacity, height 60", diameter 40"
Materials — Stainless **steel** tank with Teflon inner lining, fiberglass insulation
Level Sensors — High and low, ball float type
Inputs — 1 1/4" sewage line from MIT Pumps and 1" fresh water tank rinse line
Outputs — 1 1/2" vapor exhaust line and 2" sludge discharge line
Operation — Heaters (5.5 KW) controlled by low level sensor to evaporate liquids. Solids build-up detected by decrease in thermal demand. MIT Pumps inactivated when liquid rises to high level sensor.
- Vapor Treatment System:
Size — Height 30", diameter 18"
Materials — Stainless steel with insulation lagging
Operation — Heater (1.8 KW) controlled by thermostat and air flow

- Automatic Controls:
Cabinet Size — Height 20", depth 11", width 20"
Circuitry — Functions to control operation of MIT Pumps, monitor liquid levels, solids accumulation, and system status for servicing
Service Status — Four control panel lights indicate system status: Power On, Evaporator Heaters On, Evaporator Full, and Evaporator Service
- **Macerator/Transfer** Pump:
Capacity — 1 1/2 HP. 50 foot head at 30 gpm
Power Options Available — 115 VAC — single phase, 208 VAC — three phase, 230 VAC — single phase, 440 VAC — three phase. all 60 HZ.
Interlace Requirements — Input 3" or 4" diameter line, output 1 1/4" diameter pressure line
Foreign Objects Accepted — Shop rags, pocket combs, ball point pens, etc.
Installation — Hung from deck or flooring below toilet when space is available (allows for more than one toilet per pump in this configuration). Or, mounted above deck or floor adjacent to toilet where space is not available below the toilet.
- Controlled Volume Flush Toilet:
Flush Volume — One pint per urination and two to three pints per defecation
Toilet Space Requirement — 1. Pump below deck: 15" wide, 24 1/2" deep; 2 Pump on same deck: 26" wide, 32" deep
Toilet Size & Materials — Standard size and height vitreous china bowl
- Controlled Volume Flush Urinal:
Flush Volume — One pint
Urinal Size & Materials — Standard marine size, vitreous china

For additional information write:

GATX

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7449 North Natchez Ave.

Niles, IL 60648

312-647-9000

Suite 1000

1100 - 17th St. N.W.

Washington DC 20036

202-293-5310

B-13

Microphor

MICROPHOR®

ON-BOARD SEWAGE TREATMENT SYSTEMS



MICROPHOR®

Quality Railroad Products

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Telex: 271283 (MICROPHOR WLLT) FAX: (707) 459.6617

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Microphor Europe GmbH, Postfach 80 03 59. Huttenstrasse 45, 4320
Hattingen, West Germany. Telephone: (0 23 24) 29.5546
Telex: 8229974 (THH D)

HOW THE SYSTEM WORKS

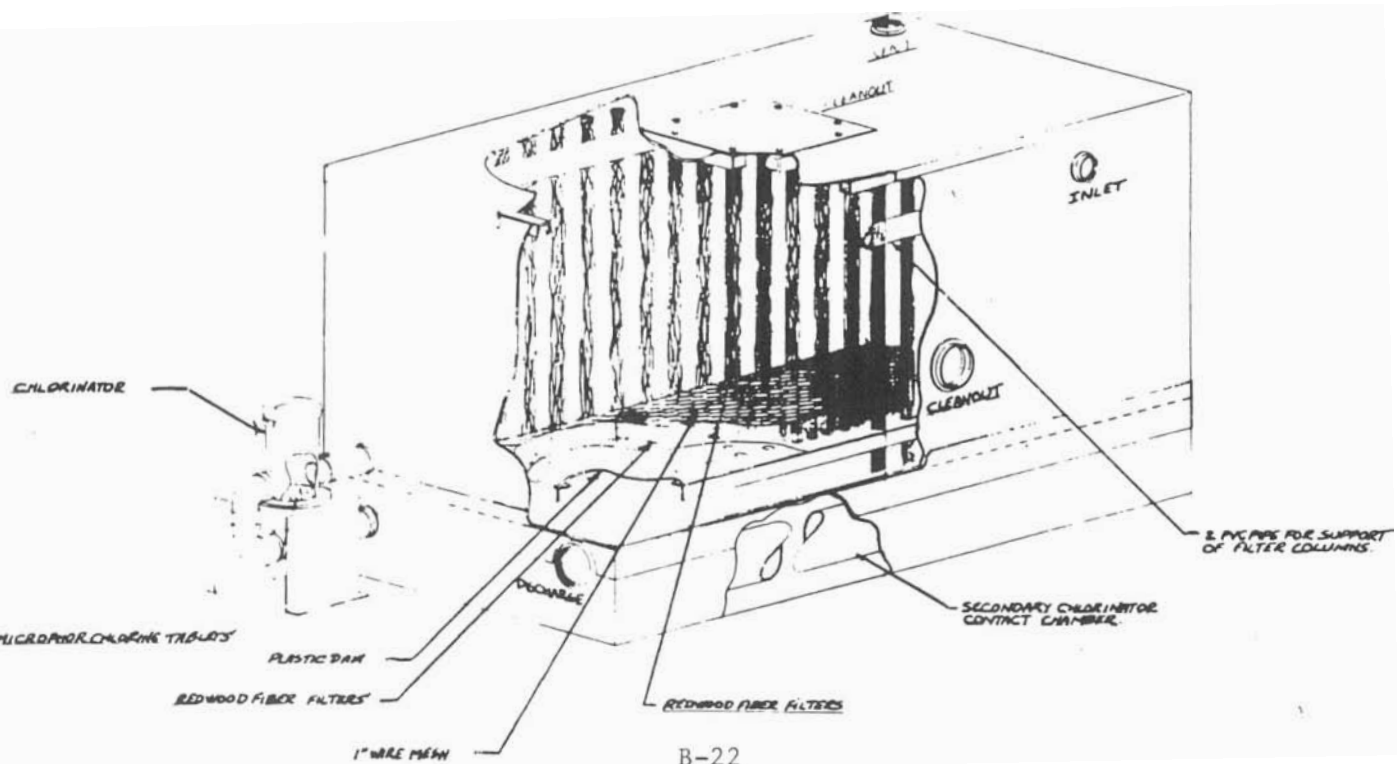
1. The Microphor toilet and sewage treatment system is a bacteriological type system for disposing of human waste products.
2. The system includes choice of either stainless steel or vitreous china two quart flush toilets with integral or wall mount flushing mechanism and waste treatment tank with chlorinator and secondary.
3. Treatment tank (or tanks) can be mounted inside the car or engineered to fit under the car depending on space available and can be insulated and electrically heated if necessary to prevent freezing in winter, heating also maintains the biological action within the treatment tank
4. The Microphor toilet is flushed by depressing the integral or wall mount lever or button. This supplies a compressed air signal to shift the air and water sequence valve to allow water to start flowing into the toilet bowl and flapper to open to accept waste into the lower evacuation chamber.
5. Flapper stays open for approximately six seconds and then closes and hermetically seals off the lower evacuation chamber. The chamber is then pressurized with air and waste is evacuated into the treatment tank. While this action is taking place the toilet bowl level is replenished with two quarts of fresh water for the next use.
6. Once the waste and liquids have entered the treatment tank the liquids are gravity filtered through a series of fibre filter columns mounted in a dam in the lower portion of the treatment tank. The liquid then passes through the chlorinator unit where it is chlorinated by solid

Continued

chlorine tablets. From there it flows into the secondary.

7. In the secondary the chlorinated liquid flows through a series of baffles thus allowing the chlorine time to reduce the coliform bacteria count to 0, before being allowed to drain onto the trackbed via a drain port on the bottom of the tank.
8. The solid waste still remaining in the treatment tank is broken down bacteriologically by microbes, which live within the treatment tank, to a liquid (which drains off as described above) and to a carbon dioxide which escapes through the tank vent port.
9. In order to maintain the optimum efficiency of the Microphor system, every effort should be made to keep antibacterial cleaners and foreign objects away and out of the system.

INTERIOR VIEW OF TREATMENT TANK



OPERATIONAL REQUIREMENTS




1. To operate, the system must have air at 60 pounds pressure and water at 1-50 pounds pressure. The toilet will not work without both air and water.
2. To adjust air and water, cover must be removed. The hex head needle valve ~~adjusting~~ screw extends to ~~the~~ left, out of the lower cap of the valve body. Using two 3/8" open end wrenches, hold hex head with one wrench and loosen lock nut with other 3/8" wrench. Turning hex head clockwise on the needle valve will give a longer flush cycle, turning counterclockwise will give a shorter flush. The ~~water~~ should cover the flapper in the bottom of the bowl. The air evacuation blast should be approximately 5-7 seconds. Always retighten lock nut on needle valve when through with adjustment.
3. The Regulator-Filter-Oiler is located in the air line ~~ahead~~ of the air controlled valve. A check should be made at the start of every trip to make sure the oiler ~~has~~ oil to the full mark. If oil is needed, turn off air and then remove oil fill plug on top of oiler and fill with Microphor light oil (part #24704). The oiler has been factory set to use one drop of oil per flush. If adjustment is needed, turning the slotted adjustment screw clockwise increases the amount of oil, counterclockwise for less oil. The regulator filter has an automatic dump device. If for some reason moisture collects in the bottom of the filter unit, it can be dumped manually by pushing exhaust pin in bottom of filter.
4. If the toilet becomes plugged, shut off the water supply, shut off the air supply, press the valve button several times to bleed off the air pressure. When air pressure is out of the valve, the flapper in the bottom of the toilet can be pushed open. Use a plunger (plumber's friend) as with any standard toilet. If the plunger does not ~~clear~~ the toilet, check to see if the restriction can be removed with a hooked wire, being careful not to damage the rubber seal on ~~the~~ flapper or the mating surface on the hopper. ~~When~~ the passage becomes clear, turn on the air and water and press flush button to start flush cycle. In the discharge line from the toilet to the treatment tank, there is a ~~clean-~~ out wye or tee which can be opened to assist in cleaning obstructions from the line.
5. To clean Microphor toilets, use non-abrasive, bio-degradable cleaners such as Fantastic, Ivory Snow, Formula 409, Mr. Clean and Janitor in a Drum. Sanitizers in general are not to be used. The carbolic or kreosote base sanitizers when they are flushed into the treatment tank stop the biological action, to clean exterior bowl use Microphor #24690 Stainless Steel Cleaner.
6. In the Microphor process, the effluent from the treatment tank flows through the chlorinator which is full of chlorine tablets. The solid waste is broken down by biologic action and becomes liquid and carbon dioxide. Chlorinators are located next to the treatment tank. The treatment tank can be plastic or



Continued





metal, inside the car, or bolted on under the car. Locate the treatment tank and then find the chlorinator. (Some large tanks may have more ~~than~~ one chlorinator.) Locate and check the chlorinator at the start of every run. The lid of the chlorinator should be removed and filled with **Microphor** tablets (part #24706).

7. This toilet is designed for disposal of human waste and toilet tissue only. Do not put any other item, material or liquid into this toilet.

SIZING A TREATMENT SYSTEM ?

Because of the many variable factors involved when sizing a system for railroad applications the following procedure is recommended.

First contact your Microphor representative, if you are not sure who this is contact Microphor directly and we will assist you. Please be able to tell us the number of people using the car daily and for how many hours daily. Also, the length of each trip in addition to how many stops the train makes along the way. These applications usually fall into several categories.

1. Commuter
2. Long Distance
3. Crew Equipment
4. Private Car

Taking these factors into account the representative will probably require a trip to your location to determine the number of toilets involved and how much space is available inside or under the car for treatment tanks of the proper size.

If this is not possible then a complete set of **undercar** and interior drawings may provide the necessary information to allow a quotation to you. If drawings are **sent** they should denote all pertinent information in English please.

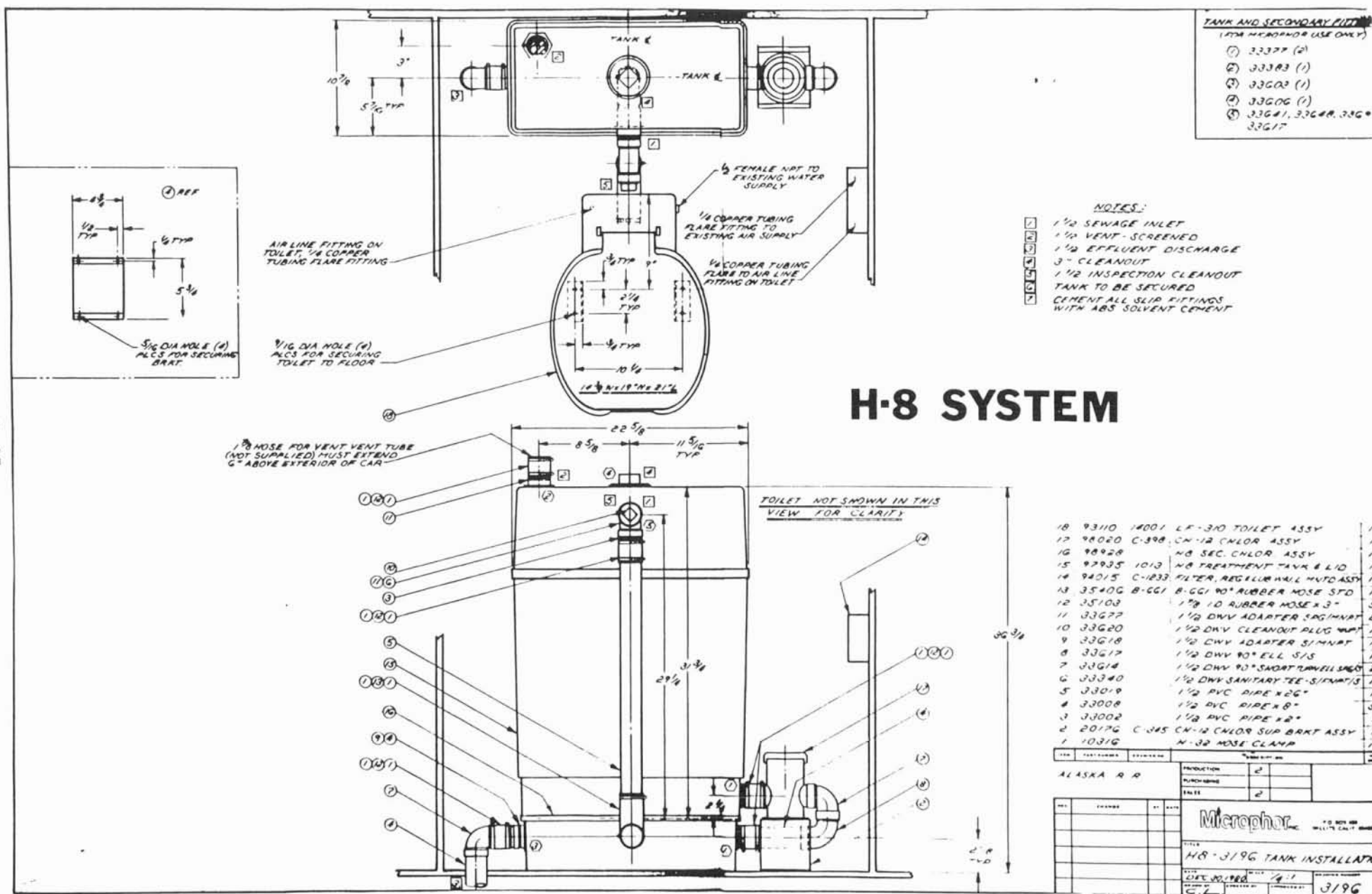
NOTE !

