Water, Water Everywhere, But is it Safe to Drink?

The quality of water available to those of us who travel in recreational vehicles has always been of concern to us. We remember reading the article by Jay Haynor and Henry Abrams, published several years ago in FMC Magazine, describing Henry's method of sanitizing water. This article particularly intrigued us because it suggested the use of iodine as a biocidal agent. More importantly, the iodine was automatically imparted to the water in a fixed concentration, independent of flow, and by a convenient method. Except for the fact that the iodine and iodide (iodine's negative ion) were not removed prior to ingestion, this system appeared nearly ideal. Iodine and iodide is physiologically active in the human body and, therefore, ingestion should be limited. To date, iodine as a sanitizing agent for water has been recommended only for short-term, emergency use. If a satisfactory method of removing iodine/iodide prior to ingestion could be found, this system could be safely used on an extended basis. It would also offer particular advantages over all of the other biocidal agents commonly available. In particular, it would eliminate the necessity of having to add chlorine bleach to each fresh water fill when municipally treated water was not available. It was inconvenient to add the bleach and we frequently spilled some on clothes that were not yet ready for the ragbag.

We subsequently found a method to remove iodine/iodide , and the system has been in use since 1986. This recreational vehicle water delivery system provides optimal safety, comfort, and convenience. While developing the system we learned a great deal about water contaminants and the limitations of some of the devices frequently employed in an attempt to either purify or sanitize it.

Refer to Table I for definitions and specifically note the distinction between "bacteriocidal" and "bacteriostatic". It is important to realize that any filter advertised to be "bacteriostatic" does not kill any bacteria contained in the source water, and therefore, such a filter cannot be used as a substitute for an effective biocide.

Table I-DEFINITIONS

MICROBE: An organism too small to be seen without an optical or electron microscope. Microbes include bacteria, protozoa, viruses, and fungi.

BACTERIA: One-celled organisms. Most do not require a host organism for reproduction.

VIRUSES: The smallest and simplest form of microbial life, which can reproduce only within a host cell.

PROTOZOA: One-celled animals which are larger and more complex than bacteria. Some types, such as Giardia, cause disease.

FUNGI: Simple, one-celled organisms lacking chlorophyll. Molds and yeast are included in this category and are sometimes found in drinking water distribution mains.

PATHOGENS: Microbes that can cause disease.

BACTERIOSTATIC: Having the ability to inhibit the growth, but does not kill, bacteria.

BACTERIOCIDAL: Having the ability to kill bacteria.

BIOCIDE: An agent that kills microbes.

DISINFECTION: The application of chemicals or energy, primarily to kill pathogenic organisms.

INORGANIC COMPOUND: being or composed of matter of other than plant or animal origin: MINERAL

ORGANIC COMPOUND: of, relating to, or containing carbon compounds

SUSPENSION: The state of a solid when its particles are mixed with, but undissolved in, a liquid.

SOLUTION: A liquid containing molecularly dispersed solids.

TOTAL DISSOLVED SOLIDS: The amount of molecularly dispersed solids in a liquid.

FILTRATION: A process of separating solids from fluids by means of a porous filter medium which retains a majority of particles and allows the fluid to pass through.

WATER PURIFIER: Strictly defined as a device which reduces the treated water to pure H_2O. Functionally, this refers to a device that renders micobiologically safe water. The EPA has defined a microbiological water purifier as a unit which "must remove, kill or inactivate all types of disease-causing microorganisms from the water, including bacteria, viruses, and protozoan cysts, so as to render the processed water safe for drinking." (99.99% reduction of all bacteria, viruses, and protozoan cysts)

MUNICIPALLY TREATED WATER: Water supplied to a community from a common source by a government agency-usually contains chlorine.

POTABLE WATER: Water that is suitable for drinking. Commonly, it is water that has been verified to be biologically and chemically safe for human consumption.

Contaminants in water may be broadly grouped into three categories: organic, inorganic and microorganisms. A specific device best treats each of these contaminants, and no single device is satisfactorily effective in treating all three. The implication of the preceding statement is that the consumer should be wary of purchasing any single product that claims to completely purify and sanitize water.

