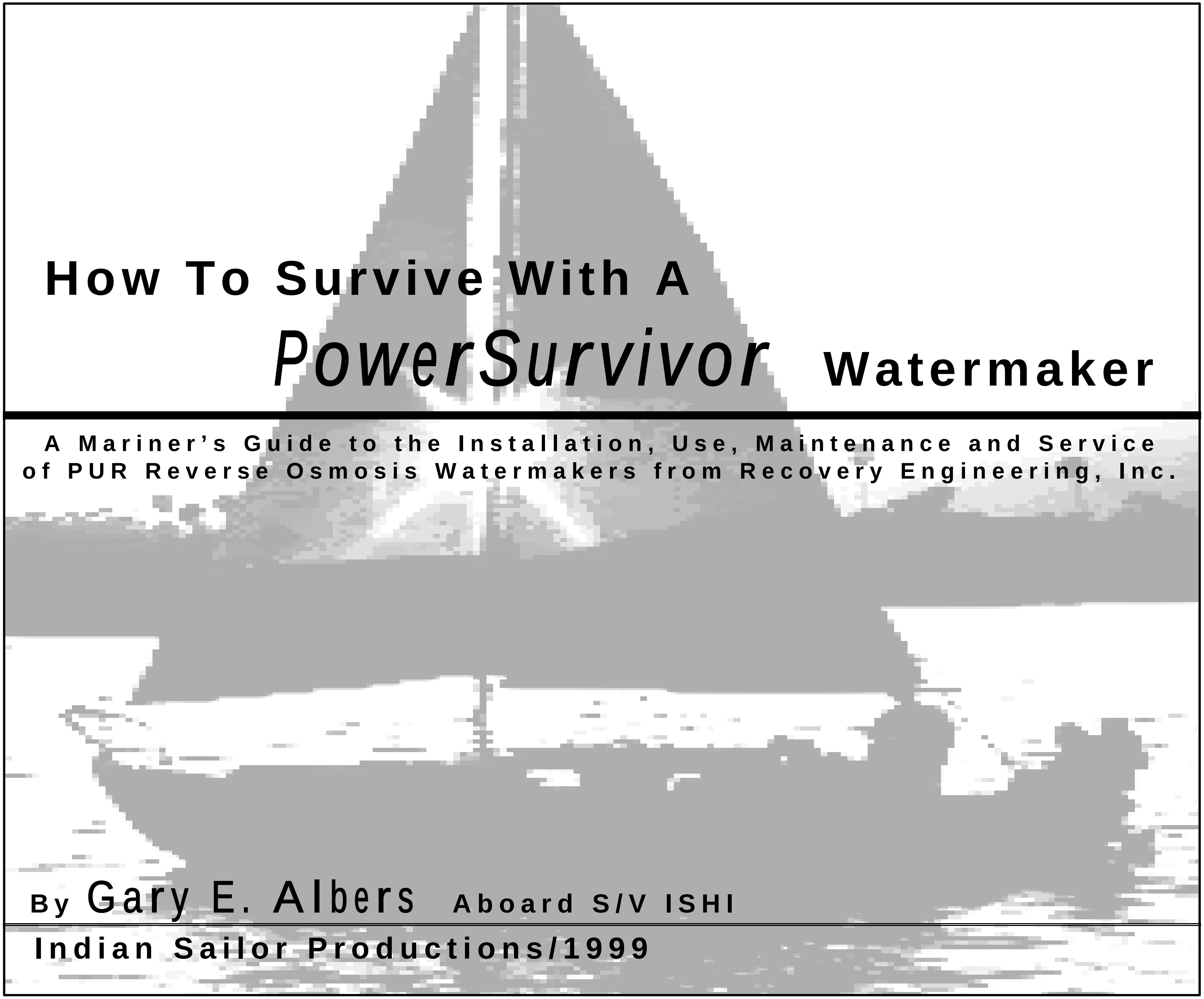

How To Survive With A *PowerSurvivor* Watermaker

A Mariner's Guide to the Installation, Use, Maintenance and Service of PUR Reverse Osmosis Watermakers from Recovery Engineering, Inc.

By Gary E. Albers Aboard S/V ISHI

Indian Sailor Productions/1999

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Composition, digital photos and illustrations by the author.

Disclaimer and Acknowledgments

THIS BOOK is offered on an "as-is" basis. I do not warrant that the information contained in the text and illustrations is fit for any purpose whatsoever except, perhaps, as conversation topics for boat skippers in anchorages, marinas and cantinas around the world. In a nutshell, this is what has and has not worked for me—it may not be appropriate for your situation.