The following drawings are representative type systems which Microphor has done in the past and are intended for reference only!

Please notice the various sizes of the treatment tanks and the different types of toilets, as well as the various layouts which depend on the space available, customer preference and load factors.

The first drawing is an isometric cutaway view showing a typical treatment tank construction which is common to all of our tanks regardless of size. The H8 and H12 plastic tanks noted are standard and require only the correct porting before they can be shipped out. All references to dimensions are American standard inches. If however, we supply approval drawings to the European market they will always contain metric millimeters as reference.

Thank You.



H-12 SYSTEM

INPUT: NONFLEX FITTINGS
FOR MICROPHONE (ACQUA)
33000 (10)
33000 33000

NOTES

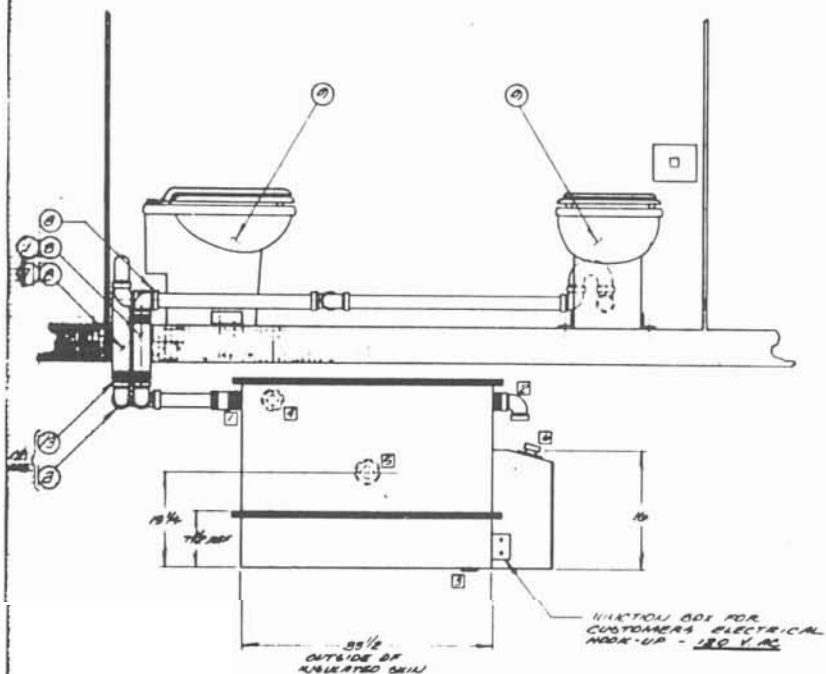
- 1/2" VENT
- 1/2" EFFLUENT DISCHARGE
- 3" CLEARANCE
- TECH TO BE DECURED
- CONVERT ALL SLD FITTINGS
- WITH ADD DELVENT
- TECH IS TO BE INSTALLED INTO
- AT LINE AHEAD OF ALL OTHER
- AT DELVENT

1. THE H-12 SYSTEM IS A...
2. THE H-12 SYSTEM IS A...
3. THE H-12 SYSTEM IS A...
4. THE H-12 SYSTEM IS A...
5. THE H-12 SYSTEM IS A...
6. THE H-12 SYSTEM IS A...
7. THE H-12 SYSTEM IS A...
8. THE H-12 SYSTEM IS A...
9. THE H-12 SYSTEM IS A...
10. THE H-12 SYSTEM IS A...

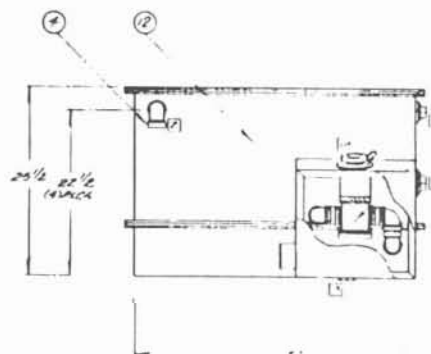
PRODUCTION	DATE	BY
PLANNING		
SALES		
Microphor		
TITLE		
1/2" VENT		
3" CLEARANCE		
33000		

B-32

W/ALLS NOT SHOWN IN
THIS VIEW FOR CLARITY



VIEW A-A
TAKEN FROM CNT. 1



(1)

SEE CNT 1 FOR PARTS LIST

PART NAME		QUANTITY	REMARKS
1	TOILET	1	
2	VANITY	1	
3	SINK	1	
4	MIRROR	1	
5	TOILET PAPER HOLDER	1	
6	TOILET BRUSH	1	
7	TOILET TISSUE	1	
8	TOILET TISSUE	1	
9	TOILET TISSUE	1	
10	TOILET TISSUE	1	
11	TOILET TISSUE	1	
12	TOILET TISSUE	1	

APPROVED: *[Signature]*
 DATE: 10/10/03
 PROJECT: 3404
 DRAWN BY: 3404

1/2 INPT TO FINISHING
WATER SUPPLY

1/2 CORNER TRUNK
FLARE FITTING TO
FINISHING AIR SUPPLY

1/4 COPPER TURNING FLARE
FITTING TO AIR LINE
FITTING TO OIL TIGHT

1/4 COPPER TURNING FLARE
FITTING TO BIRMINGHAM
AIR SUPPLY

IN OUR FILE (4)
FOR SECURITY
TRUST

2/10 DIA HOLE @ 10"
CENTERS FOR
SECURING TANK
TO FLECS

24 1/2

9" NERE
1" NE SW

10' DIA FOR FRONT
WENT THERE (NOT
IMPAIRED) AND FILTERED
6" CROWN EXTERIOR
ON CAR.

— 1 1/2 x 1 1/2 x 9/16
ALUMINUM - (B)
ALCA

SPECIAL COACH SYSTEM

Vick A-A

Mores:

1/4 AIRLINE UNCT
1/4 VENT
1/4 REFLECTOR DIMINISHED
1/4 OF PINK CLEAROUT
6" SQUARE CLEAROUT
TANK TO BE SECURED
ALL LEAKS, LEAKINGS OR
1/2 PINK PINK TO BE
OBTAINED BY CUSTOMER
CURRENT AND ALL FITTINGS
WITH ABA SOLVENT CURRENT

20	3275.3	TREATMENT TANK A441	1
24	3282.4	2" C. INJECTOR A441	1
24	3290.0	TOILET SEAT - COVER A441	1
25	3290.0	2" C. CHLORINATOR A441	1
25	3290.0	ENTER 2" C. FLOOR WASH A441	1
2	3303.0	4" C. 2" FLOOR TOILET A441	1
20	3304.0	1 1/2" 10" 2" RUBBER HOSE	1
19	3304.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	1
8	3305.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
17	3306.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
4	3307.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
14	3308.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
14	3309.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3310.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3311.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3312.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3313.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3314.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3315.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3316.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3317.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3318.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3319.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3320.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3321.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3322.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3323.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3324.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3325.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3326.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3327.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3328.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3329.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3330.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3331.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3332.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3333.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3334.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3335.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3336.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3337.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3338.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3339.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3340.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3341.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3342.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3343.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3344.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3345.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3346.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3347.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3348.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3349.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3350.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3351.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3352.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3353.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3354.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3355.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3356.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3357.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3358.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3359.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3360.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3361.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
18	3362.5	1 1/2" 10" RUBBER HOSE 1" 1/2" LG	2
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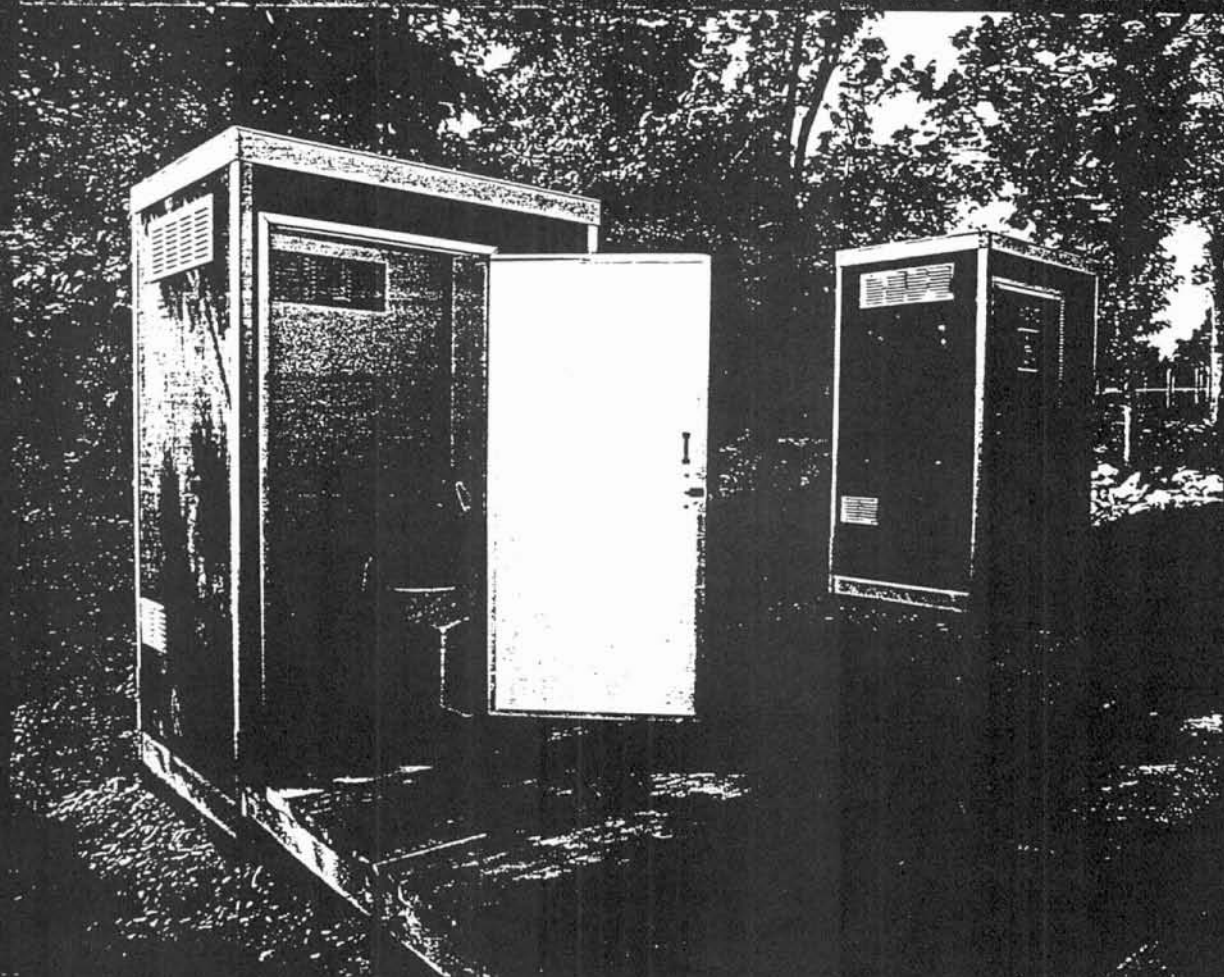
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Monogram Sanitation



800 W. Artesia Blvd., P.O. Box 9057, Compton, CA 90224-9057
(213) 638-8445 FAX: 638-8458

**PORTABLE,
FLUSHING
TOILET
SYSTEMS –
Durable, quality
sanitation
for wherever
there is the
need.**



From Monogram Sanitation A NORTEK COMPANY

We offer you:

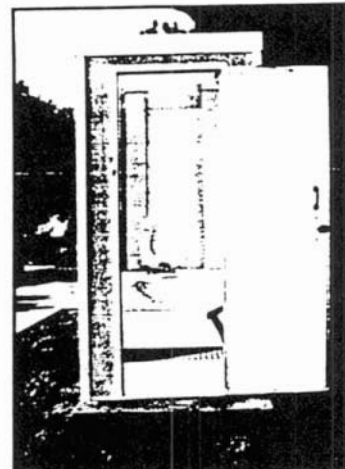
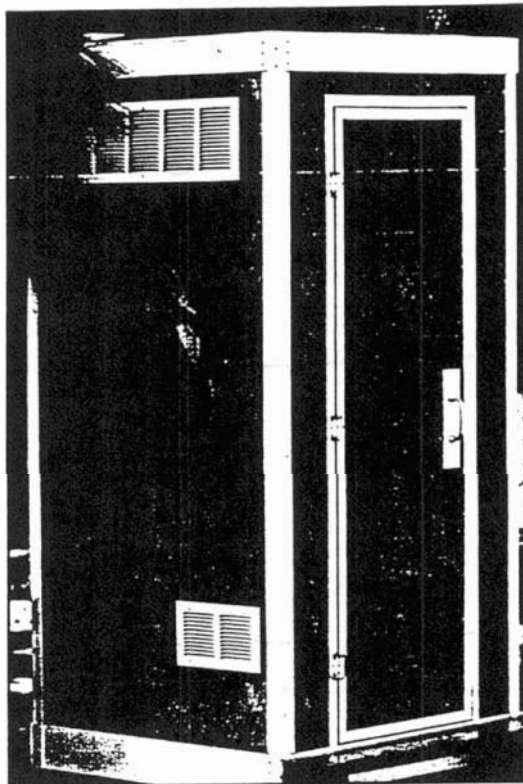
JET-O-MATIC®
Toilet systems
for remote areas
that require no
connections to:

- ☐ water
- ☐ sewer
- ☐ power

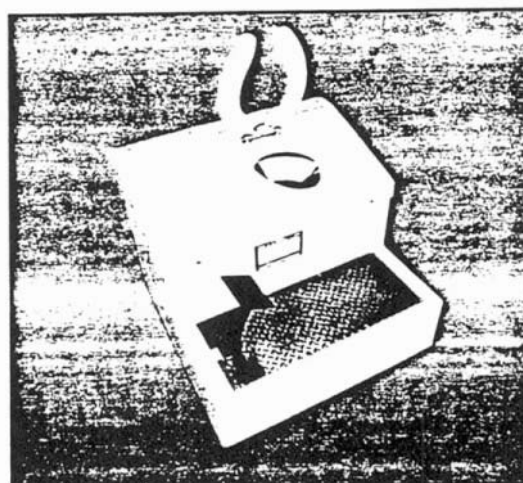
The Jet-O-Matic® product line provides self-contained sanitation products for remote areas without access to conventional sewage systems. Self-contained implies that these products **are not** dependent on the availability of water, power or sewer lines for their usage.

These self-contained retention type products are an outgrowth of and similar to the type in use by virtually all commercial aircraft. They were introduced by Monogram about two decades ago.

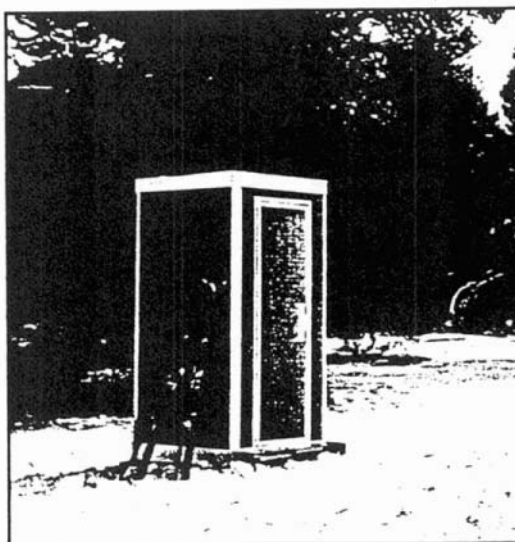
We at Monogram Sanitation have consistently maintained the lion's share of the world's commercial aircraft sanitation market for over two decades. Further, we are a dominant factor in surface transportation as well as selected other sectors in the field of sanitation.