CONTAMINANTS	*DEVICE OF CHOICE*
Organics	Charcoal Filters (fresh)
Inorganics	Reverse Osmosis
Micro-organisms	Biocide

Table II DRINKING WATER STANDARDS All Values In mg/L Unless Otherwise Noted		
Type of Contaminant	Name of Contaminant	Max Contaminant Level
Primary Regulations Inorganic Chemicals:		
	Arsenic (As)	0.050
	Lead (Pb)	0.015
	Copper (Cu)	1.300
	Fluoride (F)	4.000
	Disinfection By-products (THM)	0.100
Turbidity	Turbidity	Not more than 1 NTU as monthly average or not more than 5 NTU as average of 2 consecutive days
Microorganisms:	Total Coliform	<40 samples/month with no more than 1 positive >=40 samples/month with no more than 5% positive 3 log (99.9%) removal
	Giardia Lamblia	4 log (99.9%) removal
	Enteric Viruses	
	Legionella	
	Heterotrophic Bacteria	
Radionuclides		
• **Natural**	Adjusted Gross Alpha Emitters	15 pCi/L
	Combined Radium 226 & 228	5 pCi/L
	Radon	300 pCi/L
	Uranium	20ugm/L
• **Man Made**	Beta Particles and Photon Emitters	4 mrem/yr-(only systems determined by State to be vulnerable and surface water systems serving >100,000

Tables II and III list Primary and Secondary Drinking Water Standards and Table IV lists Major Contaminants found in drinking water. In order for a water supply to be approved, it must meet primary Maximum Contaminant Levels. Secondary MCL's can be exceeded in an approved supply. The rationale being that the water may have a reduced quality (taste and appearance) but remains safe for consumption.

TABLE III

Name of Contaminant	Secondary Maximum Contaminant Level
Aluminum	.05-.2 mg/L
Chloride	250 mg/L
Color	15 Color Units (CU)
Fluoride	2 mg/L
Foaming Agents	.05 mg/L
Iron	.3 mg/L
Manganese	.05 mg/L
Odor	3 Threshold Odor Number
pH	6.5-8.5
Silver	.1 mg/L
Sulfate	250 mg/L
Total Dissolved Solids (TDS)	500 mg/L
Zinc	5 mg/L

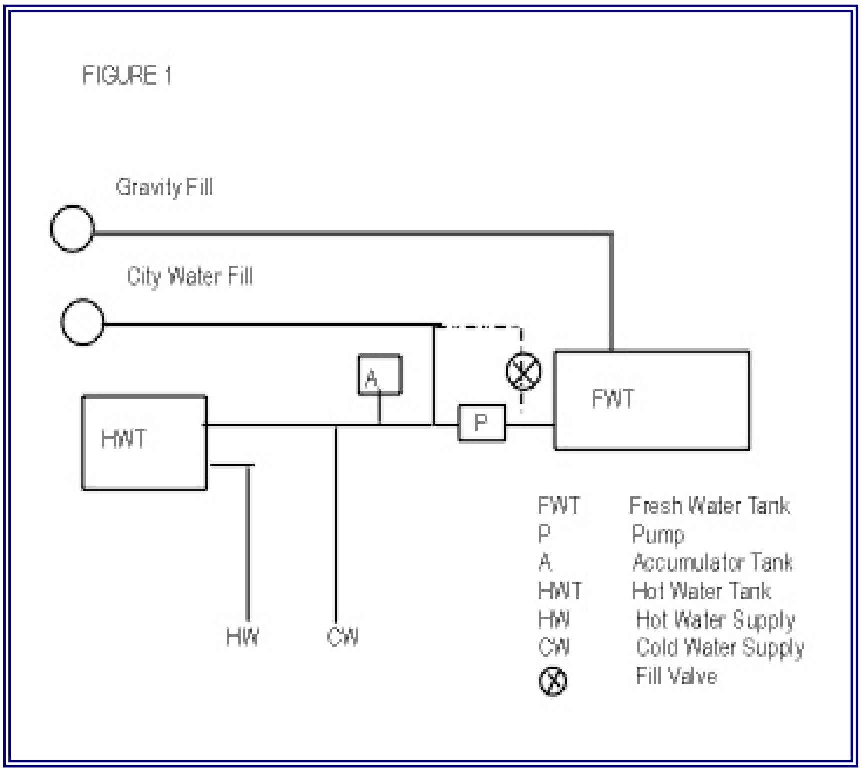
Figure #1 shows a typical recreational vehicle demand plumbing system. More sophisticated systems will use some sort of purification or sanitizing device(s). Those devices used at the fill site are referred to as POE (Point of Entry) devices. Those used at a drinking water faucet are referred to as POU (Point of Use) devices. It is common to see a charcoal filter at the POE. This should be carefully considered. It is important to realize that charcoal filters remove chlorine catalytically and that charcoal acts as an excellent growth medium for bacteria. Once the chlorine is removed from source water, bacterial contamination of the filter media is

