Down The Drain – Microphor Toilets

By ERIC WILDE

This article covers the theory of operation, installation of, modification of, tank requirements and maintenance of Microphor toilet systems on private railway cars.

Microphor toilets are found installed on many private railway cars and continue to be installed in new installations to this day.

They are flexible, in that they can be piped with relatively small diameter waste pipe, require little water for flushing and can be connected to either a holding tank or septic system. Their purchase price is reasonable and so is their installed cost, especially if you do it yourself.

Their supply requirements are few, that is to say a water and compressed air supply, both of which are readily available on a private car. If properly installed and maintained, they function well and are reliable in service.

In this article, we'll cover much of the information that you need, to understand how these ubiquitous toilets work, install them in a railway car, pipe them up to a holding tank, get them working well and keep them in tune. Septic systems, which are usually designed and built as a custom order, by Microphor, are not covered directly in this article but most of the installation and other information herein still applies.

Concepts

Microphor toilets are an air-operated and air-assisted toilet. By this I mean that the operation of the toilet, the opening of the hopper valve, the turning on of the water and the timing of the flush cycle is all controlled by compressed air. The reference to air-assisted means that the movement of the waste through the piping is assisted by compressed air (as opposed to gravity which is employed in household toilets).

The use of compressed air has several advantages over a gravity type system. The pressure that can be applied to the waste can be many pounds instead of the few pounds that are typically supplied by the head of water in a gravity type plumbing stack. The higher pressures and velocities mean that smaller pipe may be used, due to the reduced risk of clogging and pipe runs may be nearly horizontal.

The amount of water required for a flush cycle is greatly reduced. A small amount of water is all that is needed to sluice the bowl and leave it filled with a few inches of water after the flush cycle completes.

The choice of compressed air to operate the toilet also means that there is no need for electrical wiring to control the toilet. And, since compressed air is also used in water raising, it implies that if there is water available, air pressure must be present and the toilet will operate.

Key Components

The key components of the Microphor system are the: bowl; flapper valve; ejection chamber; and AWS valve. There is a pushbutton, to control the toilet and, typically in railroad installations, a regulator and oiler to ensure good quality air. Ancillary valving helps to isolate the unit for maintenance and control the amount of water used during flushing.

The types of toilet bowls available are vitreous china and stainless steel and they come in several models, including a space saver model. The stainless model is usually preferred, in keeping with the railroad motif and is

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especially appropriate for modifying (see Modification, below). A complete description of each of the models can be found at the Microphor Web site.

All models have a circular hole, near the bottom of the bowl, with a rim around the back side that seals to the top of the ejection chamber. The bowls can be fitted with various kinds of seats and lids, depending on the installation requirements. I'm sure that, given a little ingenuity, fitting your favorite, fur covered lid onto the toilet is even possible.

The ejection chamber (Microphor calls it the hopper) is an injection molded box, made of filled plastic, that comes in two halves, which are sealed by a large o-ring. This box attaches to the bottom/back of the bowl at the point where the hole is. The attachment is rendered water tight by sealing with an o-ring and butyl caulking. Just inside the hole that joins the bowl is a raised lip that is sealed shut by the flapper valve. This seal, by the way, is very important and must be ensured at all times to avoid water leaking and blowback (a nasty situation). Keeping the lip clean and free of nicks and cuts is very important (see Maintenance, below).

At the top of the ejection chamber is the flapper valve. This is composed of a round disc that has a large rubber ring around its perimeter, the rubber ring sealing the disc to the lip around the hole in the ejection chamber. The disc is attached to a flat paddle that is keyed onto a shaft which runs through both sides of the ejection chamber, such that when the shaft is rotated, the disc moves away from the hole, opening it and allowing the contents of the bowl to fall into the ejection chamber.

The shaft is sealed to the ejection chamber sides by a pair of o-rings and one end of the shaft, which protrudes from the exterior of the ejection chamber, has a bell crank on it. To the bell crank is attached an air cylinder which can push or pull on the crank, thereby closing or opening the flapper valve. This allows dumping of the bowl's contents into the ejection chamber, during flushing, and sealing of the ejection chamber/bowl at all other times.

As was noted before, it is extremely important that the flapper disc to ejection chamber lip seal is tight because it is pressurized during ejection of the waste. Furthermore, it prevents the residual water in the bowl from draining away when the toilet is not in use. Thus, the rubber sealing ring must be in good shape and the air cylinder must be properly adjusted to ensure a positive seal.

AWS Valve

To complete a proper flush cycle, several steps must happen in the correct order: the flapper valve must open; the water must be turned on; the flapper valve must close after a suitable interval; the air must be applied to the ejection chamber to pressurize it; the water and pressurization air must be turned off, after the waste is ejected and the bowl filled with some residual water for the next flush.

If any of these steps doesn't happen, is too long or too short or misfunctions for any reason, the flush cycle will not be correct and the customer won't be happy.

The heart of the system is a single valve, called the Air/Water Sequence (AWS) valve, that initiates each step in the flush cycle in order at the appropriate time. To say that it is an ingenious valve is an understatement. It controls air out to three different locations and water out to the bowl. In addition, it has an adjustable timing cycle that ensures proper flushing. All this in one valve and a pneumatic one at that is pretty impressive.

Understanding the AWS valve is important when it comes to understanding how the toilet flushes. Furthermore, an understanding of the valve's workings will come in handy when it comes time to troubleshoot problems with the toilet. Tuning the toilet for optimum performance in its installed environment will also be simpler if you understand how the valve works.

The valve essentially has five states: at rest; pushbutton pressed; pusbutton released; a short time has elapsed (flapper closes); more time has elapsed (ejection chamber pressurized). After passing through these five states the valve returns to the at rest state.

The first state is the at rest state. Referring to Figure 1 (left), you'll see the valve at rest and you can see all of the internal passages in the valve, stylized somewhat for simplicity sake.

The pushbutton or actuator lever is a two position valve that directs air from the supply to either the forward port (when at rest) or the rear port (when actuated). When the pushbutton is depressed or the lever operated, air from the supply is directed by that valve to the bottom of the AWS valve, entering through the blue port, as shown in Figure 1 (right).

Air entering the bottom of the valve exits through the white port to the top of the flapper valve cylinder and forces its piston downwards, opening the valve and dumping the contents of the bowl into the ejection chamber. At the same time, the poppet valve in the bottom of the AWS valve opens, air moves into the chamber above and forces the valve spool all the way upwards. This, in turn, begins the flow of water to the bowl to sluice the waste into the ejection chamber and rinse the bowl.

The air in the flapper valve cylinder is vented through ports in the AWS valve and the back of the pushbutton or actuator (not shown in the diagram). This allows the piston to be driven downwards by the air applied to the top end of the cylinder. Were the air in the cylinder not to vented, the piston could not be driven downwards by the air applied to it.

Once the pushbutton or actuator is released, air is redirected away from the bottom port of the AWS valve, to the center, green inlet port. The poppet valve, meanwhile, springs back to the closed position, locking the air holding the AWS valve spool up against the spring pressure, into the chamber. This is an equilibrium state which holds the valve in an open position by the pressure of the trapped air.

At the same time, air to the flapper valve cylinder is interrupted, as shown in Figure 2

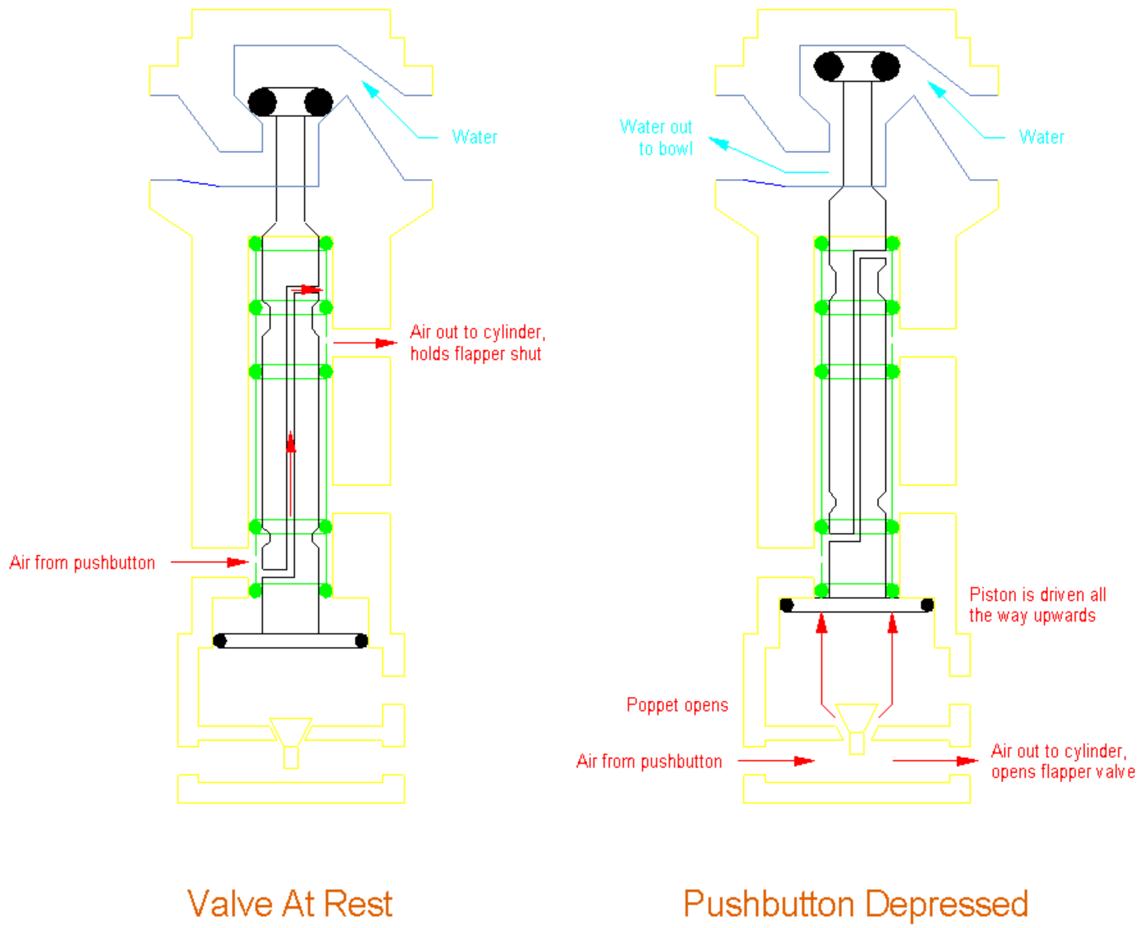

Figure 1 – Air/Water Sequence Valve – Sequence 1, 2

(left). However, there is no pressure applied to the other end of the cylinder so the flapper continues to stay open, there being nothing to alter its open state.