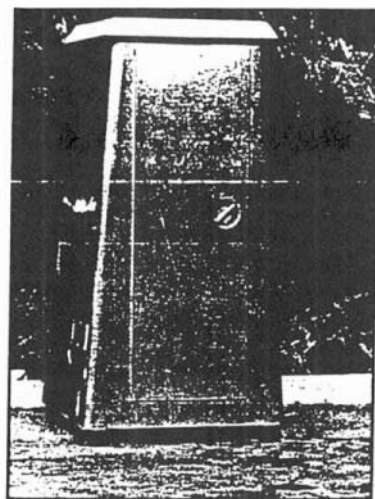
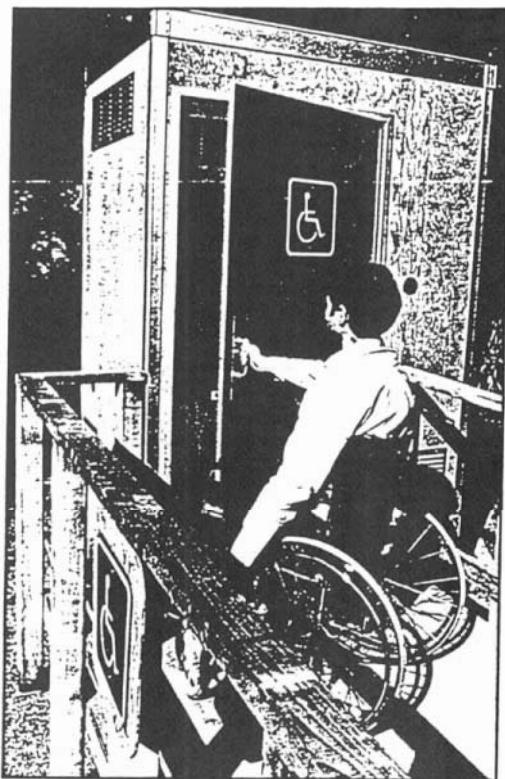


MODEL 625. Chemical Recirculating Flushing Toilet housed in a vandal resistant cabana featuring 3/4" thick replaceable wall panels, skylight roof, chemical metering pump, polished stainless steel bowl and self closing bowl flapper valve. May be anchored as permanent or moved as a portable.



MODEL 626, Top Service Bench and Top Service Drain Valve, Available for all the large capacity Jet-O-Matic® Sanitation Systems. Hinged bench top to provide access to the unit's tank interior. Simplifies service, parts replacement and everyday cleanout procedures. For installation in new or existing buildings.

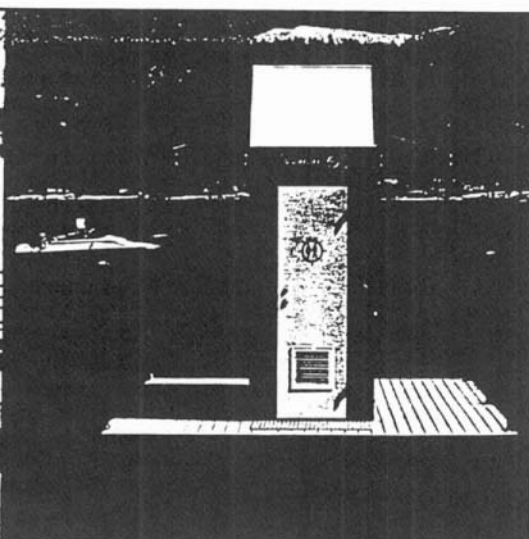




MODEL 631, Chemical Recirculating, flushing toilet housed in an all fiberglass cabana. 1000 use capacity, skid mounted for portability.

MODEL 703, High Capacity Dual Purpose Portable Restroom. Chemical recirculating flushing toilet with larger cabana combine general public use along with wheelchair accessibility. Hand operated flush, Spray rinse, backrest and grab bars are all standard.

MODEL 601 (15000-001). Medium Capacity. Chemical Recirculating Flushing Toilet. Flushes by foot pedal. Widely used in toll stations, watch towers, draw bridges, rural offices, maintenance stations, guard houses, ski lift monitor stations, buses, ferry boats, excursion boats and tug boats, to name a few.



HOW IT WORKS

1. Self-contained - The Jet-O-Matic® system has all elements necessary for use, operation, fluid recycling and waste storage. Chemical reservoir and pump system automatically meters exact amount of chemical with each flush. Holding tank retains waste until pump-out or transfer to underground storage vault.
2. Recirculating - When flush pump is activated, fluid from holding tank is combined with a measured amount of chemical from reservoir. Fluid is then recirculated through bowl to holding tank.
3. Odor control - Treated waste accumulates in holding tank. Chemicals released into holding tank control odor.
4. Waste disposal - Large capacity Jet-O-Matics have two discharge ports - one for direct Pump-out by service trucks: an optional method is to release the material directly into an underground vault. After waste removal, the Jet-O-Matic holding tank is hosed down, then recharged with water. Chemical reservoir is also refilled at this time.
5. Simplicity and durability - Jet-O-Matics are highly reliable and trouble free: built to take extensive user wear, all climate fluctuations and temperature extremes.



CHEMICALS

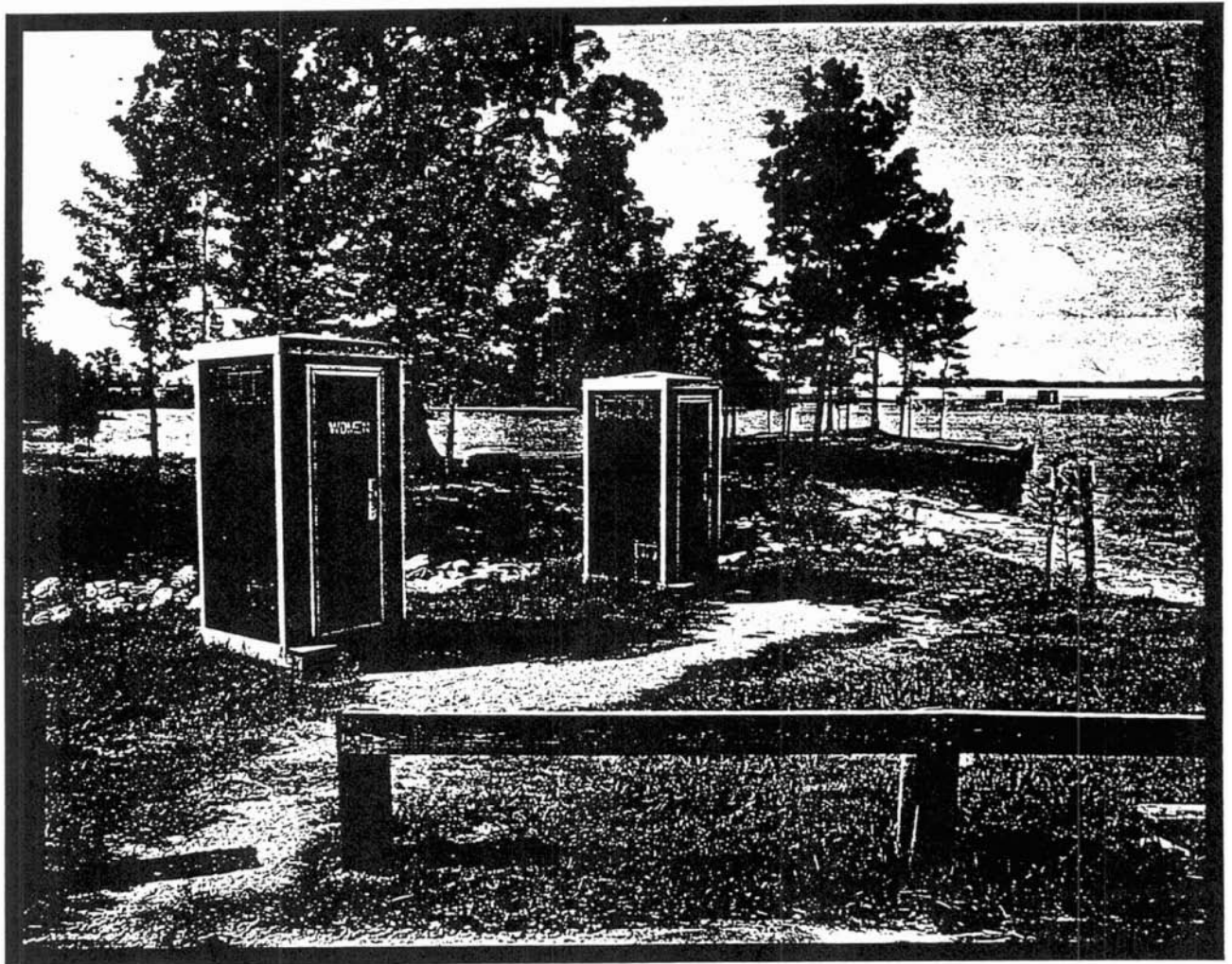
JET-O-MATIC® odor control chemicals for recirculating and Static toilets, waste storage vaults and pit toilets:

MC-1000® - liquid chemical in easy to handle. 5 gallon high impact. D.O.T. approved containers or more economical 55 gallon drums

MC-2000® - non-formaldehyde base liquid chemical in 5 gallon container or 55 gallon drum

MC-500™ - powdered chemical packaged in 32 oz. high impact plastic bottles marked off in 2 oz. increments

Additives of various kinds are also available.



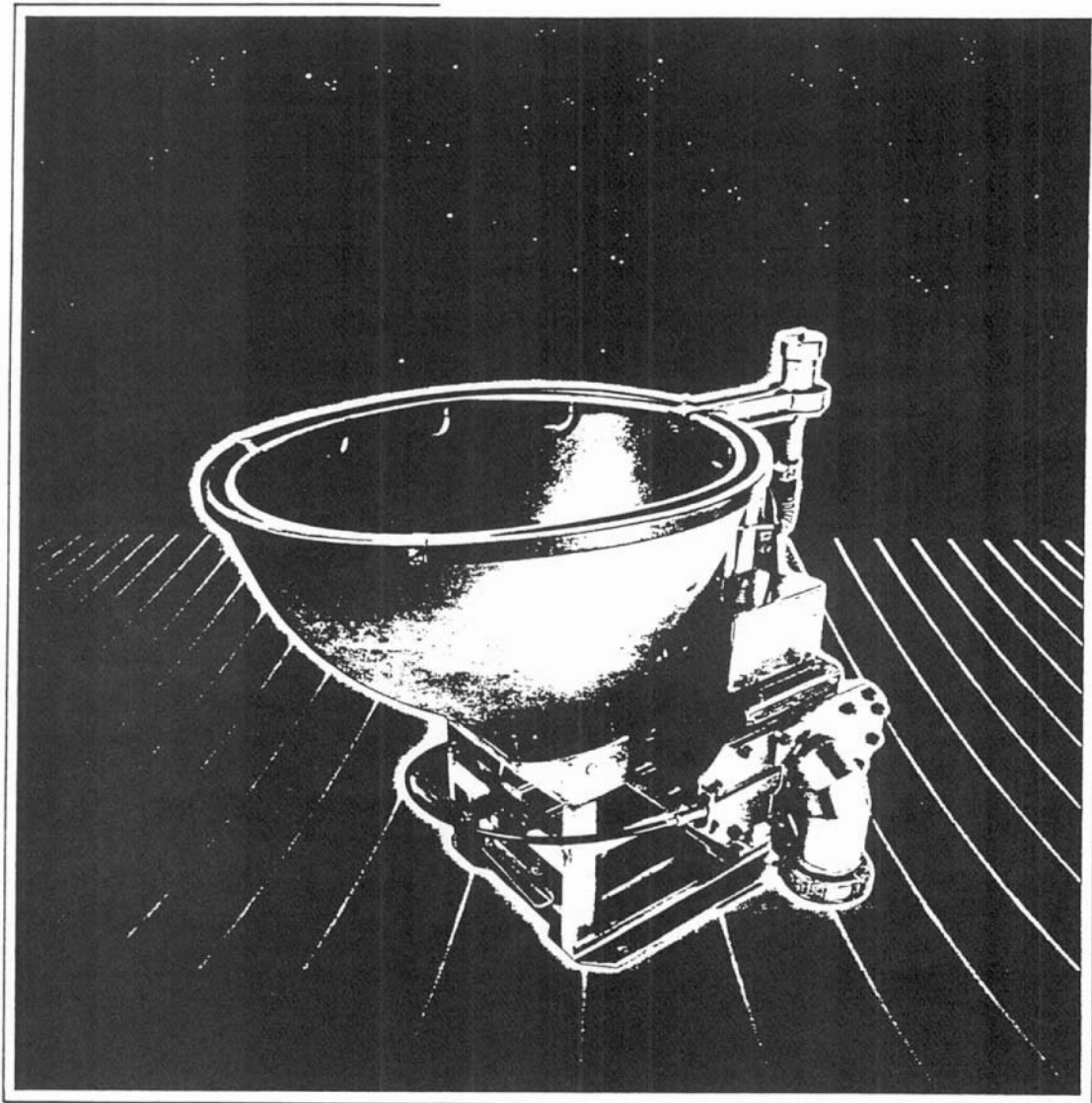
Monogram Sanitation

800 W. Artesia Blvd., P.O. Box 9057, Compton, CA 90224-9057 1180
(213) 638-8445 FAX: 638-8458

FAX: (213) 643-7478

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(213) 638-8445 FAX: 638-8458



ADVANCING THE STATE OF THE ART

**...Aircraft Vacuum Toilets and Waste Systems
for the 1990's and Beyond.**

B-40

RELIABILITY: OUR NUMBER ONE OBJECTIVE

Monogram Sanitation — the industry leader in aircraft lavatory systems for over twenty-five years. Monogram is standard equipment for the majority of production aircraft from a Beech King Air to a Boeing 747. Our established worldwide Product Support Group has been an essential element to our success.

Only Monogram can combine its extensive aircraft sanitation experience with the vacuum toilet technology we developed for use on over 600 highly sophisticated rail cars. Working closely with current operators of aircraft vacuum toilet systems, Monogram focused attention on those areas requiring improvements to develop a second generation vacuum toilet system. The result: the most reliable, advanced aircraft vacuum lavatory system available.

Monogram is particularly pleased to have been selected to supply the complete Vacuum Toilet Waste System for the Airbus A-320 as well as the Vacuum Toilet Assembly for the Boeing 767 and 747-400 aircraft.

VACUUM TOILET LEADING CHARACTERISTICS

Flush Valve

- A unique electromechanical flush valve.' Straight through flow minimizes noise and prevents clogging.
 - Toilet flush valve operation completely independent of vacuum supply. Opening of valve to full diameter of waste line is insured.
 - Flush valve mechanism completely sealed from the waste line preventing corrosion and contamination.
 - Controllable opening of flush valve produces gradual increases in sound level without explosive peaks.
- 'Pat. Pend.