TABLE IV

MAJOR CONTAMINANTS OF DRINKING WATER

	Contaminant	Main Source	Health Hazards
Organics:			
	Pesticides	Run-off & seepage in agricultural areas	Liver, kidney, nervous system damage
	Trihalomethanes	End-degradation product from surface water chlorination	Cancer
	Trichlorethylene	Industrial effluent Hazardous waste site	Nervous system damage
Inorganics:			
	Lead	Many municipal water supplies-lead pipes, lead solder	Learning disabilities in children
	Nitrates	Wells in ag. areas	Blood disorders
	Ferrous Iron Manganese Calcium Magnesium	Groundwater	Not known to be health hazard. May degrade taste, odor, color
Micro-organisms:			
	Bacteria Viruses Protozoa-esp. Giardia Lamblia	Inadequate water disin-fection	Numerous diseases, gastro-intestinal disor-ders

unavoidable. With subsequent fills, the water flow carries this contamination into the plumbing system. Anyone who has noted a metallic taste in the water supply has experienced this contamination. Fortunately, contamination with pathogenic microbes does not occur often. This growth within the filter may be inhibited by the addition of small amounts of silver. This results in a "bacteriostatic" charcoal filter. As mentioned earlier, the use of a bacteriostatic filter at this point is not a substitute for an effective biocide.