I also want to make clear that this book is not officially endorsed by Recovery Engineering, Inc., the manufacturer of PŪR watermakers,* or any other organization or business concern. It is the product of a sailing cruiser using a word processor somewhere at anchor or underway off the coast of California and Mexico. It is not endorsed, promoted, subsidized, or coveted by anyone else. *Caveat emptor*!

With all that said, I want to thank those cooperative souls whose input to my knowledge base on watermakers made this book conceivable. First, by a mile, is Christian Johnson, recent product manager at PŪR for the PŪR watermaker line. He supported my idea of using a real cruiser to not only instruct and help other cruisers on site, but also to gather valuable feedback for the engineers at Recovery Engineering. Nate Mueller, Johnson's successor at PŪR, picked up the ball and is continuing to support this unique effort.

My thanks to all the good people at Recovery Engineering for their help—especially Tom Amundson, Mark Beckenbach, Dede Cavanaugh, Ron Erickson, Dick Hembree, Rob Lazore, John Lindsay, Alan Lizee, Matt Martin, Dan Pierstorff, Chris Schlough, Sam Sharpe, Debbie Taylor, Mike Trisler, and the inimitable Capt. Jane Ford.

By any metric we adopt, PŪR ***PowerSurvivor*** watermakers are successful products. Part of the reason for that success is feedback from customers—those many sun-tanned, Spanish-learning, power(battery)-hungry cruisers roaming the seas and ports of Mexico. Among those whose knowledge and experience have been of special value to me are Joe Baños (S/V Sea Hope, WA5PHO), Rob Caruso (S/V Dream Catcher), Dennis Lepak (S/V Backstreets, KE6KKL), Tim Schaaf (S/V Casual Waters, KC6GIT), and all the cruisers who attended my "sun'n'beer" seminars along the Pacific Ocean side of Mexico during the last three years.

I also want to express my deepest gratitude to my cruising partner, Teri Damron. Without her constant support and encouragement, there is little doubt in my mind that this book would never have seen the light of day. Good women, good friends and good first mates are hard to find—she has been all of these, and much more.

Although I have written this book with the cruising sailor foremost in my mind, I hope it also satisfies a felt need among watermaker owners in general. Much of the information is of interest to anyone concerned with the use and maintenance of small-scale reverse osmosis desalinators.

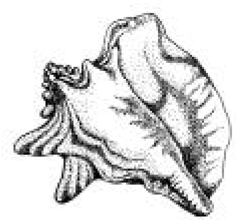
Finally, regardless of the help I've received from many other people, any errors in the following pages are entirely my own original—and unintentional—creations. For these, I profoundly apologize.

—Gary E. Albers

S/V ISHI
La Cruz de Huanacaxtle, Banderas Bay
Nayarit, Mexico

* ***Survivor*** and ***PowerSurvivor*** are trademarks, and PŪR is a registered trademark, of Recovery Engineering, Inc.

To my parents,
William and Naomi Ramsay,
who undoubtedly have wondered
from time to time, why their son,
upon whom they lavished such care,
turned out to be a sailor.



IN RESEARCHING and writing this book, my initial focus was on issues involved in the proper installation, use, maintenance and servicing of the PŪR ***PowerSurvivor 35*** watermaker, manufactured by Recovery Engineering, Inc., of Minneapolis, Minnesota. What began as a personal quest for more information on an important piece of boat equipment soon evolved into a much broader inquiry into the general subject of small-scale, reverse osmosis (**RO**) watermakers and, in particular, their use on cruising boats. The first chapter of this book details many of my experiences and observations during that quest.

In August 1997, Recovery Engineering treated me to a one-week visit to their factory and headquarters in Minneapolis. During that trip I received some training on the new PŪR ***Endurance*** series of watermakers and was allowed to discuss freely any issues I thought were of interest to users of PŪR equipment.

Following that visit, I wrote the first version of this book while cruising and giving seminars in California and Mexico during the winter of 1997-8. It dealt exclusively with the PŪR ***PowerSurvivor 35***. I finished the manuscript in May 1998 and printed a limited number of copies for distribution among the cruisers attending Loreto Fest at Puerto Escondido, B.C.S., Mexico. Fewer than a dozen copies were produced at that time. Later, while we sailed back to Santa Barbara, I decided to delay further publication of the book until I could incorporate information about the PŪR ***Endurance*** series of watermakers: the ***PowerSurvivor 40E***, ***80E***, and ***160E***.

The PŪR ***PowerSurvivor 35*** has been, without doubt, the most popular watermaker for cruising boats during the last decade. It's relatively low price, low electric power demand, small footprint, easy installation, minimal maintenance, manual operation when required, and—perhaps most important of all—lack of competition within its size class, have made it the only logical choice for many cruisers. It is to be hoped that it's successor, the PŪR ***PowerSurvivor 40E***, turns out to be an even better product.