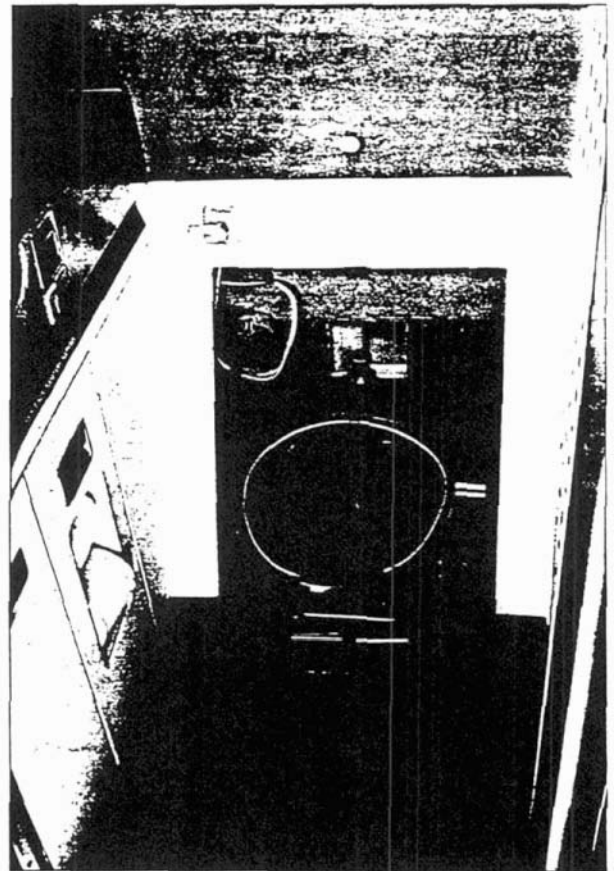
Rinse Valve/Vacuum Breaker

- Simplified, reliable floating poppet type vacuum breaker meets US-PHS requirements.
- Selfdraining, floating plunger rinse valve.
- Only one moving part, no adjustments, no springs.

Reliability and Maintenance

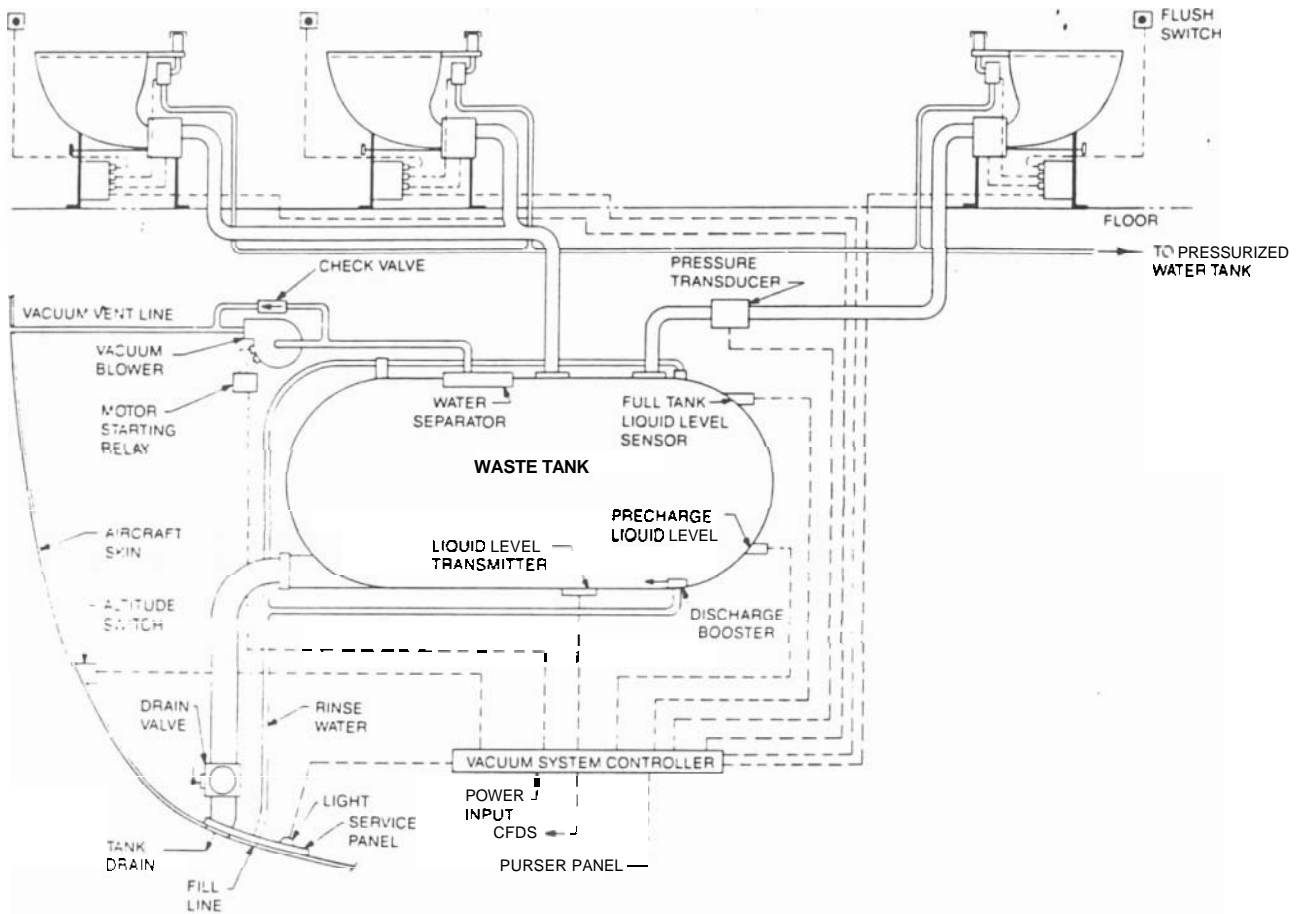
- The only electric control module with "BITE" (Built In Test Electronics).
- All stainless steel structure and components.
- **Modular** design approach improves reliability and reduces service time.
- Manual shut off valve operates independently of motorized flush valve.
- Toilet assembly easily converts from right to **left** hand configuration minimizing inventory level.
- Lightweight design.

A TYPICAL 767 INSTALLATION

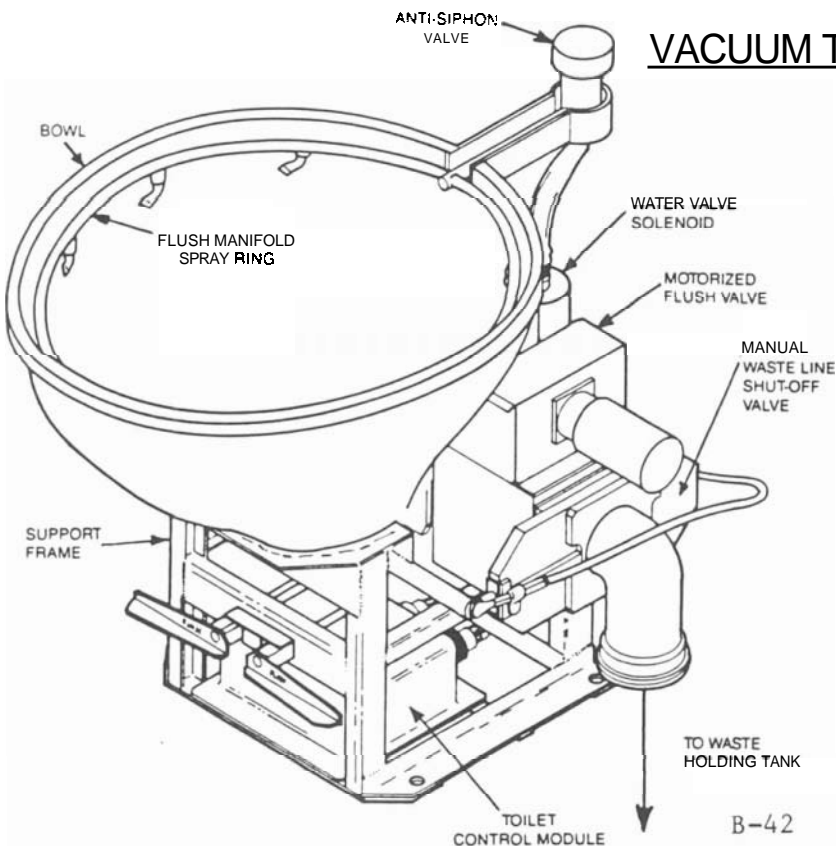


At Monogram our quest for performance goes beyond talk and statistics. Monogram has engaged in a successful flight test program to prove our concepts and designs. The experience has been nearly flawless. Flight test units were placed in daily service **onboard** regularly scheduled aircraft to demonstrate the reliability and quality of the design. In a **twelve** month period **these** units have accumulated over 2500 flight **hours**.

VACUUM WASTE SYSTEM SCHEMATIC



VACUUM TOILET ASSEMBLY



OPERATION

The system utilizes differential pressure (vacuum) to transport waste material from the toilet bowl to a central holding tank. A key element of the system is a unique electromechanical valve which positively controls evacuation of the bowl without reliance on the vacuum supply for its own activation. Fresh water (8 oz. or less) obtained from the aircraft pressurized potable water system is utilized to rinse the toilet bowl and aid in the evacuation of waste during the flush cycle.

The flush control microcomputer is a modular electronic assembly designed to control the operation of the toilet assembly by timing and sequencing various components during the flush cycle.



Quality on Board!

MONOGRAM is standard equipment on:

Boeing 737-300
 747-2001-300
 757
 767

Airbus A300
 A310
 A320

McDonnell Douglas MD-80

Fokker F-100
 F-50

ATR 42
BAE 125-800
CN 235
Dash 8
EMB 120
Falcon 900
Gulfstream IV
SF 340

MONOGRAM SANITATION A Nortek Company

800 W. Artesia Blvd.. P.O. Box 9057, Compton, CA 90224-9057
(213) 638-8445 FAX: 638-8458

Telephone: (213) 643-5957
Telex: 69-1243
Fax: (213) 643-7478

B - 43

NEWMATIC® RETENTION TYPE FLUSHING TOILETS

Monogram, the world's leading manufacturer of self-contained sanitation systems, is pleased to offer you two choices in the Newmatic® family of retention type flushing toilets.

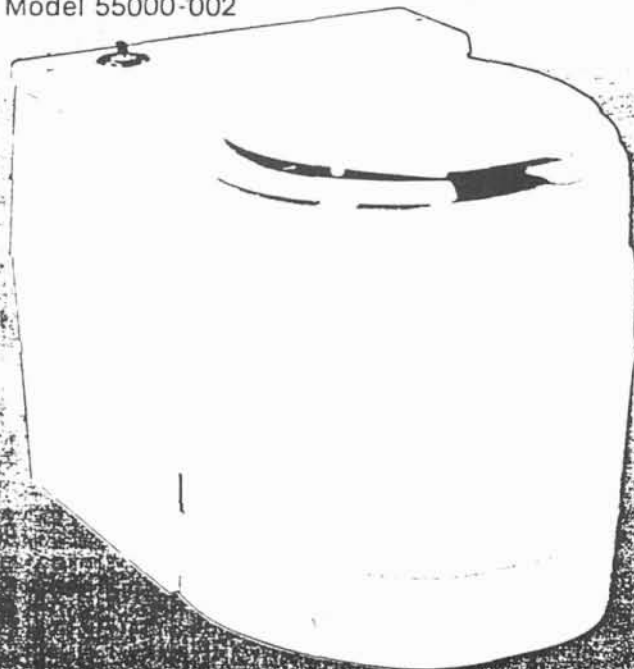
Both models utilize the most advanced technology and materials in a combination of stainless steel and injection molded ABS plastic for an attractive and scratch resistant finish. They feature a patented clog-free filter pump, a stainless steel toilet bowl and injection molded ABS plastic toilet seat and lid.

These models require an initial charge of 3 gallons of water and one packet of Monogram's specially formulated toilet chemical. Discharge is through the bottom drain valve to either service equipment or directly to existing sewer inlets. Leak-proof and freeze-proof, they meet environmental standards world wide.

FOR USE ON:



Model 55000-002

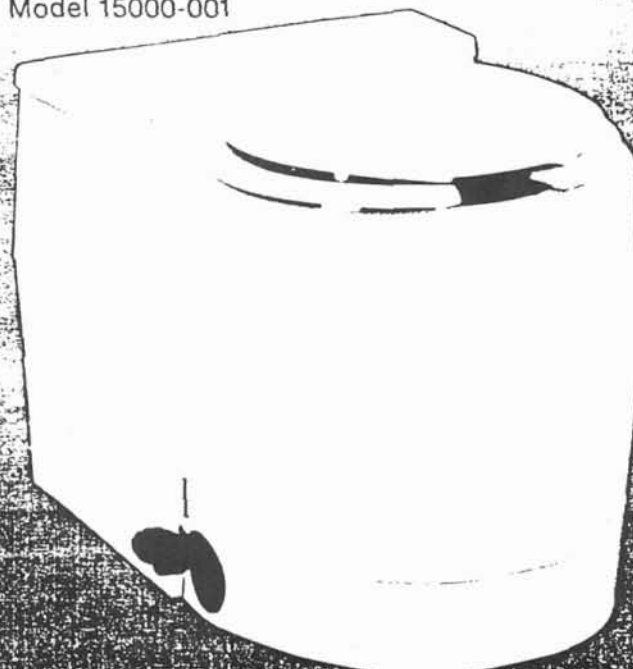


- Automatically timed flush cycle
- Foot pedal activated
- Foot pedal designed to produce a strong swirling flush
- Quiet
- Completely self-contained
- Made and packed by the world leader in commercial sanitation equipment

FOR USE ON:



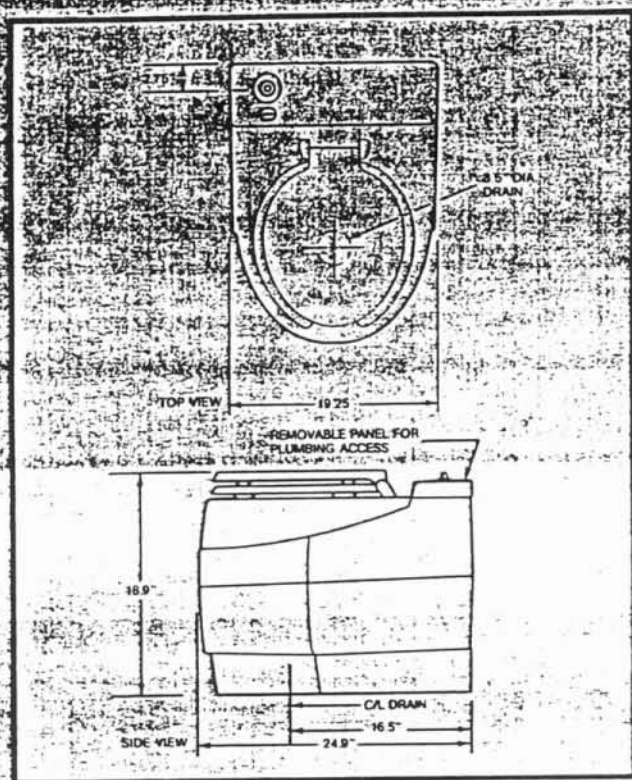
Model 15000-001



- Requires no power source
- Operates anywhere
- Foot pedal activated
- Completely self-contained
- Built and packed by the world leader in commercial sanitation equipment

Monogram Industries, Inc.