The equilibrium state does not last for long, however, since air begins to slowly bleed off from the chamber through the needle valve.

As time passes, more air bleeds off from the chamber, through the needle valve. The rate at which it bleeds off can be adjusted by turning the needle valve in or out. Turning it in will close it and slow the escape of air, lengthening the valve cycle time. Turning it out will open it and speed up the escape of air, shortening the valve cycle time.

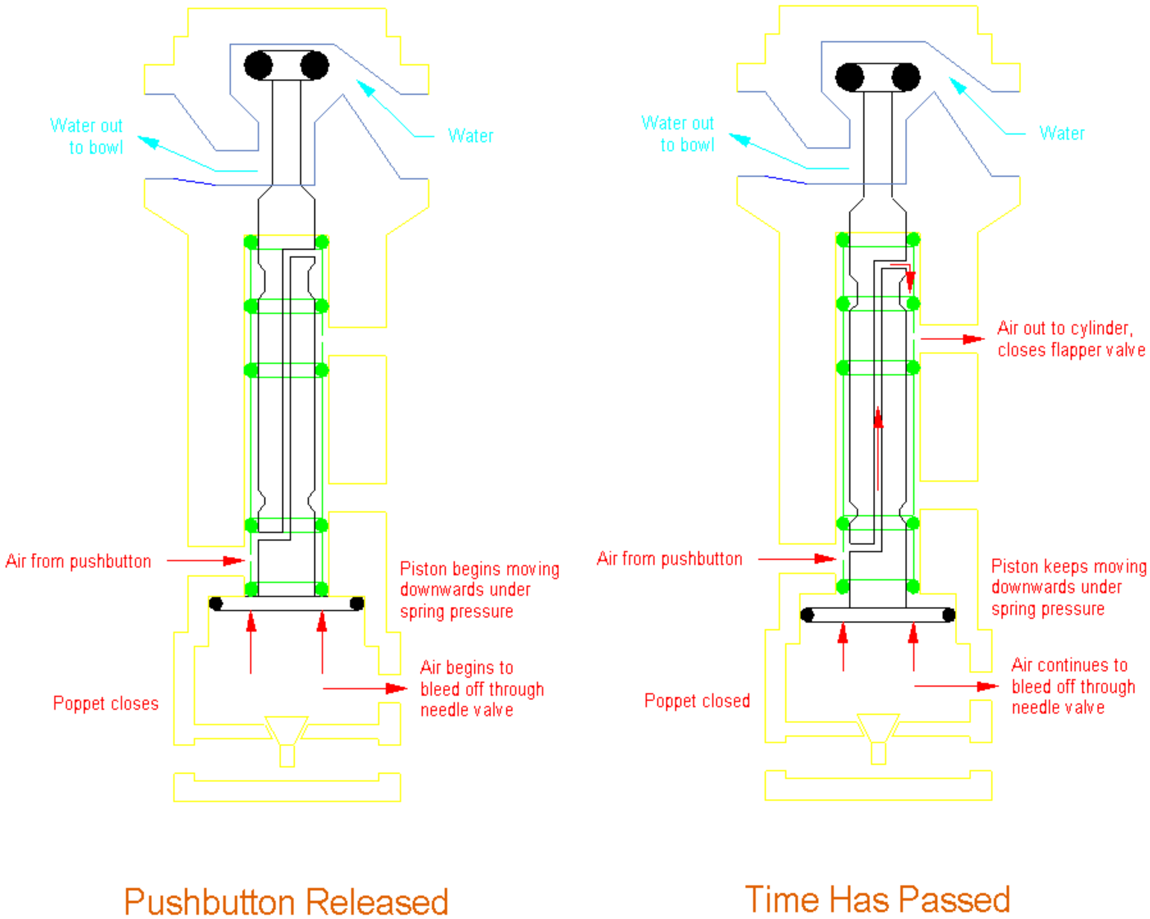

Figure 2 – Air/Water Sequence Valve – Sequence 3, 4

This allows the piston and valve spool to begin moving downwards. As the valve spool reaches the position where the top cutout in the spool allows air to pass by the o-ring, as depicted in Figure 2 (right), air can flow through the port drilled in the center of the spool and out to the bottom of the flapper valve cylinder, forcing it closed.

Water continues to flow to the bowl but, with the flapper valve is closed, it begins to fill the bowl with the residual water that remains in the bowl at all times.

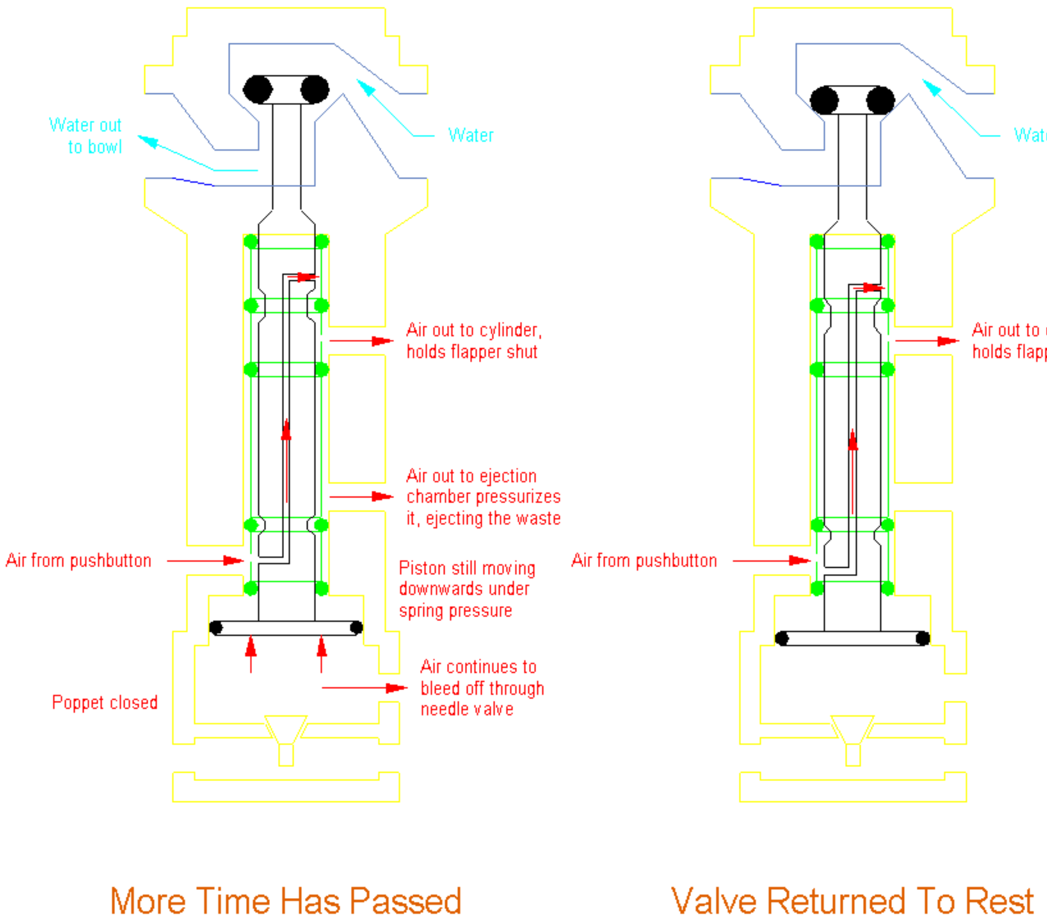

Figure 3 – Air/Water Sequence Valve – Sequence 5, 6

Nearing the end of the cycle, the AWS valve spool moves, under pressure from the return spring, to near the bottom of the valve. This causes the lower notch in the spool to allow air to flow around the o-ring and out the port to pressurize the ejection chamber, as shown in Figure 3 (left).

When this happens, the pressurized air in the ejection chamber forces the waste out the back of the ejection chamber, up around the p-trap and down the waste line to the holding tank or septic tank.

Air continues to blow the waste out of the ejection chamber and down the waste line until the valve returns to its rest position, as shown in Figure 3 (right), after all the air has bled off from the chamber, through the needle valve. At this point, the lower notch in the valve spool has

Photo 1 – AWS Valve, with water flow control valve.

passed the o-ring and once again shut off the air to the ejection chamber.

Water continues to flow, all the while, until the valve reaches its rest position. At that point, the o-ring in the water section of the valve shuts off the flow of water to the bowl.

Installation

In this section on the installation of Microphor toilets, we'll focus primarily on the stainless toilets because they are the kind typically found on private railroad cars. Most of the information herein may also apply to the vitreous china toilets but the discussion is specifically directed at the stainless models.

There are four major areas that need consideration when installing these toilets: the air supply; the water supply; attachment; and the waste line. Also, location selection for all of the components is an important factor too.