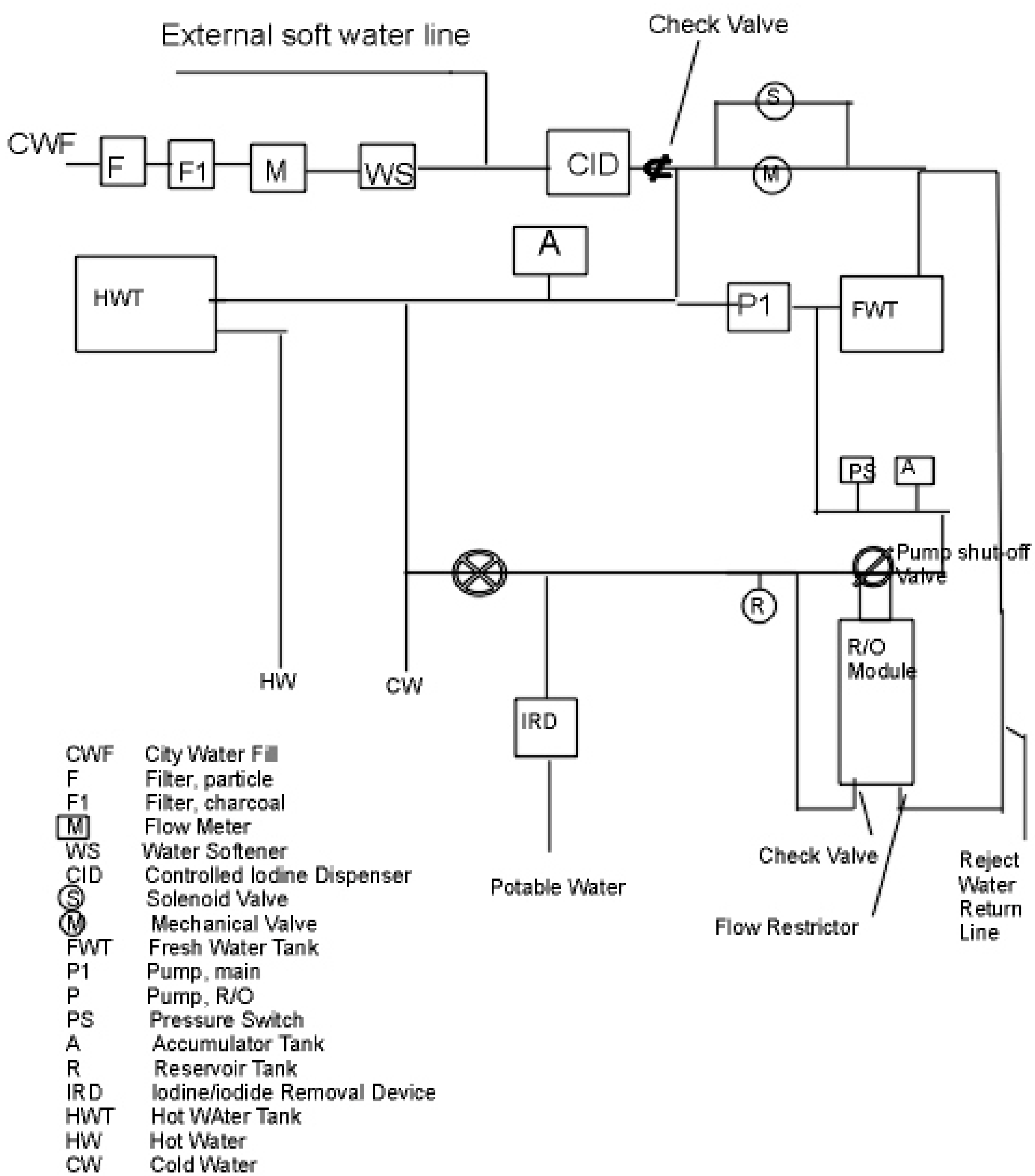


The Everpure System uses a charcoal filter at the POU to remove chlorine from the drinking water. The chlorine, in the form of household bleach, is manually added at the time the tank is filled. This system, if used consistently, does provide protection from microorganisms. In the past, it was not considered necessary to add chlorine if the source water was a municipally treated water supply. However, there are more and more reports of microbial growth being detected in municipal water supplies, presumably because of increased chlorine consumption during travel through pipes contaminated with a biofilm (a film of algae and other microbes lining the pipes).

These methods do not deal with inorganic contaminants, and both are effective in dealing with organic contaminants only if the charcoal filters are changed regularly. The ability of a charcoal filter to remove chlorine extends far beyond its effective life for removing organics, literally to the point at which the charcoal becomes clogged. Once the filter is saturated with organic compounds, further organics pass through unimpeded. Some filters will have a longer life, some shorter. The effective life will also be reduced if the source water is heavily contaminated with organics as might be found in agricultural areas. At the minimum, one should change the charcoal filter according to the manufacturer's recommendations.

Figure #2 shows a recreational vehicle plumbing system that has been modified to provide safety, comfort, and convenience. The modifications require a space of 2’ x 2’ x 2.5’ in coaches with a plumbing bay. Where such space does not exist, the components may be installed in various locations where space for individual components is available. Case in point-the components of this system have been installed in a 27’ coach using nooks & crannies of previously unused space-e.g. under the bed, sofa, and various cabinets.

Figure 2



This system is able to effectively deal with all three categories of contaminants: organic, inorganic, and microorganisms. It provides soft water for personal hygiene, laundry, dishwashing, and coach cleaning. Eliminating the hardness minerals, calcium and magnesium, also reduces scaling in the hot water tank. The potable water has a consistent high quality taste, regardless of variations in source water quality. Recharging the water softener and filling the fresh water holding tank can be automatically done from inside the coach. The addition of the biocide to incoming water is also automatic. Periodic sanitizing is no longer required and total system maintenance is reduced.