NEWMATIC® I RETENTION TYPE FLUSHING TOILETS



SPECIFICATIONS:

NEWMATIC® MODEL 55000-002

Weight (empty) 40 lbs. 18 kg
 Dimensions 19.25" wide 490 mm
 18.9" high 480 mm
 24.9" deep 632 mm

Tank Capacity 14 gallons 761
 Holding Tank High Impact Plastic
 Tank Cover High Impact Plastic
 Toilet Bowl Stainless Steel
 Toilet Seat Plastic
 Filter Pump Assembly High Impact Plastic, Neoprene rubber, Nonyl plastic and stainless steel
 Flush Actuator Assembly Cast iron foot lever
 Disposal Outlets Bottom, spring loaded drain valve (fits 3" toilet floor flanges)

SPECIFICATIONS:

NEWMATIC® MODEL 15000-001

Weight (empty) 45 lbs. 20.5 kg
 Dimensions 19.25" wide 490 mm
 18.9" high 480 mm
 24.9" deep 632 mm

Tank Capacity 14 gallons 761
 Holding Tank and Tank Cover High Impact Plastic
 Toilet Bowl Stainless Steel
 Toilet Seat Plastic
 Filter Pump Assembly High Impact Plastic, Neoprene rubber, Nonyl plastic and stainless steel
 Flush Actuator Assembly Cast iron foot lever
 Disposal Outlets Bottom, spring loaded drain valve (fits 3" toilet floor flanges)

B-45

MONOGRAM SANITATION

P.O. Box 9057
 800 West Artesia Blvd.
 COMPTON, CA 90224-9057
 213-638-8445 (FAX) 213-638-8458



Railtech

ON BOARD SEWAGE HANDLING SYSTEM

WTS 8300

GENERAL DESCRIPTION'



325 LEE AVENUE
BAIE D'URFÉ, QC
CANADA H9X 353

(514) 457-4760
FAX: (514) 457-7111

WASTE DISPOSAL SYSTEM

1. INTRODUCTION

- 1.1 This document describes in brief the operation as well as some of the outstanding features designed into the system, making it imminently suitable for application and use by railcar manufacturers and operators.

2. FUNCTION

- 2.1 The function of the "On Board Sewage Handling System" is to provide Water Flushed **Commodes**. The individual effluents are **macerated**, treated, and transferred to a **remotely** located storage tank. Figure 1 represent a typical system. Disposition of the effluent from the retention tank can be in either of the following modes:

2.1.1 Rapid flow through and onto the roadbed at pre-determined train speeds.

2.1.2 Retention through areas designed as "No Dumping" regardless of the train speeds.

3. SPECIFICATIONS

3.1	Voltage (Input)	72 V.D.C.
3.2	Power/Flush	100 Watts
3.3	Water Pressure	20 P.S.I.G. \pm 1/2 P.S.I.G. Dynamic (While flushing)
3.4	Water Volume/Flush	1 Qt
3.5	Air Pressure	40 - 45 Dynamic P.S.I.G.
3.6	Maceration Air Pressure	120 P.S.I. (Dynamic)
3.7	Air Quantity/Flush	11.5 SCFM Max.
3.8	Cycle Time - Flush	10 Sec. Max.
3.9	Cycle Time - macerate treat, transfer	83 Seconds \pm 2 Seconds
3.10	Macerated Size	To Digested Particles
3.11	Power - Heating	540 Watts Ref.
3.12	Waste Retention Tank	99 Flushes
3.13	Liquid Anti-bacterial	2 ³ in. (approx)
3.14	Voltage for heater assembly	115 V.A.C.

4. SYSTEM COMPONENTS

4.1 Logic Circuit

The logic circuit consists of solid state electronic components mounted on a glass epoxy circuit board. Selection of these components was made with consideration given to reliability, costs, and useful life encountered in rail type vehicles.

The operating characteristics of this logic circuit are represented in Figure 2.

4.2 Commode (See Figure 3)

4.2.1 Bowl Assembly. The waste receiving bowl is of polished stainless steel construction, complete with flush rim and bottom flapper valve. This assembly may be mounted within a metal frame or shield as required by the specific installation.

4.2.2 Processing Tank. The processing tank is made of polyurethane especially molded for this application. The tank has as an integral part of its construction a macerating chamber. The macerating chamber is comprised of a series of rings. Within the rings are teeth and serrations which project inward. These aid in reducing the effluent to the smallest digested particles during the macerating cycle.

4.2.3 Closure Assembly. Below the macerating chamber is a closure assembly to prevent the outflow of effluent during macerating and treatment.

The closure assembly contains a molded elastic sleeve mounted in a housing. During operation air under pressure is directed to the annular cavity between the sleeve and the housing. The sleeve then collapses inwardly toward the center. Due to its unique design this results in a drip-tight seal. There are no links, levers, pivots or seats to either wear or become misaligned. The elastic sleeve will seal drip tight even if foreign debris becomes entrapped within it.

When the pressure is removed, the sleeve returns to the open position. The opening is large enough to release the treated effluent, and any objects that may inadvertently be thrown into the toilet bowl.

4.2.4 Retention Tank. The affluent passed through the closure assembly can be accumulated in a lower retention tank with minimum capacity for 99 flushes. The tank is additionally fitted with an in-line pinch valve closure to allow the emptying of the retention tank at selected intervals or locations.

5. OPERATION

5.1 The operation of the system can best be described by referring to

the following illustrations and their captions:

Figure 3: Use

Figure 4: Flush

Figure 5: Macerate and Treat

Figure 6: Discharge

Figure 7: Retention

6. THEORY OF OPERATION

6.1 The System Ready for Usage (See Figure 1)

As can be seen in Figure 1, the flapper assembly is closed and a small quantity of water is retained in the bowl. The control switches are in the following position:

Speed sensor override, inhibit dump, and manual cycle are in normal position..

6.2 Waste System in Usage (See Figure 3)

As can be seen in Figure 3, the waste matter is retained in the bowl.

6.3 Flush Cycle (See Figure 4)

Figure 4 illustrates the system undergoing its flush cycle. The following operations take place sequentially after the flush snitch has been depressed:

(a) Upper pinch valve closes.

(b) After the upper pinch valve is closed, the flapper assembly opens, the solution dispenser injects chemical. the water valve opens allowing water to flush effluent and clean bowl.

6.4 Treatment Cycle (See Figure 5)

Figure 5 illustrates a system during this cycle. Note that flapper assembly and solution dispenser have returned to the closed position. Air under pressure is injected into the chamber. This results in a violent blending of air, water, solution and effluent. This action continues for approximately 70 seconds.

6.5 Discharge Cycle (See Figure 6)

This figure illustrates the system after the maceration cycle. The upper pinch valve opens to expel the contents through the lower pinch valve to the outside. The expelled matter has been reduced in size to the smallest digested particles, and the coliform bacteria count has been reduced to zero.

6.6 Inhibit Dump Mode (See Figure 7)

The lower pinch valve is now closed and the **effluent** collects in the holding tank. The closing of the lower pinch valve either takes place automatically by means of the speed sensor control, or may be induced by manually actuating the Inhibit Dump Switch.

6.7 Interrupted Cycle.

It has been anticipated that a user will on occasion flush the toilet during a period in which a treatment cycle is in progress. This will cause no ill effects. The system has the capacity of accepting up to **two** flushes. Should this capacity be reached, a memory circuit in the electronic controls will automatically initiate a full cycle flush after the unit **completes** treating the second flush already in the processing tank.

7. Other characteristics that become apparent after a study of this proposal suggest the following:

7.1 Virtually no moving mechanical parts

7.2 Clog proof

7.3 Minimum maintenance

7.4 Light weight

7.5 Small and compact

7.6 Lower power consumption

7.7 Low initial cost

7.8 Low installation cost

7.9 Low operating cost

7.10 Reliable performance

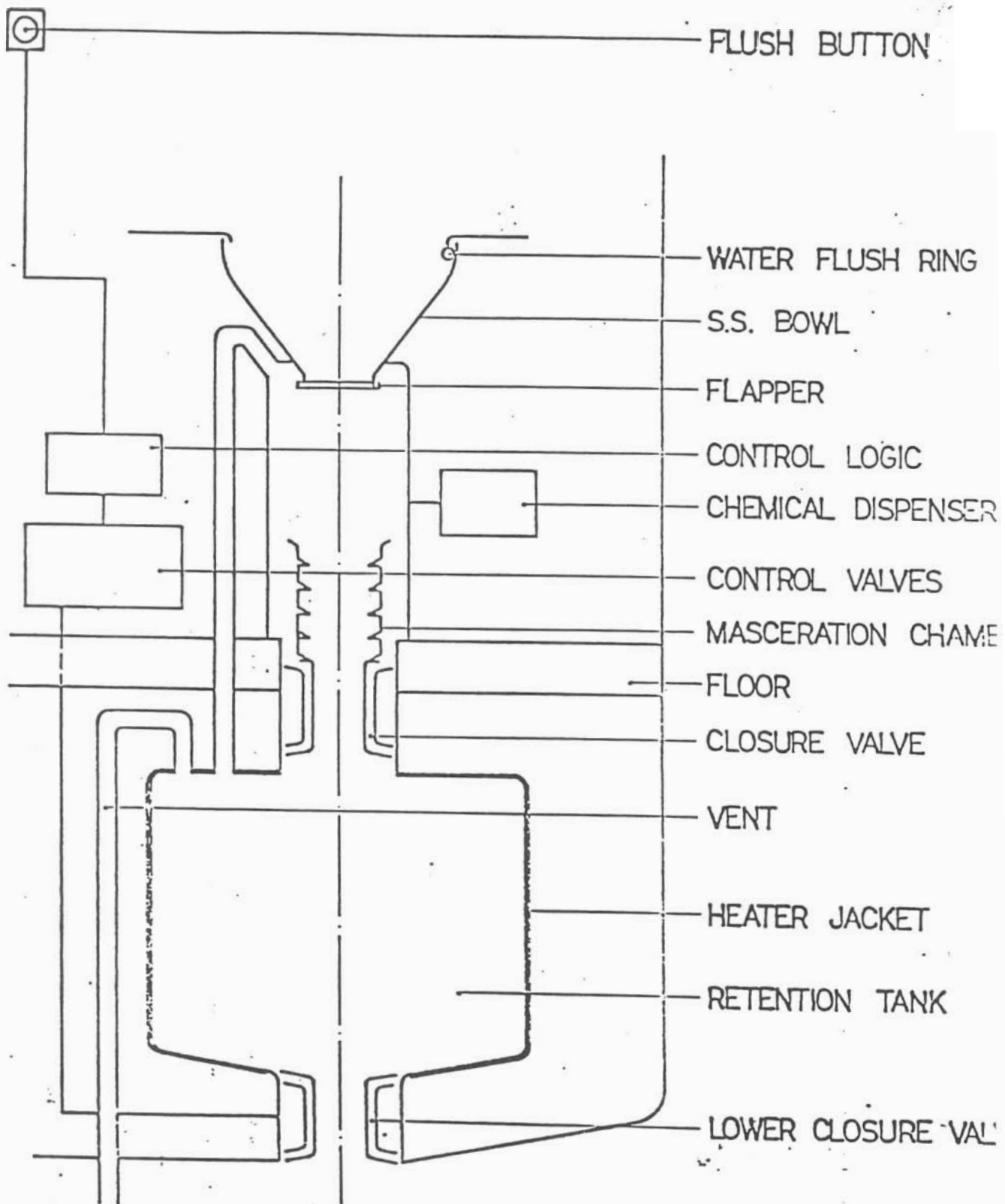


FIGURE 1

TREATMENT TANK TIMING CHART

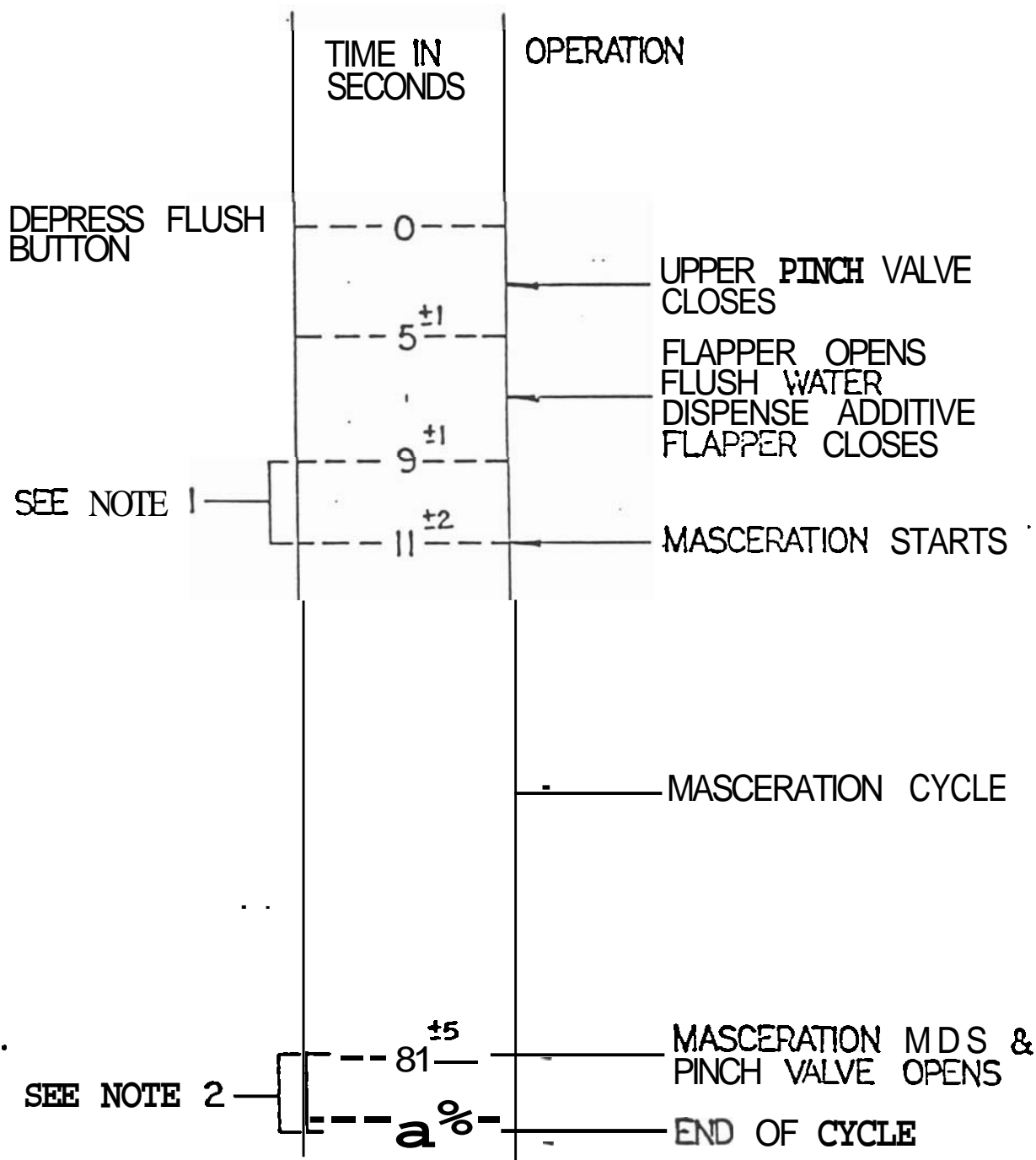


FIGURE 2
(TIMING CHART)