Air Supply

It is very important that the air supply to the toilets be able to provide them with clean air of the right pressure in a volume sufficient to operate the toilet. The toilet valves have several small orifices that could become blocked by particulate matter in the air supply, thus affecting the operation of the toilet. Water in the air could cause some of the valve parts to rust out (I've disassembled valves where the spool piston was rusted into the valve body). If the pressure is incorrect, operation of the toilets can become erratic, thereby causing many problems.

Air to the toilets should be supplied by a 1/2" pipe, if possible. If a copper or steel pipe is used, it should be run with a slight slope downwards to the end farthest away from the air source and then a downward-facing drip leg, with a drain valve on the bottom, should end the pipe so that condensate can be collected and removed. Piping to the individual toilets should be teed off the top of the supply pipe and extend upwards for a few inches before making a 180 degree turn and then a 90 degree turn to run in the direction of the toilet. It is recommended that copper air piping be brazed, not soldered.

The above are standard techniques for use on air systems to ensure that air free of condensate is supplied to the end user. Obtain a good book on hooking up air systems to learn more about the kinds of things that should be done to ensure a clean, dry supply of air and how to distribute it.

The air pressure requirements of the toilet are fairly precise. The pressure should be set at between 60 and 65 pounds, at the toilet. To allow for pressure fluctuations, drops, etc., the pressure in the line feeding the toilets should be set higher than this (say 80 – 90 pounds).

Toilets should be installed with a local

Photo 2 – A mini-FRL mounted on a bracket with a metal clip and copious glob of silicone caulking.

Filter/Regulator/Lubrication (FRL) unit, equipped with an automatic drain, very close to the toilet. This will ensure that condensate is removed from the air along with any particulates, that the air pressure is precisely regulated and that lubricant is added to the air to ensure the toilet keeps working freely. The outlet pressure of the FRL should be set with a gauge to 62.5 lbs. and locked at that setting.

Photo 3 – FRL bracket, disassembled.

A suitable bracket that allows the FRL to be removed for maintenance should be employed for mounting (Photo 2 shows a mini-FRL mounted on a metal bracket that can be attached to a wall or partition. Photo 3 shows a similar bracket, disassembled. The stud is a 1/4" x 2-1/2" cap screw, with the head cut off and welded to the plate. An elastic stop nut holds the clip).

A shutoff valve should be installed immediately before the FRL to allow isolation of the toilet from the air line for maintenance purposes.

Water Supply

As with the air supply, the pressure of the water supplied to the toilet is very important. If you refer to the diagram of the AWS valve, in Figure 1, you'll see that the water enters the top of the valve in such a way as to apply downward pressure to the valve spool. While this assists the valve in remaining closed against the water pressure, it also means that the compressed air that operates the valve must work against the water pressure to open the valve. This means that the water pressure cannot be too high or the valve will not operate properly.

On the other hand, the amount of water that flows into the bowl and how effectively it sluices the sides of the bowl depends on the pressure being high enough. Consequently, there is a predetermined range of water pressures within which the supply must fall. Since most city water systems are set for approximately 40 p.s.i. and since this pressure falls right within the range of acceptable pressures for the toilet, I use this pressure setting to allow the toilets to work acceptably while supporting all other plumbing fixtures on the car, since they are typically designed for this pressure

The volume of water that is supplied to the toilet is equally as important as the pressure. If not enough volume is available, the pressure will drop and this spells trouble. Sizing of the pipes feeding the toilet(s) is critical. At a minimum, 1/2" pipe should be used and, if there are multiple toilets on the same line, consider using 3/4" pipe.

The feed to the toilet should be teed off the main line with, at minimum, a 1/2" tee and routed to a shutoff valve. This will allow the water to be shut off for maintenance. It may also be useful to shut off the water in an emergency so this valve should be located where it can be readily accessed.

For ease of installation of the AWS valve, I prefer a short length of flexible hose between the water shutoff valve and the AWS valve. Somewhere between 12" and 14" seems about right. This connection can be made up of double walled, rubber hose and some 1/2" NPT hose barbs and ferrules. Make sure the ferrules are crimped properly to avoid leaks.

Using flexible hose will allow the AWS valve to be spun onto the hose fitting, without the need for a union. The flexible hose will also allow the AWS valve to be inserted into and removed from its installed location with very little difficulty.

A vacuum breaker should be placed in line with the water supply feed, just prior to its entering the AWS valve. This will prevent water from the toilet from flowing backwards into the car's potable water system, should something untoward happen.

The connection from the AWS valve to the toilet itself can be accomplished with a short piece of 3/4" inside diameter, clear, vinyl tubing. This tubing is never under any pressure so there

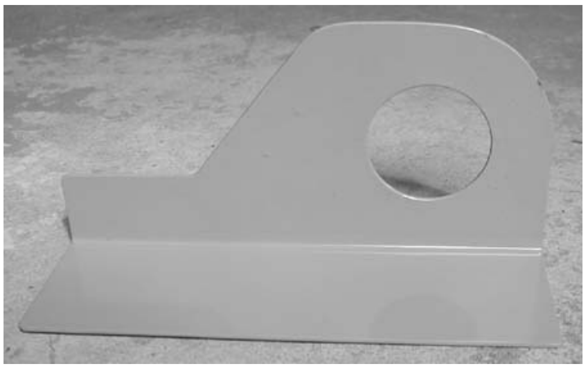

Photo 4 – Bracket for AWS valve.

is no need for it to be heavy duty. It should be secured to the AWS valve's hose barb and the toilet bowl connection with a 1" diameter stainless steel gear clamp. This will allow the tube to be easily removed, should you need to take the toilet out for servicing, at a later date.

Flow of water to the toilet can be regulated by a 1/2" needle valve which can be attached to the output side of the AWS valve. I use a plastic valve (ARO model #F04) to control flow (see Photo 1). This valve has a very sensitive adjustment that permits fine control over the volume of water flowing. Furthermore, it has a locking collar which can then be used to lock the adjustment in place.

Alternately, an orifice plate can be inserted into a piece of 3/4" pipe to form a restricter that will reduce the flow to the desired rate. Cut a slot (about 90percent of the way through) into a short length of 3/4" copper pipe. Fabricate an orifice plate out of copper sheet (minimum 18 ga.), such that it drops into the slot in the pipe. Start out by drilling a 1/16"-diameter hole in the center of the plate. Drop it into the slot and braze it in place so that a leak-tight bond to the copper pipe is formed.

Insert the restricter into the bowl feed line and try a few flushes. If the volume of water is too small, the orifice may be enlarged with a numbered drill a few sizes larger (*Caution*: increase drill size slowly, in small increments, until you arrive at the exact size required since relatively small changes in hole sizes can cause big increases in water volume).

Attachment

Attachment of the toilet to the flooring is an important aspect of installation. There can be a considerable amount of weight placed on the toilet and it would not be fun, should it come loose during a hard turn or some heavy slack action. My approach is to bolt it down well.

When replacing track dump toilets, as is frequently the case in private cars, there is usually a solid piece of plate in the floor, that the toilet was formerly bolted to but it is often at the

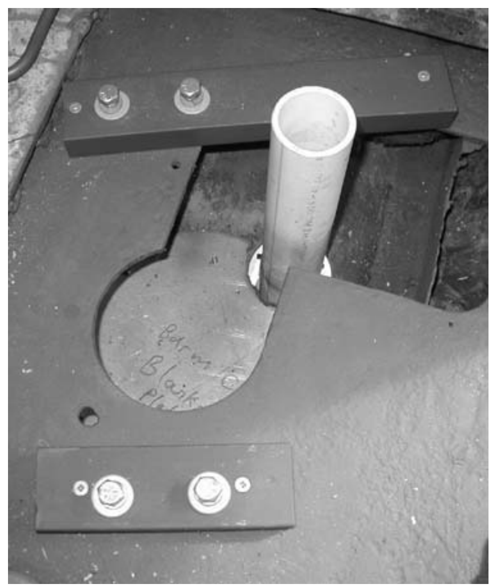

Photo 5 – Inverted channel in floor provides a sturdy mount for the toilet.

wrong height and has a large hole where the old toilet sat. I've found that a piece of 1" channel (C 2" x 1" x 3/16"), inverted and welded or screwed to the plate can bridge the hole, raise the toilet base to floor level and provide a sturdy attachment point for the toilet. There is enough thickness in the web of the channel to allow a hole for the mounting bolts to be tapped. Photo 5 shows this arrangement for a Microphor toilet that will replace one of those inventions of the devil, the folding toilet.

Another typical installation location is on top of a plywood floor. Often, these floors are 3/4" plywood with a piece of sheet metal glued or nailed to them. One example of where such a floor might be used is in an upper duplex roomette. Many cars used this material for their main flooring too.

Messing with nuts is never my favorite thing to do, especially when it may be difficult to reach the back side of the floor where you're bolting something down. And, there's nothing like that sinking feeling you get when you're backing out a bolt and, as the last thread disengages, you hear a small thump made by something falling free. You certainly don't want someone thinking of you, "What idiot would put a nut in a place like that?" In the case where you're installing a toilet onto a plywood floor, consider applying a 3/16" steel backing plate to the reverse side of the floor and tapping mounting holes into it so that the toilet may be installed and removed without fiddling with nuts and washers.

The bolts that hold the toilet down should be of a substantial nature and be applied with large washers to distribute the load. The preferred size bolt is 3/8" and, given the environment, stainless bolts would be reasonable. Don't forget the lock washers.

At first, you may want to install the toilet loosely, with the bolts inserted and tightened finger tight. Often, the installation process requires that it be removed several times as the waste line and other plumbing are attached to it. There is often very little room to work so removing the toilet to get at things is sometimes the only option.

Waste Line

Once the toilet is fitted onto its mounts, the connections to the waste line can be made. The coupling of the ejection chamber to the waste line should be done with a rubber no-hub connector and gear clamps. This will allow the toilet to be removed for maintenance and will permit a bit of adjusting of the plumbing as well.