Closer scrutiny of Figure #2 reveals the following items installed at the POE: a particle filter, a charcoal filter, a water softener, a flow meter, and a Controlled Iodine Dispenser (CID). At the POU is an Iodine/Iodide Removal Device (IRD). Just before the POU is a Reverse Osmosis unit specially modified for recreational vehicle use. The automatic fill system is represented by the solenoid valve. Water enters through the fill port. This is a city water fill, not a gravity fill. The water then passes through a combined particle/charcoal filter. This combination filter contains a .5 micron particle filter as well as a high quality charcoal element. The function of this filter is to filter out the cysts of Giardia Lamblia and other protozoa responsible for various gastro-intestinal disorders; to remove organic contaminants; and to remove any chlorine in the source water. The chlorine removal will add significant life to the resin of the water softener and the membrane in the R/O Module. The life expectancy of this combined filter is limited to 1,000 to 1,500 gallons due to the 0.5 micron sizing. A separate particle filter and charcoal filter may be substituted for the combination filter. In this case, the particle filter is 5 microns, which can filter out any protozoan cysts. The separate charcoal filter could be used longer than 1,500 gallons if one was not concerned about organic contaminants. Its only effective function the would be to remove chlorine.

Next, water passes through the water softener which uses an exchange resin to exchange positive metallic ions contained in the source water for sodium. These positive ions include calcium^{++} and maqnesium^{++}, which are responsible for hardness in water. Other positive ions, like lead, are also exchanged. This resin must be periodically recharged. The period between recharging varies from several days to several months depending upon the degree of positive ion contamination and quantity of water used. A manually re-charged softener is also available for RV use. In our particular installation, recharging was required so frequently that it became inconvenient. The solution was an on-demand, automatic unit. This unit had the additional advantage of providing storage space for forty pounds of salt, enough for 8-10 recharges. Whenever the coach is connected to a water source, it is possible to activate the recharging cycle from the kitchen. We usually do this at night. The coach plumbing system is not interrupted while recharging is taking place.

Water passes through a flow meter that records the amount of water the system has processed. Up to this point, the water could be contaminated with bacteria or viruses. Water now passes through the Controlled Iodine Dispenser. This device imparts 2-4 ppm of iodine to the water, regardless of flow rate. The useful life expectancy of the dispenser is approximately 18,000 gallons. From this point, the water in the plumbing system contains an iodine residual. Iodine's biocidal activity is well documented. A 2-ppm concentration can kill the extremely virulent Poliovirus with a contact time of 15 minutes. The residual level has the additional advantage of constantly cleansing the entire plumbing system, thereby eliminating the need for periodic sanitizing procedures.

When considering a biocide, there are several available choices besides the Controlled Iodine Dispenser. We chose the CID because it appeared to be the nearly ideal agent once the removal technology was assured. Other choices for a biocide include heat distillation, ultra-violet light, ozone, and the other halogens, chlorine and bromine. The first three were rejected because they provided no residual activity, or were difficult to use for total system sanitizing. If that is not accomplished, the plumbing system requires periodic maintenance. In studies done by NASA, all were subject to recontamination because of this lack of residual activity. In addition, the ultra violet does not seem to be virucidal in all instances. Heat distillation, aside from being cumbersome to use, is subject to having heat-resistant organisms become airborne and travel with the water vapor to the reservoir tank. Bromine was not considered because it is too costly. Chlorine remains the second choice of the biocidal agents and can be used if there is known iodine sensitivity or there is an aversion to using iodine as a biocide. Chlorine does appear to have some potentially carcinogenic end-degradation products. If chlorine is used, a manually operated fill port for injection of household bleach should be placed where the CID unit now exists. In addition, if the R/O option is utilized, a CTA rather than a TFC membrane should be used. (Explained in detail later in this text) The IRD is replaced with a bacteriostatic charcoal filter.

From the CID, water flows either to supply the coach or to fill the fresh water holding tank. The direction of flow is controlled by a check valve. When the coach is connected to city water, we prefer using a combination of the city supply and water from the fresh water holding tank. This is accomplished by keeping the main pump on while the coach is connected to source water at the fill port. Total flow now becomes a combination of that supplied by the pump and that supplied by source water. There are several reasons for this procedure. First, we are able to preserve maximum flow. There is a pressure drop as water passes through the filters, softener, and CID and it is even more noticeable if one uses a pressure reducer at the source to protect the fill hose. Second, if we were to use fill-port water to the exclusion of fresh-water-holding tank water, the iodine contact time would be reduced. Third, as will be shown later, the Reverse Osmosis system will be concentrating the TDS in the fresh-water-holding tank. For these three reasons, namely maintenance of flow and pressure, maintenance of contact time, and maintenance of nearly equal source water and holding tank TDS concentrations; it is preferable to use a combination supply.