NOTES:

1. Maceration will not start until flapper has closed.
2. Delay to empty maceration chamber.

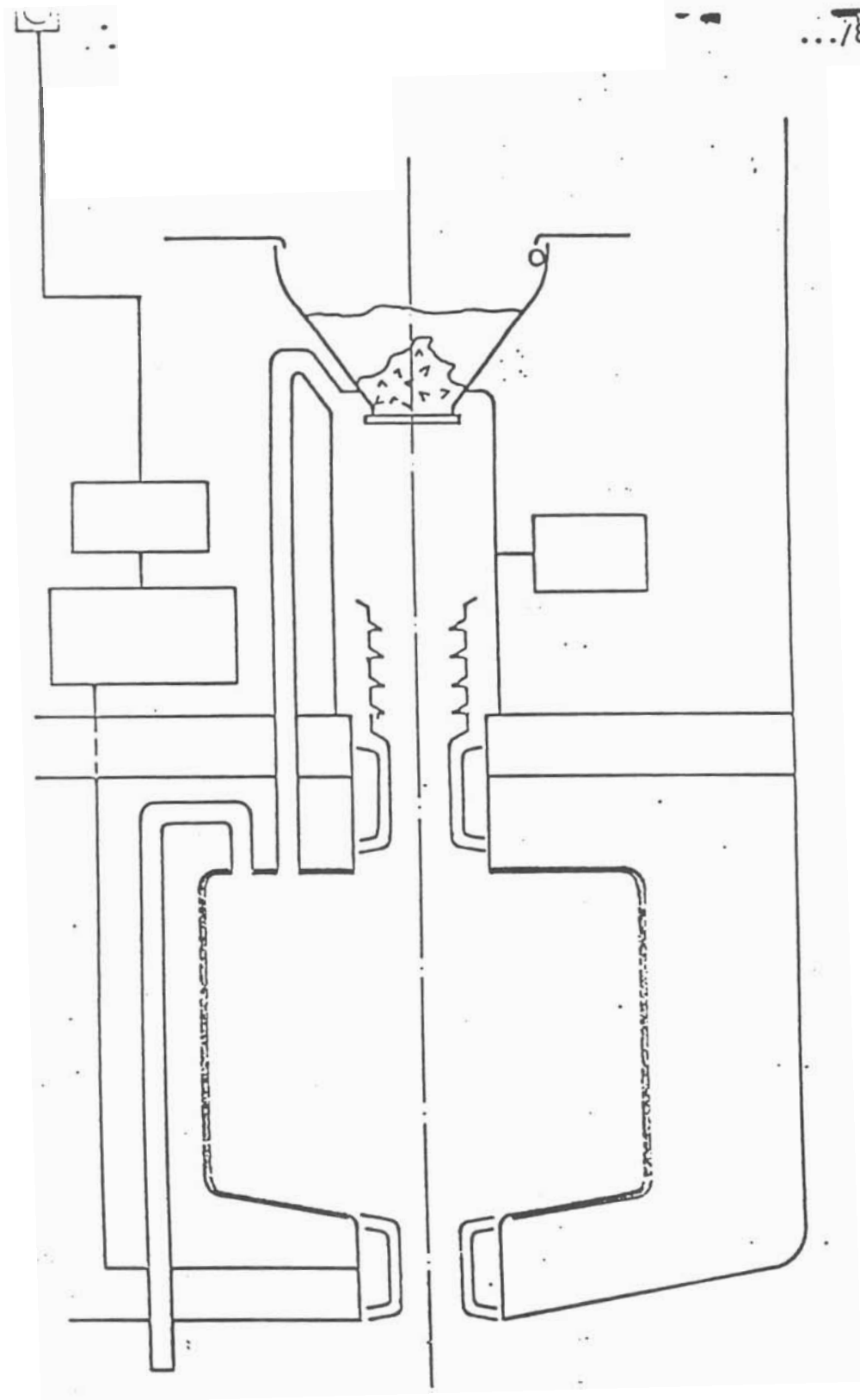


FIGURE 3 . . .

The illustration above represents the system after being used, just prior to depressing the flush button. Note that the effluent is contained in the upper bowl, very similar to that of a conventional toilet.

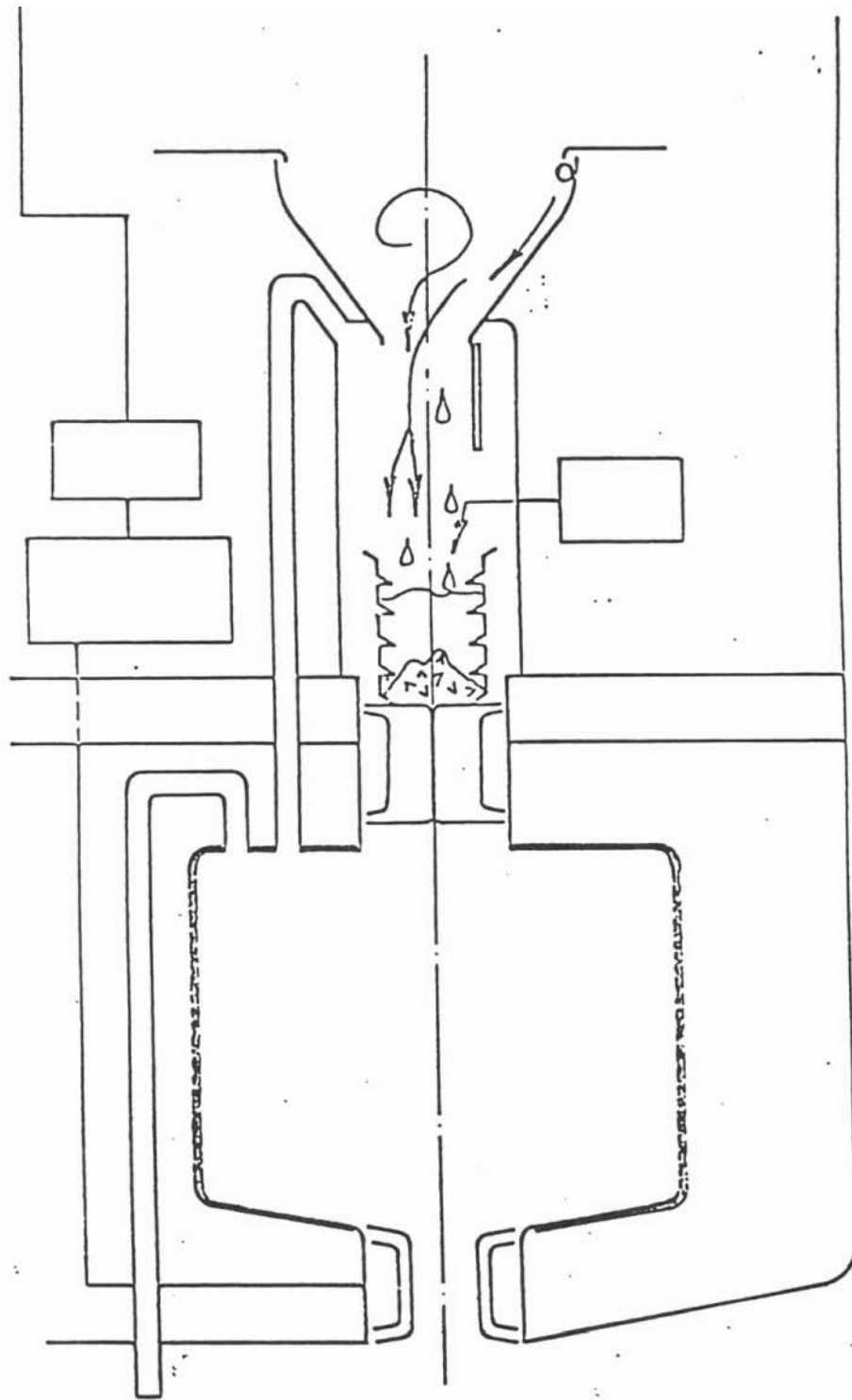


FIGURE 4

Figure 4 illustrates the system undergoing its flush cycle. The following events take place sequentially after the Flush Button has been depressed:

1. Pinch Valve closes
2. Flap Valve opens
3. Chemical is dispensed
4. Water Valve opens allowing flush water to clean bowl and flush waste

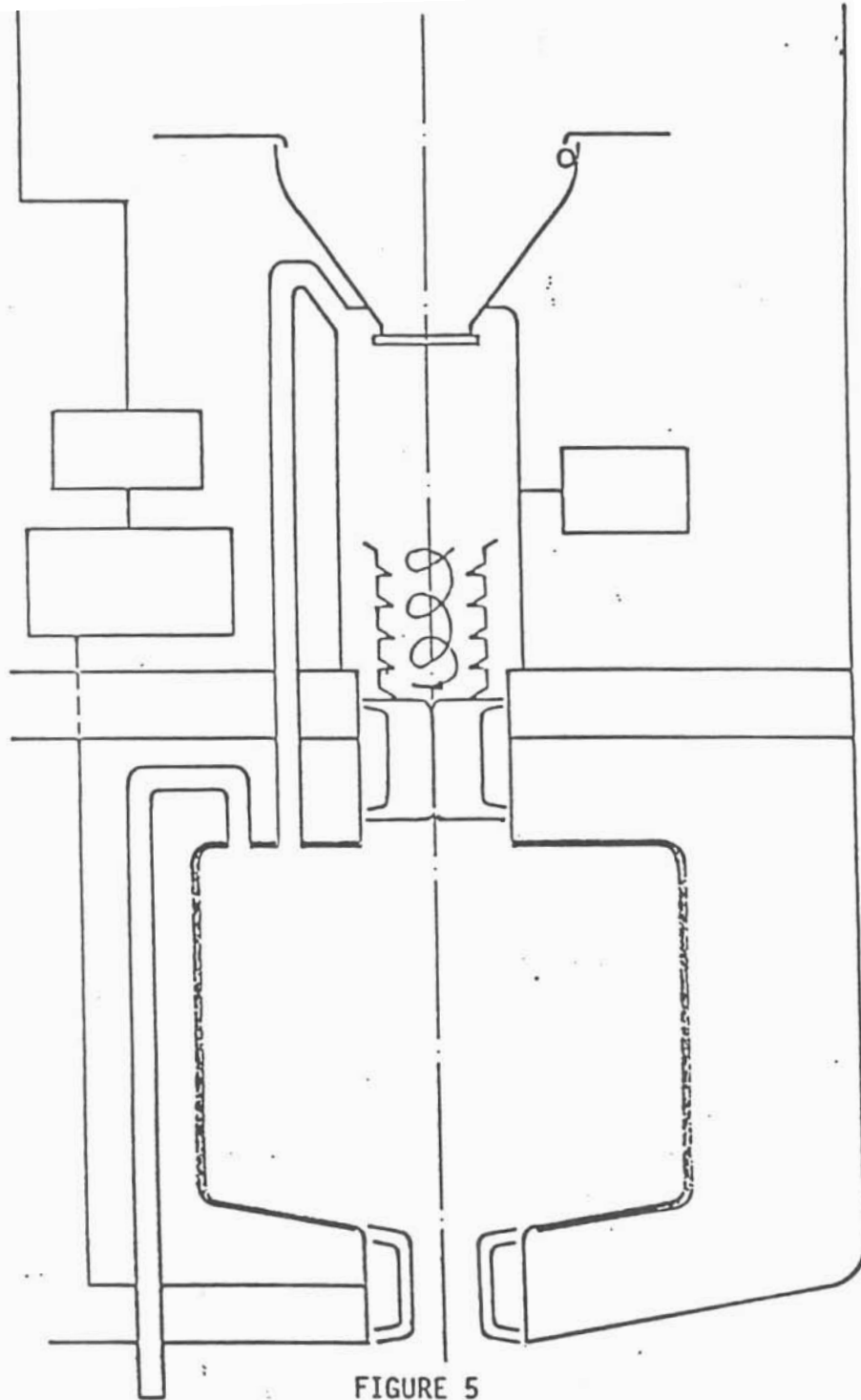
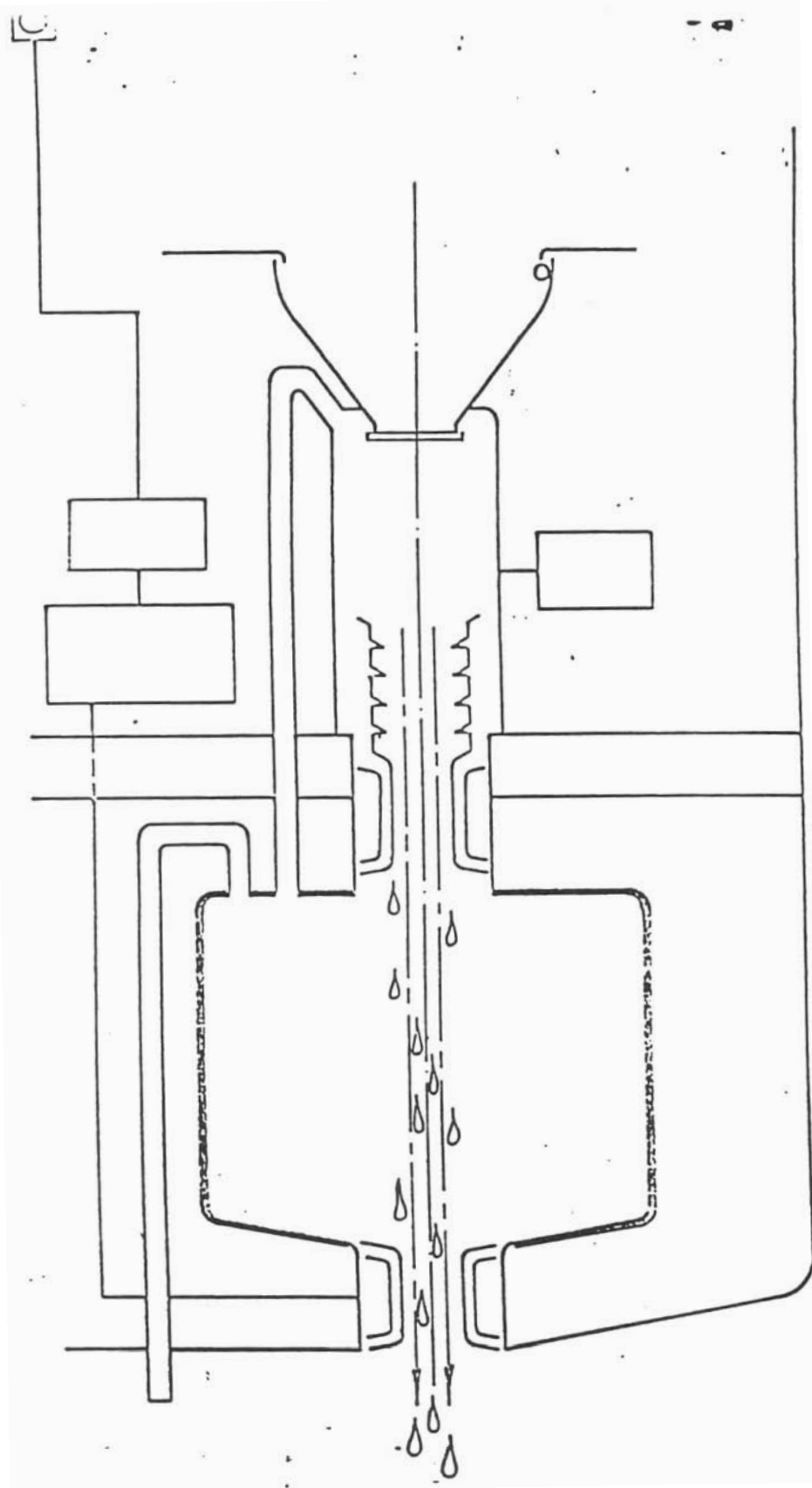


FIGURE 5

Figure 5 illustrates the system during the maceration and treatment cycle. Note that the Flap Valve is closed. Air under pressure is injected into the chamber. This results in a violent blending of air, water, chemical and waste. This action continues for approximately seventy (70) seconds.