When the waste line exits the ejection chamber, it must be connected immediately to a p-trap (Microphor specifies within 7"). The p-trap provides a water seal for the ejection chamber and gives it something to work against when the waste is ejected (if not for this, the compressed air would just go whistling down the pipe and not move anything).

A standard p-trap can be used or one can be fabricated from a 90 degree street elbow, short length of pipe and a 180 degree return bend. This arrangement gives much more flexibility in hooking up, since the height of the p-trap can be varied, as can the position of the downward exiting pipe. The no-hub connector is fitted right over the straight end of the street elbow to give a close connection to the toilet.

Dry fit everything, with the toilet in place, before you glue anything up. All of the parts can be marked with a magic marker and removed for gluing up into sub-assemblies, once they all fit. The final glue up can be done in place but consider the sequence carefully. You wouldn't want to glue up a sub-assembly that you can't fit in place nor would you want to make a glue joint in an impossible place to reach. Photo 6 shows a

Photo 6 – No-hub connector connects a fabricated p-trap to the ejection chamber.

picture of a no-hub connector and fabricated p-trap attached to the back of a toilet.

The size of the pipe (1-1/2") and the type (schedule 40 PVC) means that it is commonly available. Assembly is easy and fast, using a solvent type glue to essentially weld the pipe together. This kind of pipe is suitable for use inside the car and underneath but you may want to consider schedule 80 pipe in locations where impact is likely. The extra ruggedness of pressure fittings may also be desirable in the railroad environment.

When assembling waste lines, you may want to keep on hand a selection of 90 degree sweep elbows, 60, 45 and 30 degree elbows, 180 degree return bends, 90 degree street elbows and straight connectors. All of these are useful in fitting up waste lines. Cans of glue and pipe cleaning solvent are de rigueur.

You can also bend straight pipe into graceful sweeps, by hand, using a hot air gun (use the real thing, not a hair dryer). Carefully heat the pipe uniformly (take your time) until it becomes soft (a.k.a. plastic). Bend it slowly by bending and pulling ever so slightly to stretch the outside of the bend and prevent kinking on the inside. Anything less than a 15" radius may be a little dicey but this method is perfect for gentle kicks, offsets, etc. Not only that but you shouldn't have to make allowance for these kinds of bends when calculating run length (see below).

Although a private car spends plenty of time rolling down the track, leaning into curves, going up and down hills, it probably spends most of its time sitting on straight and level track. This being the case, it is advisable to pay attention to all of the usual rules about slope for waste lines. Admittedly, there isn't that much drop between the floor of the car and the top of the holding tank or septic tank but, if at all possible, a slope of 1/4" per foot should be observed. This will ensure that, when the car is sitting level, everything will drain down towards the tank.

The distance, of the pipe runs, from the toilet to the tank must be taken into consideration. Although an air-assisted toilet is a wonderful thing, it is not capable of working miracles. Pipe runs of over thirty feet of 1-1/2" pipe are probably going to cause problems, the last thing you need when you're on the road with a car full of friends or customers. The friction in this much smaller diameter piping adds up quickly and works against the ejection chamber, a blockage just waiting to happen.

90 degree standard elbow	4'
90 degree sweep elbow	2.6'
90 degree street elbow	6.3'
60 degree elbow	3.1'
45 degree elbow	2.1'
45 degree street elbow	3.4'
22.5 degree elbow	1.2'

Table 1 – Equivalent lengths of various fittings.

When you are calculating the length of your pipe runs, also note that you must take the angle of any curved fittings into account. The equivalent length of each fitting must be added to the length of the pipe run to arrive at the perceived, in terms of friction, length of the run. Table 1 lists the length that must be added for each fitting used in a pipe run.

Photo 7 – two 1-1/4" lines teed into a 3" line.

If you have a lot of toilets on your car or they are at opposite ends of the car, consider using two tanks. At the very least, locate the tank exactly in the center of the car so that none of the pipe runs is excessively long.

Another possibility is to tee several waste lines into a standard diameter waste line (i.e. 3", which can then be run to the tank, following the usual standards for slope of drain lines (i.e. 1/4" per foot). A 1-1/2" to 3" offset wye can be used to connect a waste line to the larger pipe, providing you make sure to run the smaller line into the larger pipe from the side or top. This same fitting can also connect a smaller line straight into the larger pipe if a bushing is used in the end of the fitting. Although it may seem obvious, it is worth repeating that you should make sure the angled line points towards the tank. Photo 7 shows two lines teed together in the manner described.

Any waste lines that run underneath the car should be insulated (and possibly traced) to prevent them from freezing in winter. Admittedly, if the lines are properly sloped, the waste will only be a transient inhabitant of them. However, if the pipes are at ambient temperature, it is possible that a film of ice will build up on the inside of the pipe wall, even as the waste is flushed towards the tank, not to mention what will happen if the car is on a slope that cancels out the piping's slope. Any waste standing in a waste pipe is liable to freeze and the pipes are such small diameter that any reduction or restriction could prove fatal.

At least 1/2" of closed cell foam insulation (e.g. Rubatex) or 1-1/2" of fiberglass insulation should be applied to all piping. Cover it with scrim, if desired and then apply an outer layer of sheet metal or heavy plastic for mechanical protection. The RBX Industries Web site has quite a few application notes on how to apply the closed cell foam insulation to piping systems.

Locating Components

All of the components of the system should be located behind the toilet in places where it is convenient to get at them and laid out in a logical arrangement, according to flow and function.

The FRL should be placed out of the way, to one side or another so that the air line can be run to the air shutoff valve and thence to the FRL. Since the pushbutton or actuator is typically located high up on a wall near the toilet, the FRL can also be located high up so that the air line out of it can be run directly to the pushbutton, out of the way of the rest of the components. Keep in mind that the air shutoff valve and the FRL's oiler bowl should be easy to get at to shut off the air and to fill the bowl with oil.

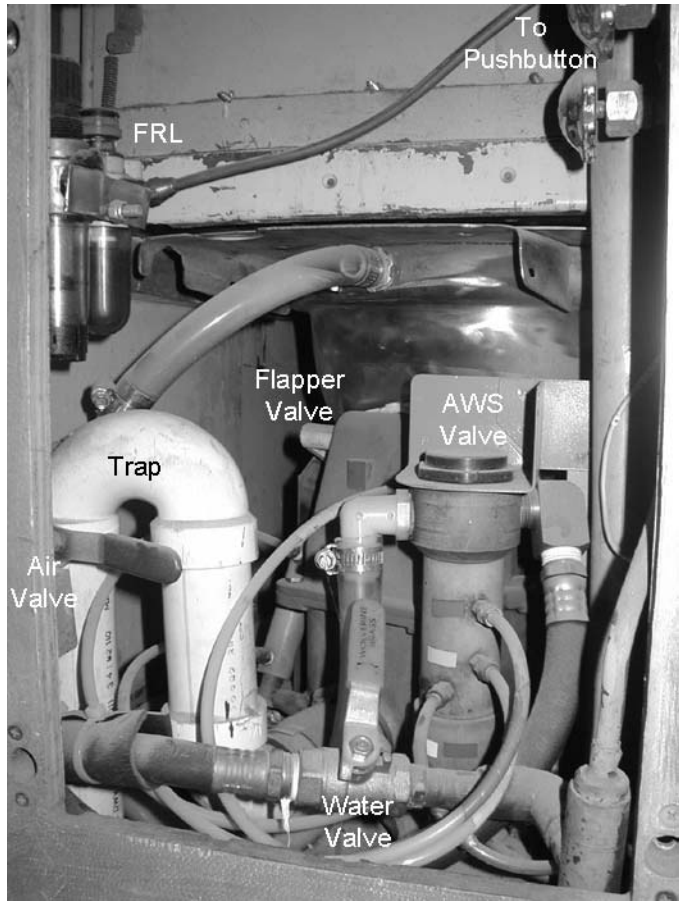

Photo 8 – System components installed behind a roomette toilet.

The AWS valve should be located so that its timing adjustment needle valve can be reachable and the various air and water lines can be connected to it. Marking the valve ports with squares of colored electrical tape and applying a similarly colored piece of tape to the air lines can eliminate confusion and speed the connections to the AWS valve.

The water shutoff valve should be located so that it is easy to reach, should the water need to be shut off. As was noted earlier, a short length of rubber hose can be used to connect the water shutoff valve to the AWS valve.

The water connection to the toilet bowl and the no-hub, p-trap and waste line should be located as necessary and routed where they will fit. The screws on the gear clamps should be accessible so that they may be opened to remove the toilet for maintenance.

Given the limited amount of space behind the toilet in most railroad installations — especially roomettes — it can get a little crowded when all of the system components are installed. Photo 8 shows such a roomette installation.

Modification

The standard, stainless steel Microphor toilet is very amenable to modification to fit within close clearances. All that is required is a plasma cutter and the sculpting can begin.

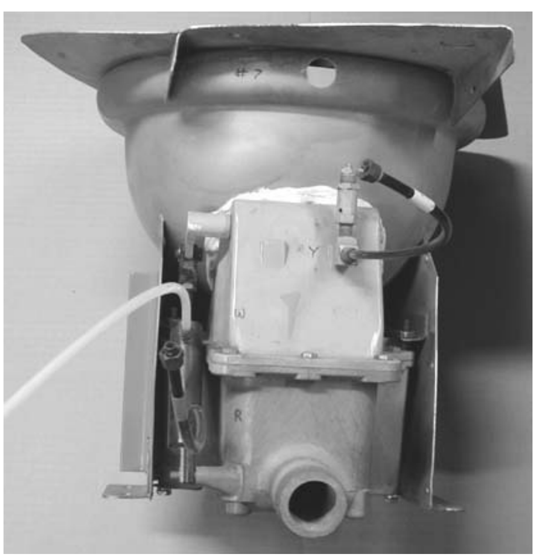

Photo 9 – Cut down toilet.