If the system is used in the described manner, a convenient way of periodically adding source water to the fresh water tank becomes necessary. This can be accomplished by using an automatic filling device. Activating a switch in the coach turns off the main pump, opens a solenoid valve and fills the tank to 3/4 capacity. At this level, the solenoid valve closes. Thus, when parked with hook-ups for an extended time, there is never a need to leave the coach in order to re-fill the tank.

Water contained in the fresh water tank now passes through the regular RV plumbing system which includes the water pump, the hot water tank, and the hot and cold water supply lines. More elaborate RV plumbing systems use an accumulator tank in one form or another. The modern type of these accumulator tanks has a rubber bladder which has been pressurized and contains a capacity of approximately one gallon absolute (they are often rated at 3.2 gallons). The function of this accumulator tank is to smooth pressure variations in the plumbing system and to cycle the water pump in a more leisurely fashion. If a Reverse Osmosis system is not used, water passes through the valve and through the Iodine Removal Device, to an exclusive drinking water faucet, and ice maker or instant hot, if present.

The purpose of the IRD is to remove all iodine and iodides from drinking water. Thus, what was added to the water supply at the CID is removed at the IRD. The capacity of the IRD is 60,000 gallons. As plumbed in this system, iodine/iodide is removed from only about 10% of the total available water. The excess capacity of the IRD is intentional in order to assure that no chance of iodine/iodide breakthrough could occur. A recreational vehicle plumbing system has the potential for microbial contamination at either the point of entry or at the point of use (faucets). From the point of the CID to all faucets and the IRD in the potable water supply, iodine is present and no possibility of retrograde contamination can occur. With this in mind, the IRD unit is intentionally plumbed as close as possible to the drinking water faucet. The heat of the instant hot and the cold of the icemaker inhibit bacterial growth in those areas.

So far we have shown how the system deals with organic decontamination, water softening, microbial sanitation, and ease of maintenance and operation. However, we have not addressed the problem of inorganic contaminants, one of which is the excess sodium introduced by the water softener. For this we must consider Reverse Osmosis.

Table V compares the characteristics of TFC and CTA membranes and Table VI compares rejection rates of various ions by each membrane.

Table V TYPES AND CHARACTERISTICS OF MEMBRANES

	CTA MEMBRANE	IDEAL MEMBRANE	TFC MEMBRANE
pH	9.0	11.0	11.0
Temperature	85 F	100 F	100 F
Bacteria	Good Resistance	Bacteria Proof	Bacteria Proof
Free Chlorine	Excellent Resistance	Excellent Resistance	Poor Resistance
FLUX	1.5 gal/sq. ft./day	2.5 gal/sq. ft./day	2.5 gal/sq. ft./day
% Rejection	94%	97%	97%
Nitrate Rejection	45-50%	85-90%	85-90%

There are a number of reverse osmosis systems available to the RV consumer. However, it is better to choose one that has been specifically designed for recreational vehicle use. The R/O option shown in Figure #2 has no pre or post filters like residential units. Also, there is a separate pump specifically for the R/O system. There are definite reasons for both differences. The pre-filters are redundant because they are contained at the POE for the entire system. In addition, there are no filters contained between the CID and the IRD. To do so would eliminate the residual biocidal activity of the free iodine, thereby allowing contamination of any charcoal filter that might be placed between the CID and the IRD. Either a pre or post charcoal filter associated with the R/O system would fall into that category.

A separate R/O pump is used because the R/O system requires pressures of 60 to 80 psi which is 20 to 40 psi higher than that of the standard system. Depending upon available space, an accumulator tank ranging between .6-1 gallon capacity is installed. This creates less frequent pump cycling and contributes to a longer pump life. A heavy duty pressure switch is also used for long term reliable operation.