8-57

FIGURE 6

Figure 6 illustrates the system at the end of the maceration and treatment cycle. The Pinch Valve opens and expels the treated effluent onto the roadbed. The resulting matter is a liquid/liquid slurry with the solids reduced and separated to digested particle size. The toilet tissue is pulverized

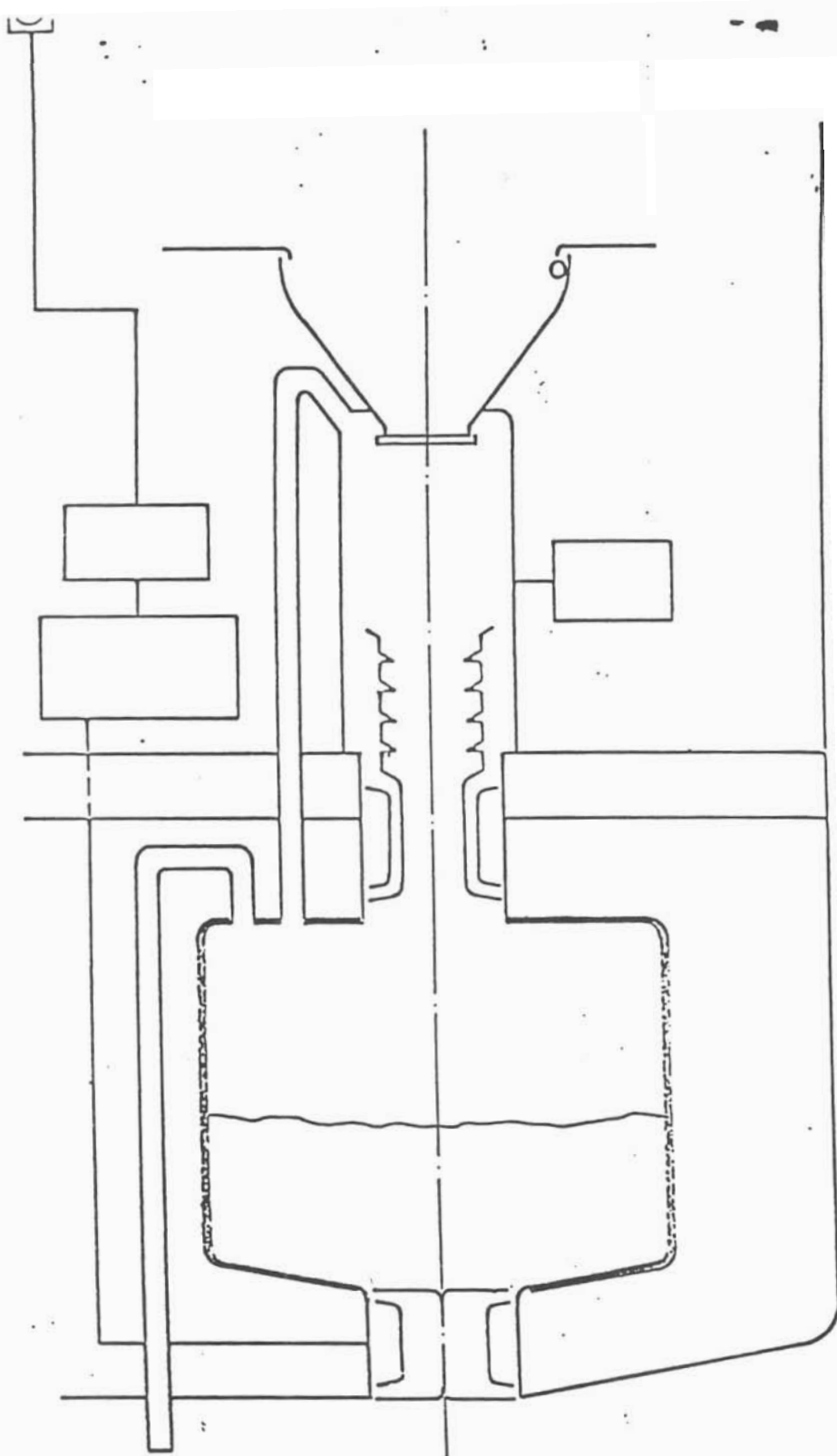


FIGURE 7

Figure 7 illustrates the system accumulating the treated effluent in the retention tank when the car is in the station or under a "No Dump" restriction. The effluent will be discharged automatically when the restriction is removed.



RAILTECH

ON BOARD SEWAGE TREATMENT SYSTEM

**FOR EFFICIENT
WATER FLUSHED COMMODES**

- ☐ **VIRTUALLY NO MOVING
MECHANICAL PARTS**
- ☐ **CLOG-PROOF**
- ☐ **MINIMUM MAINTENANCE**
- ☐ **LIGHT WEIGHT**
- ☐ **SMALL AND COMPACT**
- ☐ **LOW POWER CONSUMPTION**
- ☐ **LOW INITIAL COST**
- ☐ **LOW INSTALLATION COST**
- ☐ **LOW OPERATING COST**
- ☐ **RELIABLE PERFORMANCE**

**RAPID FLOW THROUGH AND ONTO ROADBED
AT PREDETERMINED TRAIN SPEEDS
RETENTION THROUGH AREAS DESIGNED AS
NO-DUMPING, REGARDLESS OF TRAIN SPEED**

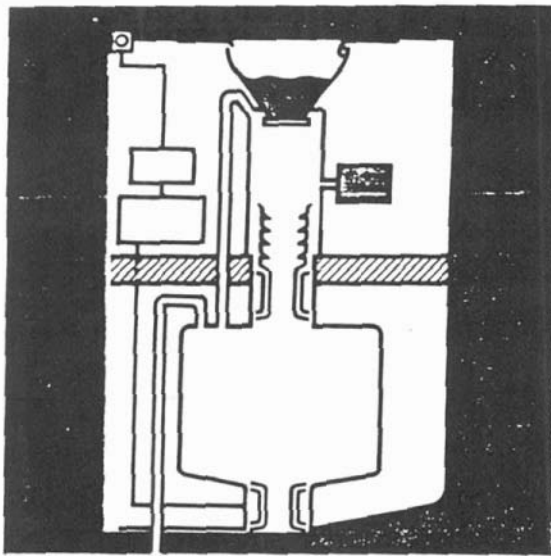
Patented

OPERATION OF I

When toilet is flushed, the effluent goes into a small maceration chamber directly under the bowl where it is macerated, treated so all bacteria is killed and then dumped to trackside.

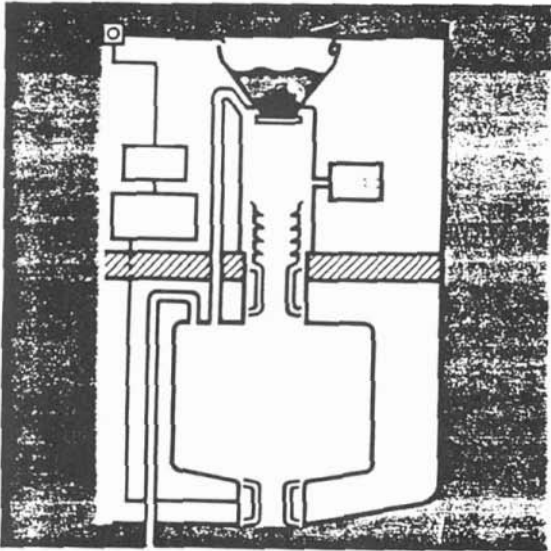
If train stops or travels at less than 35 k/hr, the effluent goes into small holding tank until train reaches 35 k/hr, then effluent is dumped to trackside.

Completely protected for **cold** weather operation



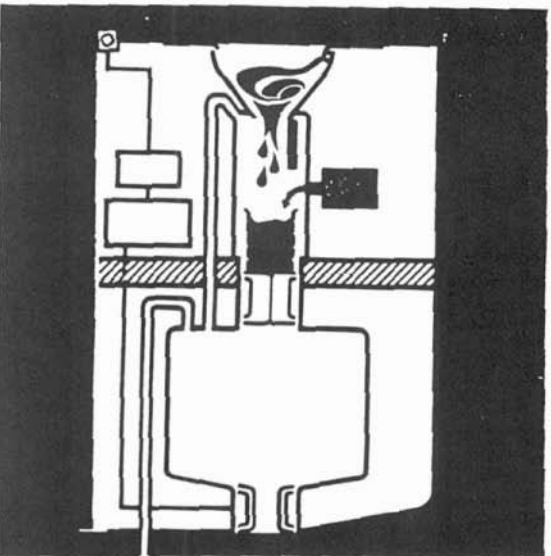
SYSTEM READY FOR USE

Flapper assembly closed and small quantity of water in bowl.



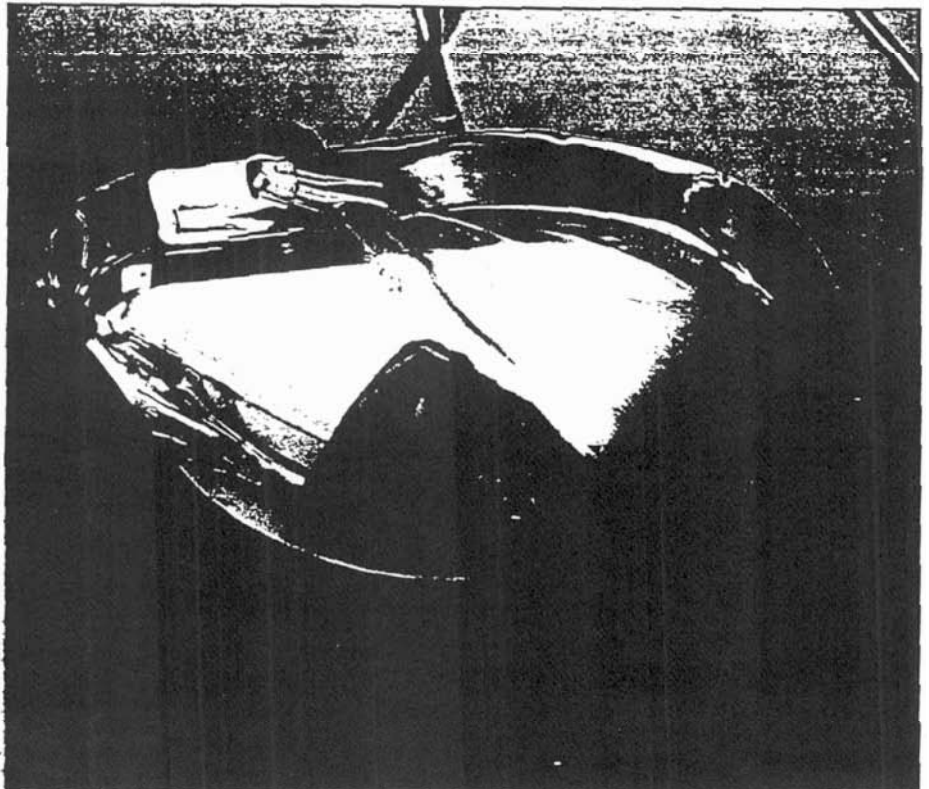
SYSTEM IN USE

The system has just been used, prior to depressing the flush button. Effluent is contained in upper bowl, similar to conventional toilet.



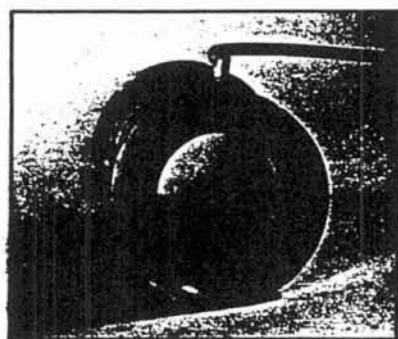
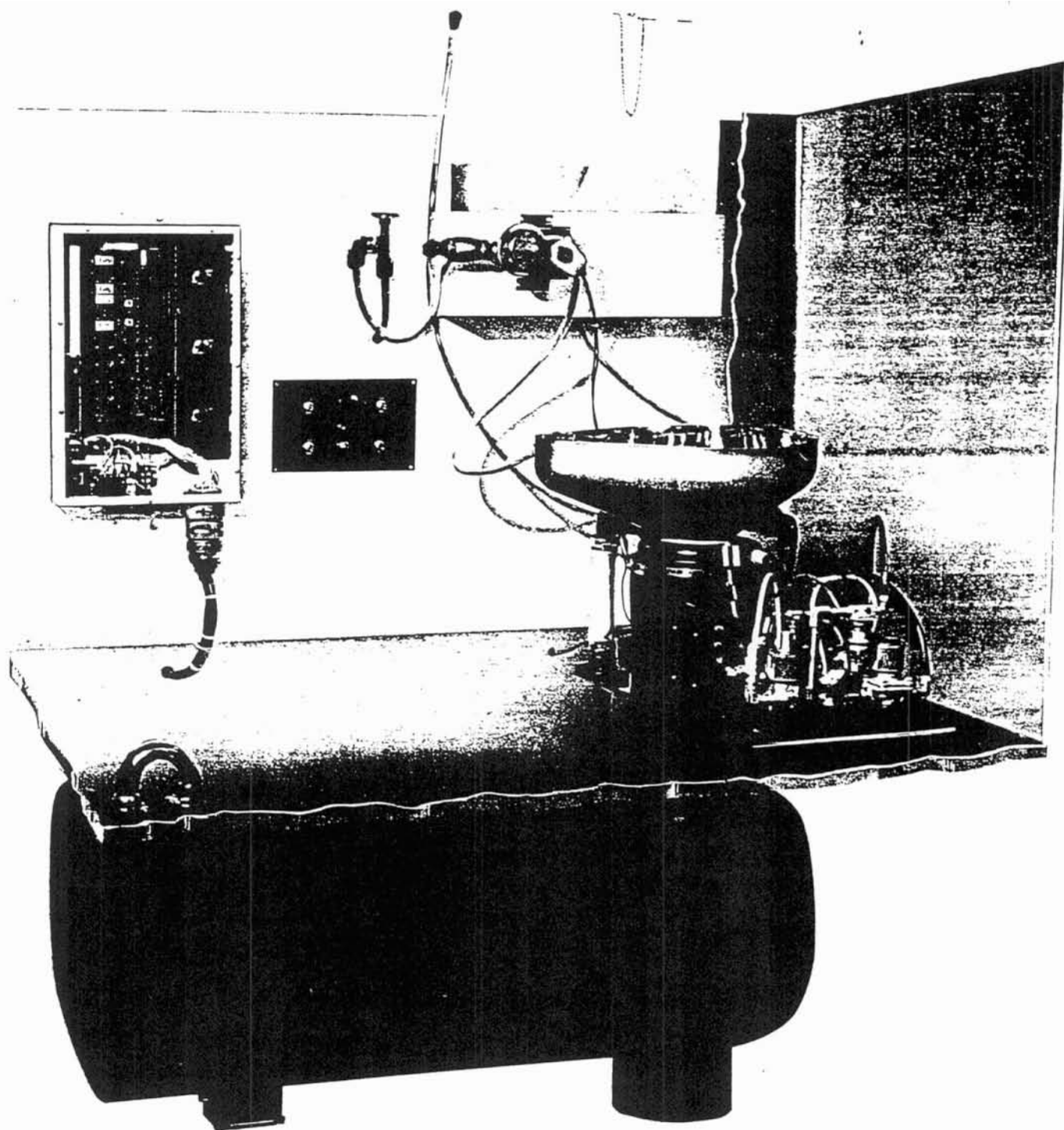
SYSTEM IN FLUSH CYCLE

Pinch valve closes. Flap valve opens. Chemicals dispensed. Water valve opens allowing flush water to clean bowl and flush waste.