Several inches of vertical height may be removed from the toilet to lower it to fit under an existing seat. Typically, this would be necessary in the case of a roomette installation where the seat is built into the room's wash stand and set at a fixed height, governed by the fact that the bed must cover it when in the lowered position.

Measure carefully from the bottom of the toilet, around the entire base at regular intervals (perhaps 1-1/2"). Using a flexible ruler, scribe a line through all the marks so that it extends all the way around the toilet's base. Make sure this line is accurate since, once you start cutting, all reference points will be gone (there is nothing else to measure accurately from on the toilet).

When cutting a toilet down, the first step is to remove the ejection chamber so that the stream of hot metal from the plasma torch won't set fire to the plastic. Next, carefully remove the mounting tabs (so that they can be reused) by cutting around them, prying up the metal they are attached to, grinding it off, etc. Once the tabs are recovered, proceed to cut along the line and then grind it off so that it is smooth and flat. Reattach the mounting tabs by welding or spot welding (see Photo 9).

Note that it is possible to gain an additional reduction in height by recessing the ejection chamber into floor, if the floor has any depth (as does the typical car floor which is approximately 3" deep). An appropriately sized hole is cut into the floor and the ejection chamber extends below the bottom of the toilet into the hole in the floor. In such an installation as this, it is particularly important to use a layer of high-quality insulation between the bottom of the ejection chamber and the exterior of the floor to prevent the toilet from freezing in winter.

Many roomette installations have the toilet angled into the room (due to the close quarters) and covered by a square seat and lid which are attached to the roomette wash stand. To fit a toilet into such a location, the top is cut on an angle (see Photo 10) and a cover plate is cut out of a flat sheet of #16 gauge stainless. This sheet is then welded (preferably by TIG welding) to the top of the toilet to trim it off and allow it to fit where the original toilet went, under the seat (see Photos 11 and 12).

Photo 10 – Toilet angled to fit in a roomette.

Tanks

As was mentioned earlier, the waste stream from the toilets can be directed to either a holding tank or a septic system. Septic systems are mostly beyond the scope of this paper. They are usually custom built, based on the capacity necessitated by the number of toilets feeding into them, expected passenger load, etc. Their size and shape also depends on the location where they are situated underneath the car. The septic tank is filled with filler material that sustains a bacterial colony which decomposes the waste and produces clear water, which is drained to the track after treatment with chlorine.

Holding tanks are much more common. They can be any size and shape, depending on their required capacity and where they are located. There are several choices for the materials to use in fabricating holding tanks. We will discuss them next.

Capacity

It is wise to do some calculations of holding tank size, based on the number of toilets, the projected passenger loads and the volume of waste in the toilet's flush. This will give an indication of how big the tank needs to be to give a reasonable operating range.

Believe it or not, I actually asked a group of fellow employees, at one of my places of

Photo 11 – Stainless sheet trim applied to toilet top to fit roomette seat.

employment, to record their trips to the toilet for a week. After I explained my reasons for doing so, they got into the project with gusto. The numbers were between five and eight trips to the toilet, each day, on average. Mind you, this didn't factor in cocktail consumption, something which doesn't apply (hopefully) in an office environment but probably does on a railroad car. But, I believe that, if one chooses the higher number (i.e. eight times a day), one will be covered for any eventuality, even an extended happy hour.

Photo 12 – The finished toilet. Installed in a roomette with the seat applied on top.

Measurements of the volume of waste voided in either case indicate that between a cup and a pint of liquid equivalent-volume is typical. Add to this the roughly 2 quarts of water flushed by the toilet and one arrives at a volume of liquid of about 5 gallons per person, per day.

A typical calculation would multiply the expected number of passengers times 5, times the number of days operating range. A useful operating range might be 3-5 days so, for example, on a car that carries 8 passengers and two crew, a 250-gallon tank would theoretically give a 5 day operating range, based on a waste stream of 50 gallons per day. You get the idea.

The next thing to do is figure the size of the tank, based on the fact that one cubic foot equals 7.48052 US gallons. You can use some of your high school trigonometry to figure out the volume of the projected holding tank, in cubic feet (or cubic inches, for that matter, in which case, one cubic inch equals 0.00433 US gallons). Hopefully, the desired size tank fits in the space allotted.

Location

Speaking of space allotted, one needs to pick a location for the holding tank and then determine what shape it can be, as well as its length and width. This information will be fed into the volume calculations and one can iterate back and forth a bit to arrive at a tank size that meets the requirements.

The ideal location for a waste tank (septic or holding) is at the center of all the toilets feeding into it. This will cause the pipe runs from all the toilets to be at their shortest. Often, other constraints (e.g. all the other equipment mounted under the car) preclude the tank being placed in the ideal location but this should the goal.

The tank should probably be slung immediately below the center sill, for three reasons. The first is to allow a good drop, from the floor of the car to the tank, thereby ensuring that all the waste will drain to the tank. The second is to allow holding tanks to cross from side to side, creating a tank with much bigger capacity in a small amount of linear space. The third is to allow pipe runs from both sides of the car to enter the holding tank without needing to pass through the center sill.

Another consideration is that water weighs a heck of a lot. Pick some location where you can attach a heavy tank to the car's superstructure and try to arrange for it to be balanced itself as well as with all the other items attached under the car.

Fabrication

The complete steps to fabricating a holding tank are beyond this paper but you will probably proceed through these steps (get out your engineering books).

Calculate the weight of the waste in the tank. To arrive at a rough guess, a gallon of water weighs 8.333 pounds. Calculate the pressure on the tank sides and bottoms (it would be a shame for your nice, new tank to bow out in a curve under the pressure of the waste in it). A column of water one foot high exerts a pressure of 0.434 p.s.i. at the bottom of the column. Don't think a half a pound per square inch is much? Just multiply the length of the side by its height and you'll see that its important to pay attention to this aspect. There's a lot of square inches there.

Once you know the weight and pressure, you can determine what thickness of plate you need to build the tank out of and what kind of external bracing, if any, is necessary.

Choose the material to build the tank. The obvious choice is stainless steel, given the corrosive nature of the waste. However, carbon steel may be an option, if you make provision for cleaning the interior via grit blasting and applying a couple of coats of coal tar epoxy or similar coating, before assembly.

Jack Heard strongly recommends stainless steel rather than carbon steel, having initially installed both kinds of tanks on the Georgia 300. Here's what he says: "I suggest that you go the extra mile and purchase stainless steel tanks. I did and the two stainless steel tanks are still in excellent condition after almost 18 years. The other tank was only steel and it rusted out at about five years and lasted another five before it was gone."

Baffles should be placed inside the tank at strategic locations to prevent the waste from sloshing and overloading the walls of the tank when it is partially full and the car is in motion (see Photo 13).

If you want to heat the tank to prevent freezing in winter, the time to add a loop of pipe at the bottom of the tank, through which heated antifreeze can be circulated, is before the top is attached to the tank. Alternately, threaded ports where cartridge heaters can be inserted can be welded into the bottom of the tank at several locations to ensure even heating. A third option, external tracing with heat tape doesn't require that anything be done until the tank is completely fabricated, unless you wish to weld clips to the outside of the tank to attach the heat tape with, in which case it should be done before any coatings are applied to the tank.

Consider where you want the tank inlets to

Photo 13 – A holding tank being fabricated for the Coffee Creek clearly shows the use of baffles to prevent sloshing. *Photo in April of 2003 by Taylor Johnson (www.coffeecreek.info).*

be and, either drill and tap flange holes or weld threaded ports into the tank to accommodate them. Contemplate adding a backing or facing plate where the flange attaches, if the tank material isn't thick enough for tapping.

Proper venting is extremely important, from several perspectives. Firstly, the toilets are air-assisted toilets which means that they will be blowing compressed air into the tank, each time they are flushed. This air must be vented or the toilets won't flush right.

Venting is also paramount when it comes time for the honey wagon to empty the tank. In order to remove all of the waste, this vehicle is capable of pulling a pretty good vacuum on the holding tank. If it isn't vented, there is an excellent chance that the air pressure differential will crush the tank like a bug. Not a pretty sight.

Finally, bacterial action inside the tank can release quantities of sewer gas. Not only does it have an obnoxious odor but it can be corrosive, flammable and even hazardous to people's health. At the very least, entry of sewer gas into the car won't do anything to achieve the kind of ambience you're looking for. A venting arrangement that removes this gas effectively is a key requirement.

From the recent discussion in the car owners forum, it seems that the best (i.e. works well and is simplest) method for venting is to run a pipe out of the top of the tank, loop it around 180 degrees with a return bend and run the pipe right down to the bottom of the tank where a tee, aligned parallel to the track, that extends below the bottom of the tank, is left open to the atmosphere. When the train is moving, air rushing through the tee pulls the gas out of the tank and whisks it away. Even when the car isn't moving, the gas escapes low down, away from the car floor, where it flows away (bearing in mind that it is heavier than air) without ever entering the car. (*Thanks to Tony Marchiando for this idea.*)

Pumpout Fitting

The standard pumpout connection used by honey wagons, everywhere, is a four-inch Andrews cam and groove connector. This connector should be immediately preceded by a four-inch ball valve, to shut off the connector when the tank isn't being pumped and should be capped by a cam-lock cap when not it use. The connectors themselves are readily available at supply houses such as Grainger. According to the corrosion resistance chart supplied by the Dixon Company, the coupling should either be malleable iron or stainless steel.

The pumpout fitting should be plumbed to a low point in the tank and located close to the edge of the car (within the clearance profile, of course), in such a place as to make it readily accessible to the honey wagon operator. Since the waste is being pulled out of the tank by vacuum, it is even acceptable to run the pipe to the fitting slightly up hill, in order to get the fitting closer to the car side and make it more easily accessible while staying above the clearance profile (see Photo 14).