Water is brought from the fresh water holding tank and sent through the R/O Module. The water is pressurized against a semi-permeable membrane. Two types of R/O membranes are commonly used. The TFC (Thin Film Composite) has a rejection rate of 97%, but is very sensitive to chlorine. It has however, provided ten years service with the iodine levels encountered in this system. The CTA (Cellulose Tri-Acetate) has a rejection rate of 94%, but is able to withstand chlorinated water supplies. For every five gallons of water sent through the R/O unit, approximately one gallon of water with 90%-96% of the inorganic contaminants removed, is segregated in the reservoir tank. When the three-gallon reservoir tank becomes filled, it activates a shut-off valve, which causes the pump to discontinue cycling. Normal cycling time is two minutes on and twenty to thirty seconds off. This tank supplies

TABLE VI
NOMINAL REJECTION CHARACTERISTICS OF REVERSE OSMOSIS MEMBRANES

TFC MEMBRANES		CTA MEMBRANES	
ION	% REJECTION	ION	% REJECTION
Aluminum	97-98	Aluminum	96-99
Ammonium	85-95	Ammonium	86-92
Borate	40-70	Arsenic	94-96
Boron	60-70	Barium	96-98
Bromide	93-96	Bicarbonate	90-95
Cadmium	95-98	Borate	30-50
Calcium	95-98	Bromide	87-93
Chloride	90-95	Cadmium	96-98
Chromate	90-97	Calcium	94-97
Copper	97-98	Chloride	87-93
Cyanide	90-95	Chromate	86-92
Fluoride	93-95	Chromium	96-98
Iron	97-98	Copper	98-99
Magnesium	95-98	Cyanide	86-92
Manganese	97-98	Ferrocyanide	98-99
Mercury	95-97	Fluoride	87-93
Nickel	97-98	Iron	95-98
Nitrate	92-95	Lead	96-98
Orthophosphate	98-99	Magnesium	96-98
Phosphate	97-98	Manganese	95-98
Polyphosphate	98-99	Mercury	96-98
Potassium	94-97	Nickel	98-99
Silica	94-96	Nitrate	60-75
Silicate	94-96	Phosphate	96-99
Silver	95-97	Potassium	87-94
Sodium	94-98	Selenium	94-96
Sulfate	97-98	Silicate	85-90
Thiosulfate	97-98	Silver	93-96
Zinc	97-99	Sodium	87-93
Bacteria	99 +	Strontium	96-98
		Sulphate	98-99
		Sulphite	96-98
		Thiosulfate	96-99
		Zinc	98-99

water through the IRD to the drinking water faucet, instant hot, and icemaker. When the R/O option is used, Valve ⊗ remains closed. It should be opened only if there is failure of the R/O system. In that event, potable water is obtained from the cold water supply flowing through the IRD. Water that was not forced through the semi-permeable membrane, reject water, is returned to the fresh water holding tank to be used for non-potable purposes. In this way, for every 100 gallons of water passing through the flow meter, there is 100 gallons available for use. Because the R/O system is segregating drinking water from general use water, the relative concentration of TDS in the fresh water tank will increase slightly, while the potable supply will always remain acceptably low. The increasing TDS measurement is part of the reason for using the fresh water tank even while hook-ups are available. The R/O system can supply at least 15 gallons of potable water every 24 hours.

This system offers a standard water quality regardless of wide variations in source water quality. Other than for periodic filter replacement, it is maintenance free. We use a test kit to measure the free iodine at the kitchen faucet and total iodine (free iodine plus iodide) at the drinking water faucet in order to monitor the CID and IRD components. Usually, a mild iodine odor in the hot water supply is ample indication of the presence of free iodine in the non-potable water. A hand-held TDS Meter can provide an accurate measurement of source water TDS. Water from the Colorado and Rio Grande Rivers are notoriously high, often exceeding federal standards. In addition, TDS measurement of the potable water supply compared to the source water indicates the effectiveness of the R/O system.

During the last thirteen years, we have never had to perform an elaborate sanitizing procedure because the fresh water holding tank is automatically sanitized with every fill. There is no evidence of any microbial growth or contamination in the entire plumbing system. After 55,000 gallons of water, it is clear that using an integrated water treatment system significantly has reduced plumbing component failure and maintenance. Supporting statistics will be included in a future article.

The total cost of this system is around $2,000.00. The iodine dispensers are not widely available, but contact us through this web site for more information.