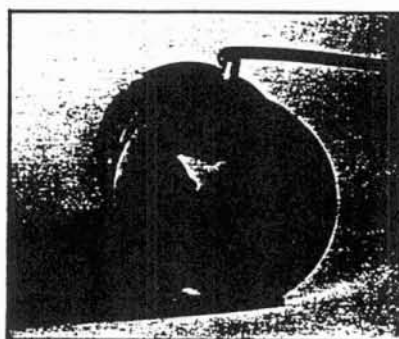


STAINLESS STEEL BOWL DURING FLUSHING OPERATION

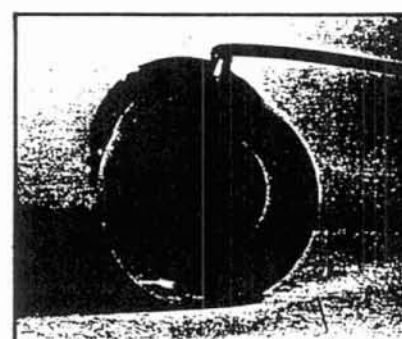
AILTECH ON BOARD SEWAGE TREATMENT



PINCH VALVE IN OPEN POSITION



PINCH VALVE CLOSING

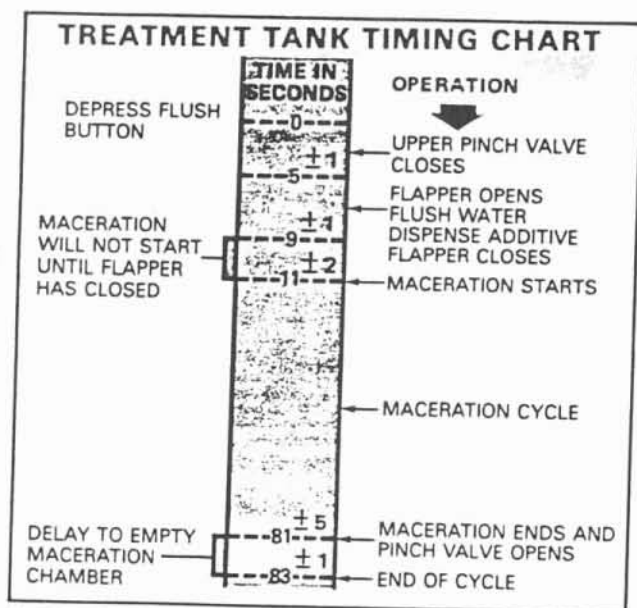


PINCH VALVE FULLY CLOSED

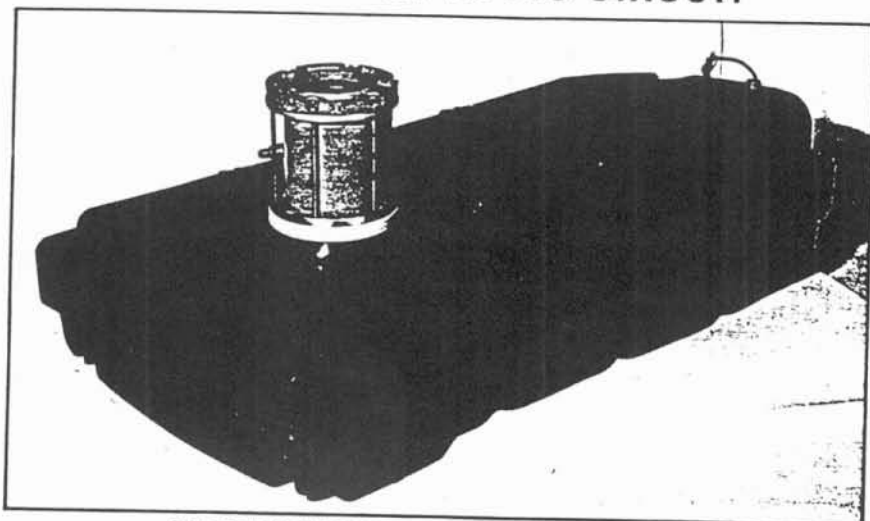
TREATMENT SYSTEM

LOGIC CIRCUIT

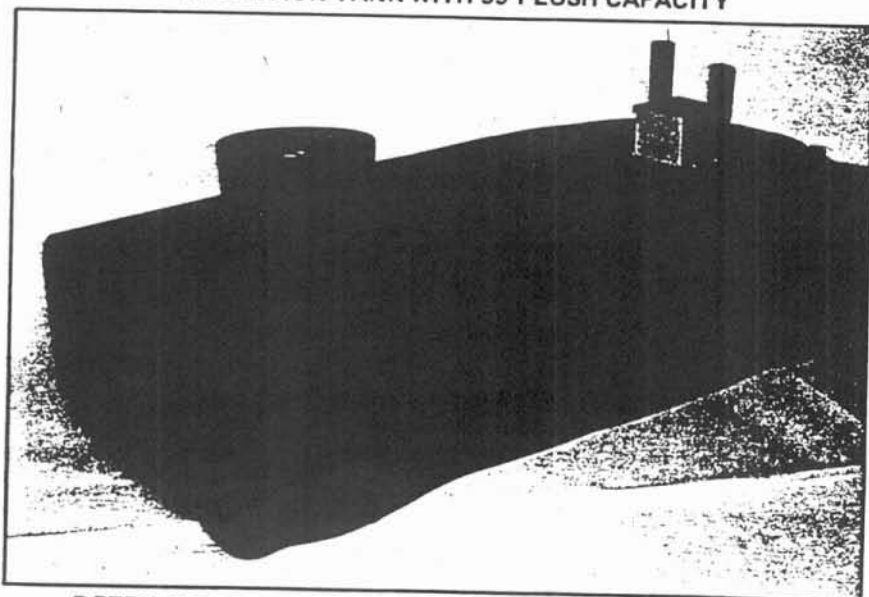
The logic circuit consists of solid state electronic components mounted on a glass epoxy circuit board.



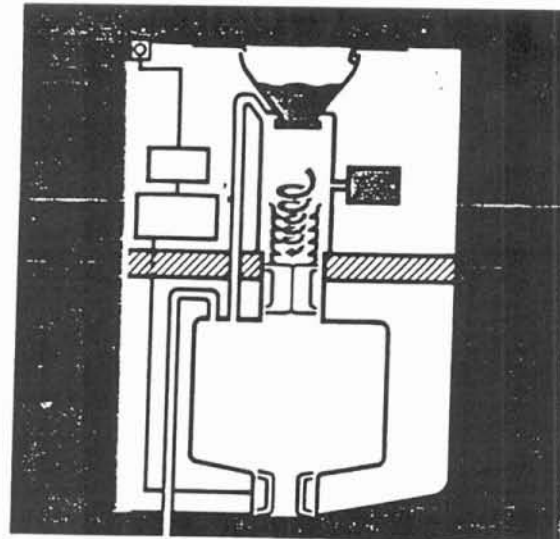
OPERATION CHARACTERISTICS OF LOGIC CIRCUIT



RETENTION TANK WITH 99 FLUSH CAPACITY

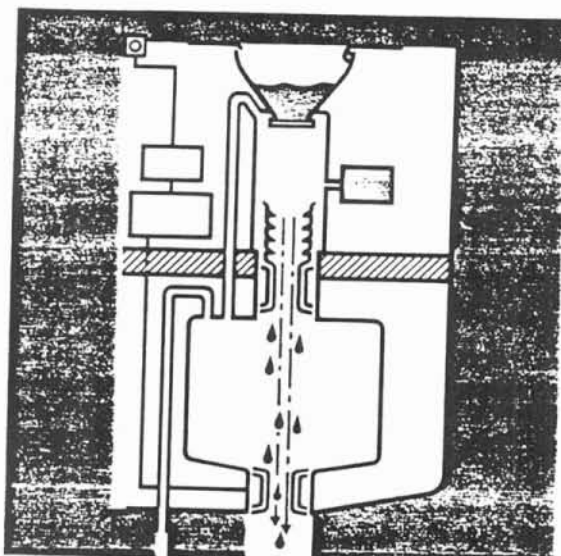


RETENTION TANK FITTED WITH HEAVY-DUTY INSULATION



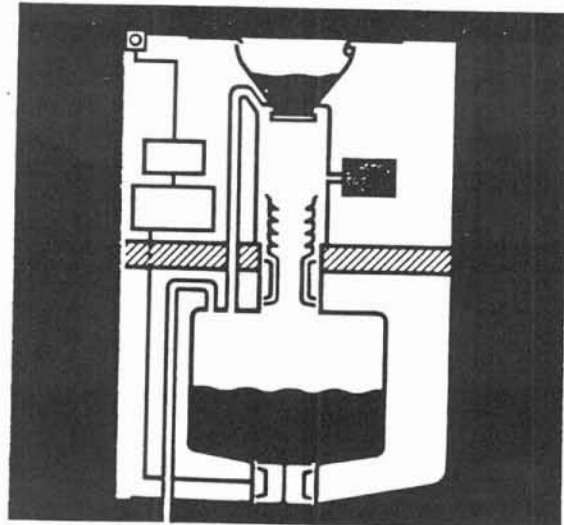
SYSTEM DURING MACERATION AND TREATMENT CYCLE

Flap valve closed. Air under pressure is injected into chamber. Violent blending of air, water and chemicals for 70 seconds.



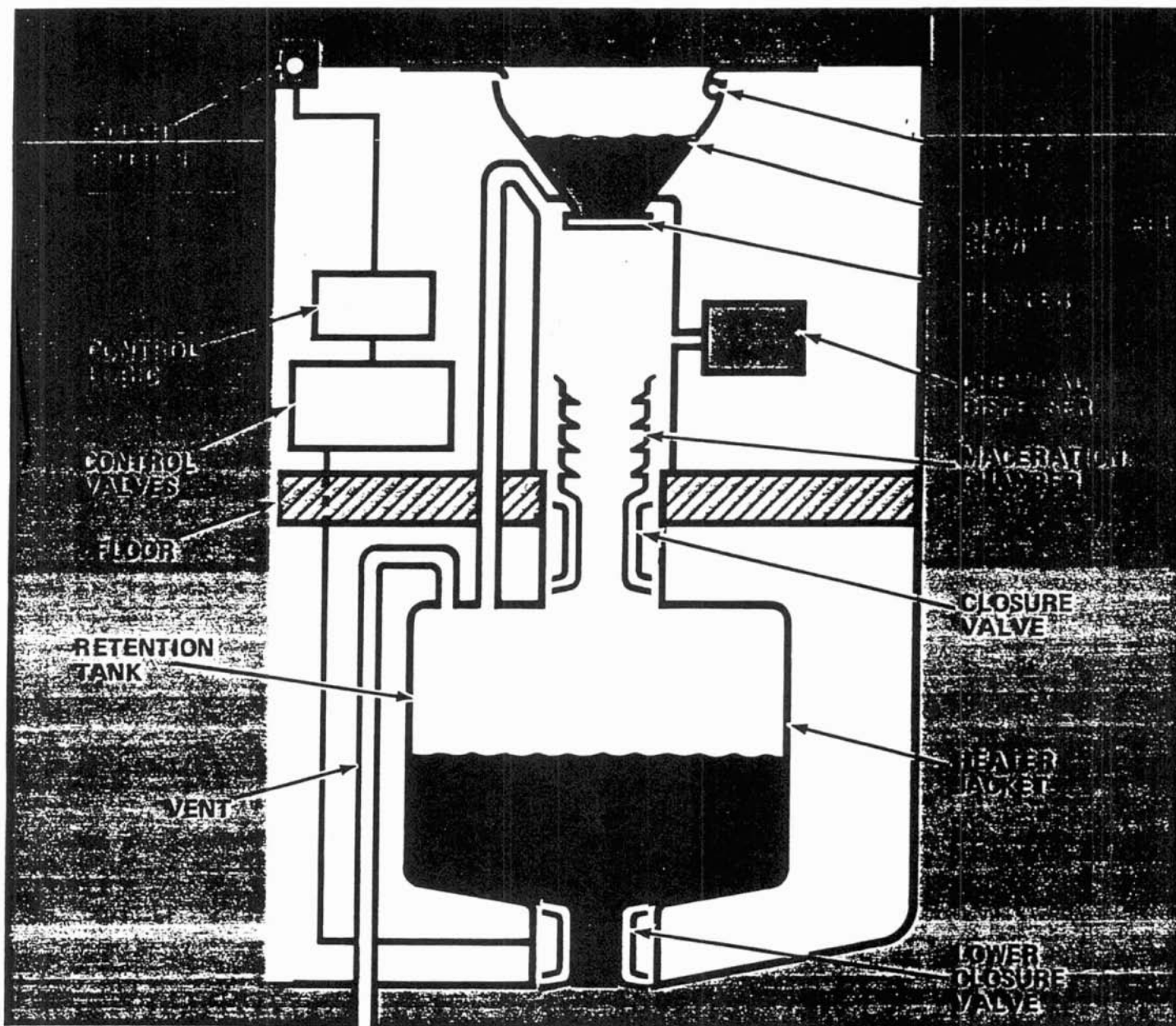
SYSTEM DURING DISCHARGE CYCLE

Pinch valve opens and expels treated effluent onto roadbed. Treated matter is a liquid/liquid slurry with solids reduced to particle size. Tissue paper is pulverized.



SYSTEM IN RETENTION CYCLE

Treated effluent is retained in tank when car is in station or "No Dump" area. Effluent will be discharged automatically when restriction is removed.



Voltage (Input)	7.2 V.D.C. or any voltage supplied	Air Quantity / Flush	11.5 SCFM Max.
Power ■ Flush	100 Watts	Cycle Time - Flush	10 Seconds Max.
Water Pressure	20 P.S.I. ± 112 P.S.I. Dynamic (While Flushing)	Cycle Time - Macerate	
Water Volume I Flush	1 Litre	Treat, Transfer	83 seconds ± 2 Seconds
Air Pressure	40 - 45 Dynamic P.S.I.	Macerated Size	To Digested Particles
Maceration Air Pressure	80 P.S.I. (Dynamic)	Power - Heating	540 Watts Ref.
Operating Ambient Temperature	- 40° C to + 65° C	Wade Retention Tank	99 Flushes
		Liquid Anti-Bacterial	2 mL (Approx.)
		Voltage for Heater Assy	115 V.A.C. or any voltage supplied

Completely protected for cold weather operation

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