If you'd like to make your honey wagon operator happy, consider putting dual pumpout connections, one on each side of the car so that they will not be required to drag the hoses under the car to get to your fitting. Remember, an unhappy honey wagon operator is just as likely to skip pumping out a car that doesn't have an obvious, easily accessible pumpout fitting and then where will you be?

Chlorine Fill

If you choose a septic system over a holding tank, be sure to have the chlorine fill located on the tank such that it will be in a convenient location for filling, since you will be adding chlorine tablets regularly.

Also, here's an excellent tip from Jack Heard: "Never stencil the tanks with the word 'chlorine' or 'chlorine tablets only' or 'toilet tanks'. Just use the word 'Microphor'. 'Chlorine' and 'Toilet' only excites inspectors that mistake it for chlorine gas or direct waste tanks."

Insulation

Natural heating of the contents of the holding tank from bacterial digestion of the waste plus the fact that at least part of the waste stream leaves the source at approximately 95 degrees means that a passive system for ensuring that the tank doesn't freeze may be sufficient in all but the coldest climes. On the other hand, a frozen tank that can't be pumped out until the car reaches Florida may not be a car full of happy

Photo 14 – The new holding tank on the Birch Grove has a conveniently located pumpout fitting. *Photo, September 2003, Sea Island Passenger Co.*

campers so, if you do decide to heat the tank, you'll have all bases covered.

Regardless of whether the tank is heated or not, some form of insulation should be applied. This usually takes the shape of an inch of rubber, insulating sheet, foam board or sprayed-on insulation. Whatever insulation is used, it should have a low coefficient of water absorption, since it is likely to get soaked on numerous occasions.

On top of the insulation, a covering of sheet metal or heavy plastic sheet should be applied to provide impact protection. Attachment points should be pre applied to the outside of the tank at suitable locations, probably by welding, prior to applying any coatings to the tank. If a sprayed-on insulation is used, it may be acceptable to apply some sort of waterproof coating (e.g. epoxy) to it keep it dry and give a modicum of impact resistance, providing you are prepared to repair the odd divot that appears from time to time.

All of the piping to the holding tank should also be insulated with your favorite pipe insulation. Once again, pay attention to the insulation's water absorption coefficient and pick the material with the lowest number. Some of the lower cost insulators are meant to be kept dry, since they will absorb significant amounts of water and turn into a block of ice or, at best, perform poorly.

If you are applying pipe insulating material that requires an outer covering, consider the fact that a 5" diameter furnace pipe makes a pretty good outer covering (pre-formed to the right size) for an inch of insulation applied to the typical 3" waste line. It can be quickly clipped in place via stainless steel wire ties.

Tank Connection

Once the holding or septic tank is completely installed and plumbed up, you may have occasion to roll it out from underneath. Although repairs to waste tanks are not really feasible, there still are other reasons that the tank may need to be removed for service.

If you arrange the connections to the tank in such a way that they can be bolted to the top of it with a flange (Photo 15) then the tank can be unbolted, lowered away from the flanges and slid out from under the car. Alternately, making the connections with a no-hub at a convenient spot will allow the connection to be broken when the tank needs to be extracted.

Photo 15 – All the connections to the Birch Grove's holding tank enter via the top. Disconnecting them would allow the tank to drop down and be easily removed. *Photo, September 2003, Sea Island Passenger Co*.

Maintenance

Just like any other complex system involving compressed air, water and waste handling, pneumatic valves and cylinders, maintenance is required on the Microphor system. If the toilets and their support components are kept in good shape, the system will perform well. If not, you're asking for trouble.

Consequently, it is best to develop a set of maintenance procedures, based on your car's usage patterns, and follow them. Always remember that an ounce of prevention is worth a pound of cure.

Clearing Obstructions

Given the diameter of the toilet's waste line and the size and nature of the objects put into the toilet (especially when cocktails are being served) it is perhaps inevitable that an obstruction will occur from time to time. Here is what Microphor has to say about clearing them:

If the toilet becomes plugged, shut off the water supply, press the flush button or operate the actuator and hold it. The flapper valve in the bottom of the toilet will remain open until the button or actuator is released. Check to see if the restriction can be removed from the ejection chamber with a hooked wire, being careful not to damage the rubber seal on the flapper valve or the mating surface of the hopper.

If the obstruction cannot be picked out with a hook or with tongs, use a toilet plunger, pushing in slowly and pulling out quickly to pull the object back into the hopper.

If necessary, turn the air off and use a small drain snake, inserted into a short piece of plastic pipe, placed in hopper (the pipe will protect the flapper valve rubber and hopper seal from damage). When the passage becomes clear, turn on the water and air and operate the flush actuator to start the flush cycle.

Flapper Seal

The flapper valve seal is very important because it closes off the ejection chamber so that the waste can be blown down the waste line. Keeping it in good condition and the ejection chamber lip clean and free of nicks and cuts is a top priority.

In the original design of the toilet, the rubber ring on the flapper valve was glued in place. It was not uncommon for this glue to fail, in service and for the toilet to flip the ring into the ejection chamber when the flapper opened. Needless to say, this could and did have nasty consequences.

The ring has been redesigned so that it now has eight pigtails that can be pulled through slots in the flapper valve disc. This holds it securely in place while allowing it to be removed for replacement without disassembling the toilet. If your toilets have the old-style ring, you should modify the flapper disc at the next rebuild to accept the new-style rings. Carefully mark the location of the tail holes, using a new ring as a template and drill holes in the disc, as shown in Figure 4.

To change the rubber ring on an in-service toilet: shut off the air and water; push the flapper valve open so that you can get at the rubber ring; pull the tails out of the slots or holes; insert the tails of the new rubber ring into the slots or holes (you may have to rotate the disc to get at all the tails); ensure that the tails are all the way through to give a smooth surface to the rubber ring.

Oiling

Microphor toilets should always be installed with an oiler in the air line, immediately before the connection to the toilet (see Air Supply, above). The oil delivery rate knob should be set somewhere in the middle of its adjustment range and then locked in place. The oiler will reduce the need to periodically disassemble the toilet valves and piston to lubricate with grease.

However, regular maintenance of the oiler is required, with the interval depending on toilet usage. When toilets are first installed, you should check the oilers frequently, to establish a pattern of oil use and then write an appropriate interval into your maintenance procedures.

When the oiler does need oil, shut off the air supply, carefully remove the reservoir and fill to the fill line with a good quality air-tool oil.

You should also check, at this time, to see that the automatic water drain on the FRL is working properly (bowl should have no or very little water in it). If not, remove the bowl, disassemble the drain, clean it and make sure it works. The drain employs a small float that rises up with the water level until it unseats as valve that allows the water to escape. If you add some water to the bowl, you should be able to see it work.

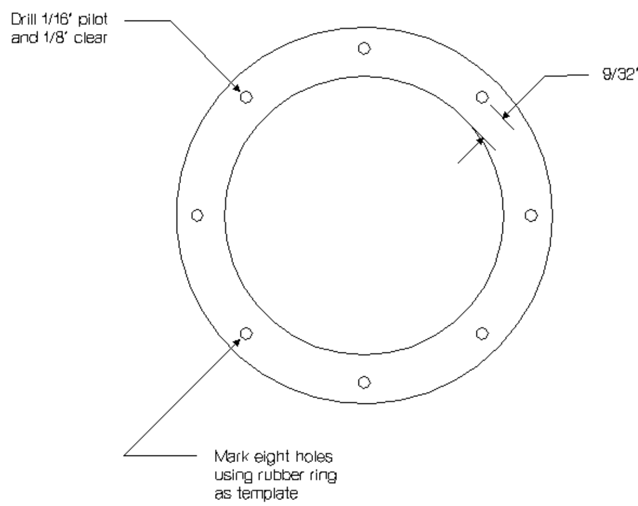

Figure 4 – Modifications to flapper valve rubber ring to accommodate new ring design.

Winterization

When a railroad car will be out of service and off power (heat) during winter months, it should be winterized to prevent freeze damage to the plumbing. In addition to all of the other things that you should do to the plumbing, here are the steps necessary to winterize the Microphor toilets.

Turn off the water to the toilet and flush it several times until water stops flowing into the bowl and all the water or waste in the ejection chamber is ejected.

Follow your usual procedures for draining the rest of the system. If need be, disconnect the water line to the toilet, open the supply valve and allow all the water to drain backwards to the water tank. Don't forget to open the valves on the air line drip legs and elsewhere to allow any condensate to drain out of the air lines.

Valve Lubrication/Rebuilding

Microphor toilets require periodic lubrication with silicone based lubricants, depending on the amount of usage. If they receive light use, lubricate every 5 years. Medium usage requires lubrication every 2-3 years, while heavy usage requires lubrication every year. To lubricate the toilet properly, you need to remove, disassemble and rebuild the air piston, AWS valve and pushbutton.

Personally, I like to replace all of the rubber on the valves when I lubricate and rebuild them, since taking the valves apart is a lot of work. The cost of a rubber kit is minimal, compared to the amount of time involved. You are the judge, of course and it is certainly OK to keep the old rubber if it is in good shape (not worn or cracked and still pliable).

AWS Valve Rebuild

The AWS valve is undeniably the most complicated part of the toilet and the most interesting one to work on. Fortunately, it is not that difficult to rebuild. Microphor has a nice little instruction sheet (part number 24511) that shows how to assemble one of the new style AWS valves (if anyone needs this sheet, I have a scanned image that I can email them). The only thing you **really** need to know about rebuilding this valve is o-rings, o-rings, o-rings. Having said that, let's get into it.

Qty	Microphor Part	Size	Standard Part	Description
1	27011	5/16" x 1/16"	2-011	Air cylinder shaft seal
1	27018	3/4" x 1/16"	2-018	Air cylinder top seal
1	27162	n/a	—	Quad Ring (extended A.W.S. spool only)
1	27205	5/16" x 3/32"	2-109	Ejection chamber crank seal (small)
1	27207	n/a	—	Flapper seal ring
2	27214	1-1/16" x 1/16"	2-023	AWS water seal
1	27215	3-1/2" x 1/8"	2-238	Bowl/ejection chamber seal
3	27217	3/8" x 1/16"	2-012	Pushbutton seal, bottom of shaft (old AWS)
1	27242	7/16" x 3/16"	2-309	AWS water portion
1	27244	1-5/8" x 3/32"	2-130	Bottom of AWS body
6	27250	9/16" x 3/32"	2-113	AWS spool spacer seal, air cylinder piston
1	27251	3/16" x 1/16"	2-008	AWS poppet seal
1	27253	1-3/16" x 1/8"	2-217	AWS piston
1	27270	9-1/4" x 1/8"	2-271	Ejection chamber top/bottom seal
1	27xxx	7/16" x 3/32"	2-111	Ejection chamber crank seal (large)
Wilkerson FRL Rubber				
1	—	1/4" x 1/16"	2-010	Drain seal
1	—	1-1/8" x 1/16"	2-024	Oiler bowl seal
1	—	1-1/4" x 1/16"	2-026	Regulator bowl seal

Table 2 – Rubber list for Microphor toilet and Wilkerson FRL.

There are two styles of AWS valve that you'll run into. The older style valves are pretty much the same as the new style valves, with the seal where the spool exits the top of the valve being the only part that's different. On the older valves, an insert plugs the top of the valve whereas on the newer valves, the valve spool exits the top of the valve. The fact that the valve spool exits the top of the valve necessitates the use of the quad ring in the newer valves whereas it is not needed in the older valves. Conversely, the older valves require an o-ring for the insert whereas it isn't used on the newer valves. The last time I got a rubber kit from Microphor, it had the rubber for rebuilding both types of valves so I had a few parts left over after I was done. If this happens to you and, as long as there's no water or air leaking out of the valve and it works, not to worry.

Since the older valve seems to be the one I've seen on most private cars, we'll look at rebuilding one of them. Table 2 shows a rubber list for all of the o-rings used in the toilet. You can use standard, 70 Durometer, Buna-N o-rings (the standard part numbers are listed) for almost all of them. A few special o-rings (such as the quad ring) may have to be ordered from Microphor but the rest are readily available.

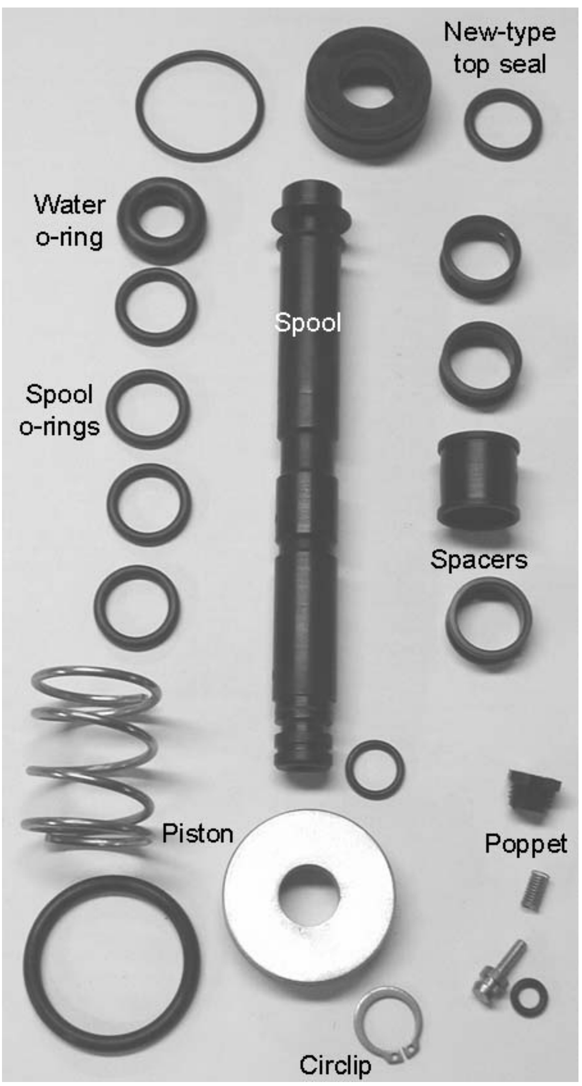

Photo 16 – AWS valve parts, more or less in order from top to bottom.

The AWS valve body comes in four parts. You should be able to unscrew all of them by hand. You can start by removing the top and the bottom of the valve. As you go, pay attention to the order in which the parts come apart. Either lay them out on a flat sheet in order or string them together with a piece of wire so that their assembly sequence is maintained (until you can reassemble the valve by heart, in the dark in 90 seconds, that is – there will be a test).

If you want, you can replace and lubricate the rubber as you go. That way, once you've disassembled the whole valve, you can just put it back together.

The bottom of the valve contains the poppet valve which has one o-ring. Unscrew the small nut and remove and replace the o-ring inside. There is also a sealing o-ring around the outside groove below the threads in the base. The top, depending on which type of valve you have, also has a couple of o-rings that need replacing.

To get the remainder of the valve apart you need a pair of circlip pliers to remove the circlip that holds the piston to the spool. Set the valve up in a vice, upside down (be careful you don't crack it by applying too much pressure) and apply some pressure to the piston with your hand. Using the circlip pliers in the other hand, remove the clip holding the piston onto the spool shaft. The piston should come out under spring pressure (beware of flying parts) but I've seen some that were so corroded that they were welded into the valve body. The piston has an o-ring that has to be replaced.

Once the piston is removed from the spool, you should be able to push the spool up until you can pull it out of the valve body from the top. This will let you unscrew the water body from the top of the valve and pull out all of the o-rings and spacers inside the valve. It is here that threading everything onto a piece of wire to preserve the order especially pays off. Photo 16 shows a disassembled valve's parts, with callouts for the major assemblies. If you run into trouble, refer to this picture.

The thick o-ring on the top of spool is the water valve seal. Due to the thickness of this valve, you may have a struggle to get it off. Sometimes, it is easier to work it down the length of the spool rather than going over the larger diameter stop on the top of the spool.

That's about all there is to it. Replace all the o-rings with like o-rings from your rubber kit. Apply a good-quality silicone based grease to all of the o-rings as you put them in. Reassemble the valve in the reverse order, being careful not to fold over the spool o-rings and pinch them. Make sure the spacers go back in the correct order (start with an o-ring, one small spacer, an o-ring, the large spacer, an o-ring, a small spacer, an o-ring and the third small spacer).

When it comes time to put the piston back on the spool, put the valve body back in the vice and push the piston down with one hand. You may find it helpful to block the spool from moving with something or, if you have three hands, hold it with the third one. Apply the circlip with your circlip hands (too me, this is the only difficult part).

Put the top and bottom back on and you're in business. If you have one of the old style valves, don't forget the insert in the top and its o-ring, otherwise you'll have a miniature replica of the Jet D'eau in Geneva.

Pushbutton Valve Rebuild

The pushbutton valve (or the lever actuator, since it uses the same valve as the pushbutton with a lever attached to it) should be lubricated and rebuilt at the same time as the AWS valve is done. If you think about it, for every time the AWS valve was operated, the pushbutton had to be operated too. Consequently, it will have just as much wear on it as the AWS has.

This valve is simple to rebuild. Grab the spool where it protrudes from the valve body with a thin pair of needle nose pliers so that it can't rotate. Unscrew the button. Then, using your circlip pliers, remove the circlip from the back of the valve. This will allow the small, brass disc to be pushed out by the valve spring.

Once the disc and spring is removed, you can push the valve spool out of the body (see Photo 17). Replace the two o-rings and lubricate them. Slide the spool back into the valve body, pop the spring and disc in place and reinstall the circlip with the circlip pliers. It almost takes longer to read about it than to do it.

Photo 17 – Pushbutton valve disassembled for rebuilding.

Air cylinder

The air cylinder that operates the flapper valve is a key component of the toilet. It must work well and be set up properly to ensure that the flapper valve seals, not just during ejection of the waste (at that point, the air pressure in the ejection chamber is actually assisting the valve to hold the flapper shut) but when the toilet is not going through a flush cycle, since it is then that the pressure exerted by the cylinder is solely responsible for holding the residual water in the bottom of the bowl and making sure that no odors come up through the toilet.

Rebuilding this cylinder is a pretty simple task, as is the pushbutton rebuild. Start by removing the two clips that hold the clevis pin and base pin in place and push the clevis pin out. This will allow the cylinder to be swung up, away from the flapper crank and then slid off the base pin to release the cylinder from the toilet so that it can be worked on.

Remove the clevis and then nut from the cylinder rod. Clean off any dirt, etc. from the rod and make sure the threads aren't torn up or exceeding the diameter of the rod (you'll see why in a moment). Unscrew the top of the cylinder and slide it off the rod. Pull the rod and piston out of the air cylinder.

The air cylinder has three o-rings. Replace them all, lubricate and reassemble the piston. Tighten the top until it contacts the cylinder in a positive manner. Spin the nut onto the rod and we're ready to set up the cylinder.

Set up of the cylinder is the critical step. The distance between the two pins must be set to the precise amount required to keep the flapper valve seal pressed up against the lip of the ejection chamber to ensure there won't be any leaks. Too much pressure and the flapper crank arm can break or the rubber seal become deformed. Too little and the residual water in the bowl leaks away.

Turn the jam nut onto the cylinder shaft all the way and then turn the clevis onto the shaft until the distance, between centers, of the two pin holes is exactly 7-1/4" when the cylinder is fully extended. Once you've arrived at this setting, run the jam nut up against the clevis to lock it in place and recheck the distance. If it hasn't changed, the cylinder is ready to reinstall, in the reverse order from how it was taken out.

Ejection Chamber Rebuild

You shouldn't ever have to rebuild the ejection chamber. If it isn't leaking and the flapper valve is working properly, I'd leave it be. If, on the other hand, you're experiencing leaks or a problem with the flapper valve (unfortunately, due to the high pressure that must be applied to the flapper valve to keep it sealed shut against the lip of the ejection chamber, it isn't all that uncommon to see broken flapper valve cranks), you will need to rebuild the ejection chamber. Just in case you need to do it, here's how.

The first step is to remove the toilet from its installation. Remove the bolts that hold the ejection chamber in place then cut through the butyl caulk that glues the ejection chamber to the bottom of the bowl. You need to free it from the bowl so that it can be disassembled.

While you're at it, scrape as much of the old butyl caulk off and then clean the rest of it away with mineral spirits. The cleaner the surfaces, the better the seal/bond when you put the toilet back together. One note of caution: be careful what kind of solvent you use to clean off the caulking as some of them can dissolve the ejection chamber plastic. Test a small spot first or work quickly.

Before you proceed any further, you may wish to soak the ejection chamber in a bucket of hot water, detergent and chlorine bleach. I find that it makes the task at hand somewhat less onerous. Using a long-handled brush, you can clean the ejection chamber inside and out, while it is in the water. Flush it out with plenty of clean water.

Open it up by removing the bolts or screws around the edge of the seam. Separate the two halves and, if need be, toss it back into the cleaning solution for a second bath. Needless to say, removal of as much residual waste as possible is the goal.

Once the ejection chamber is separated, remove the old o-ring from the groove around the seam and toss it. This o-ring has been compressed for years, probably to the point of plastic deformation so there is no way that it will seal properly, if reused.

The flapper valve crank is pulled out of the flapper by removing the retaining clip an pulling the crank straight out. Replace the two o-rings on the old crank or install them on the new crank, if it is being replaced. Don't forget the grease. Note that the square key goes on the shaft so that the paddle and the crank arm point in the same direction. Photo 18 shows an ejection chamber ready to be reassembled.

If you are replacing the flapper valve disc or just tuning things up, make sure that the clip that pushes over the stud on the back of the disc (which holds it to the paddle) is not pushed up tight. The disc should be able to swivel a little bit so that the disc can find its seat properly and make up for any misalignment between the disc and seat.

When reassembling the ejection chamber, make sure the groove for the large o-ring is clean and that the flat, mating surface is clean and flat. Put the two halves together, using the pins as guides and then bolt or screw them together with stainless bolts/screws (new if necessary). Tighten the bolts/screws in a criss-cross pattern until a firm, positive stop is reached.

The ejection chamber is attached, with long bolts, to captive nuts on the back of the bowl. Due to corrosion, these nuts and/or the bolts may have to be replaced. Hopefully, you've learned by now that stainless is the way to go.

Before the ejection chamber is set in place, an o-ring is fitted into the groove around the opening's rim and a nice bead (perhaps 3/8" – 1/2" in diameter) of butyl caulk is run all around

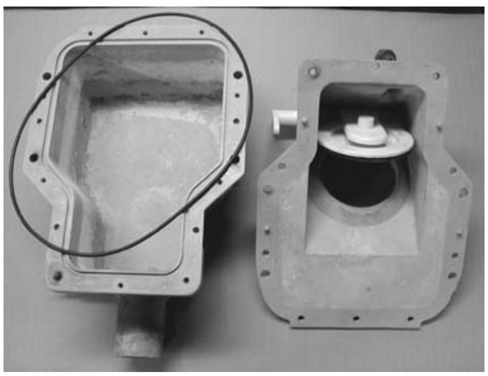

Photo 18 – Ejection chamber, disassembled, showing o-ring and flapper valve.

the surface of the ejection chamber where it meets with the bowl. When the ejection chamber is properly seated onto the bowl, the rim of the exit hole should contact the o-ring and the caulk should ooze out and form a flat seal. Butyl caulk is used, incidentally, since it remains flexible and retains its sense of humor, even as the years of deferred maintenance pile up.

Filter/Regulator/Lubricator Rebuilding

The typical FRL that is installed with a Microphor toilet lasts a long time without any need for maintenance. However, there are three o-rings which may need to be replaced. Two are the seals between the polycarbonate bowls and the third is the valve seal for the self-draining valve at the bottom of the filter bowl. The most common FRL used with these toilets is a Wilkerson and the part numbers for its o-rings are found in the rubber list in Table 2.

While you are changing the o-rings on the FRL, you should check the polycarbonate bowl for signs of cracking, crazing or other defects that may cause it to fail under pressure. If any are found, consider replacing it with a new one. Also, give the regulator a thorough cleaning and refill the lubricator with fresh oil.

Once the FRL is cleaned, has new rubber and is reassembled, that is as good a time as any to check that it is still set up correctly and that the self-draining valve is working properly.

Tips

1) I find it easier to adjust the valve's cycle time first and then adjust water flow second. To ensure uniform removal of the waste from the ejection chamber, the toilet should be adjusted so that the flush cycle is long enough to blow the waste down the pipe to the tank. This adjustment is first made via the needle valve typically protruding from the base of the AWS valve (some installations have them remotely located). Turning the valve in will lengthen the cycle and turning it out will shorten it. Once the length of the cycle has been set to a reasonable value, the amount of water that sluices the bowl and remains behind after the flapper is closed can be set by adjusting the water flow control valve.

2) The new style of flapper disc rubber seal is much preferable to the old style, which was glued to the flapper valve disc. However, if you have an older toilet, you either need to alter the disc (as shown in Figure 4) or replace it altogether, before the new flapper disc rubber can be used. The alteration does work quite well, although it may be more difficult to change a disc on an in-service toilet than it would otherwise be if the new, slotted disc were used. Start at the bottom of the disc, where you can get your fingers behind to pull the pigtails through the holes and rotate the disc as you go so that you're always working at the bottom. This should make replacing the disc possible.

3) As was mentioned in the section on the ejection chamber, butyl caulking should be used for all your toilet caulking needs. It remains flexible during its entire service life and can be removed with mineral spirits or other kind of solvent.

4) O-rings are specified by an industry standard part number (2-nnn). The first digit, before the dash, specifies the material (Buna-N) and the three digits after the dash specify the

size. The first digit after the dash is the axial cross-section of the rubber and the next two digits is the diameter of the o-ring itself. If you need o-rings for any job, Marco Rubber has a nice o-ring sizing chart at: www.marcorubber.com/sizingchart.htm.

5) The environment around toilets can be corrosive on the fasteners used. Personally, I coat all the fasteners, pins, etc. with a film of white lithium grease before I assemble it. It makes disassembly later on much easier. You could also use antiseize compound or pipe compound to prevent seizing. Don't forget to reduce the torque numbers on all the fasteners accordingly (approximately 40% for lithium grease) to allow for the decrease in friction caused by lubrication.

6) Toilet air lines can be cut to any length from a roll of 1/4" nylon hose. However, it is probably not economical to buy more than one color (usually white). The colored tapes used by electricians for marking electrical wiring can also be used to speed toilet hookups. Apply a small square of the tape color next to the fitting on the valve, toilet or cylinder and add a couple of wraps of tape around the hose at each end. During hookup, where everything goes will be immediately obvious.

Jack Heard sent me a great list of tips for Microphor toilets that are hooked to septic tanks. Here's what he sent:

7) **DO NOT** use 90 degree elbows in your waste piping. Only use 45 degree elbows. I had serious backup problems before I replaced the elbows.

8) Try to encourage users to always flush twice, otherwise odor is present.

9) If the car is not in use, try to flush all toilets at least once a week. This keeps the seals from drying out.

10) Depending on the use, it helps to open the chlorine fill inlet and bottom inlet and flush with a garden hose then refill with chlorine tablets. I try to do this before every trip.

11) Of course, do not clean the toilets with any bio-degradable chemical such as Mr. Clean, etc. This will kill the bacteria and render the tank useless.

12) In extreme winter, use heat tape on the pipes and around the tank to prevent freezing.

13) Last of all. **DO NOT** try to run two or more toilets off of one tank, unless the tank is built for more then one. I had a friend that did this and he was always having problems.

Appendix A – Contact Information

Canal Car Company: Rubber kits for Microphor toilets, valve rebuilds – 44 Whitewood Circle, Norwood, MA, 02062, (781)551-0153, www.gntrains.com/CanalCar/

Dixon Valve & Coupling Company: Cam and Groove couplings – 800 High Street, Chestertown, MD, 21620, (410)778-2000, (800)355-1991, www.dixonvalve.com/pdf/literature/CamandGroove.pdf

Energy Solutions Center: Tutorial on air compressors and air distribution - www.energysolutionscenter.org/Learn/Air_Compressor_Tutorial.htm

IR ARO: Valves - Box 151, Bryan, OH, 43506, (800)276-4658, Fax: (800)266-7016, www.arozone.com

Microphor: 452 East Hill Rd., Willits, CA, 95490, (707)459-5563, (800)358-8280, Fax: (707)459-6617, www.microphor.com

Marco Rubber & Plastic Products, Inc.: O-rings, quad rings – 334 Clark Street, North Andover, MA, 01845, (800)775-6525, Fax: (978)688-6915, www.marcorubber.com

RBX Industries, Inc.: Closed cell insulation - RBX Corporate Office,5221 Valley Park Drive, Roanoke, VA. 24019, (800) 782-2839, www.rbxcorp.com

TP Tools: Picture of shop air distribution system - www.tptools.com/statictext/airline-piping-diagram.pdf