Shortly after our return in June 1998, Nate Mueller, the new MROD (Marine Reverse Osmosis Device) product manager for Recovery Engineering, treated me to a second factory visit. During that trip, I was able to learn more about, and document, the ***Endurance*** series of watermakers. The result—the present book—includes, therefore, information on the entire current line of PŪR ***PowerSurvivor*** watermakers. This is the more appropriate because production of the popular PŪR ***PowerSurvivor 35*** has been discontinued.

If Recovery Engineering can be faulted, it is surely for the shortcomings in both the accuracy and content of their support documentation. Although PŪR ***PowerSurvivor*** watermakers come closer to being "turn-key" systems than many competitors' products, they still require intelligent use and some periodic maintenance to keep them working well. With a little additional knowledge about the equipment and RO technology, most problems encountered by users of watermakers can be solved—if not avoided altogether!

Practical and affordable RO watermakers are among the many new technologies that are revolutionizing the cruising lifestyle. Although this book describes PŪR watermakers in specific detail, much of the information is of a general nature and should be useful to anyone using a watermaker, regardless of the brand. When properly applied, reverse osmosis is a marvelous—and dependable—technology, and a very welcome addition to the cruising sailor's on-board equipment.

It is my hope that, by taking the extra time to make this book more inclusive, I have extended its usefulness well into the future. In addition to meeting an existing need among the thousands of legacy PŪR ***PowerSurvivor 35*** owners, it should appeal to the growing ranks of purchasers of the new ***Endurance*** series. I will continue to gather data and seek information from the factory in preparation for a future edition.

The first printing of the first edition of this book was identified as "Draft Edition 2 — 1998." For this second printing, this Preface was rewritten and there were several changes on the title and copyright pages. The main body of text is identical to the first printing, with the exception of a few minor, mostly typographical, corrections that were made. In particular, all previous references to Recovery Engineering, Inc., as "REI" were replaced by "PŪR" or "Recovery Engineering" as the context warranted, due to potential copyright conflicts.

—Gary E. Albers

June, 1999

In the Beginning…

AT THE END of January 1996, my partner Teri Damron and I finally cut the cord and took off cruising in our 34´ Aloha sloop, ISHI—destination: Mexico. It was the long-awaited consummation of a dream we had shared for almost two decades. ISHI and our relationship were the last of many boats and other partners through the years and we set sail thinking we had finally gotten it together—and together right!

Among the high-tech equipment aboard ISHI were a GPS, VHF and SSB/Ham radios, radar, two computers, weatherfax demodulator and software, knotmeter and log, depth sounder, seawater temperature gauge, autopilot, 1000W inverter, 1000W generator, bread machine, recreational electronics…and a PŪR ***PowerSurvivor 35*** watermaker. With the possible exception of the bread machine, this was a fairly typical selection of equipment found on many modern cruising sailboats.

The watermaker was nowhere near the top of our priority list as we doled out thousands of hard-earned dollars to outfit the boat with the things we wanted or thought we needed. Our many years spent as full time liveaboards and sailors guided our choice of gear for the boat. As an FCC-licensed marine electronics technician, I evaluated our electronics purchases with confidence. We both agreed that radar was a priority item, having experienced some near misses with freighters in the fog. Radar also allowed us to consider more night landfalls. We felt compelled to install ham and SSB long distance radio communications to lessen the concerns of parents and relatives, some of whom believed we were about to sail off the edge of the earth.

To be honest, we didn't give a lot of early thought to the problem of obtaining water while cruising. When we finally discussed the issue, a machine that could make all the water we needed from seawater seemed like a very useful device and we added it to our list of items to install. At the time, we considered it to be a luxury—something we could do without, but would be nice to have. We balked a little at the $2000+ price tag for a watermaker and extended cruising kit.

As it turned out, our watermaker quickly became an indispensable component of the free lifestyle we were able to develop. During the next three winter/spring seasons of cruising Mexico, we spent only two days in a marina and never once took on a drop of water.

Trouble in Paradise

Sometime in the late spring of 1996, as we were preparing to sail back up the coast of Baja California to wait out hurricane season in the northern latitudes, I stumbled across a letter to the editors of *Latitude 38* written by Christian Johnson, then product manager for PŪR watermakers at Recovery Engineering, Inc. Johnson was responding to a letter critical of PŪR watermakers and Recovery Engineering's customer support. Among other things, he stated his concern and his company's desire to support their products. The *Latitude 38* editors appended a lengthy comment to Johnson's letter, in which they listed a series of problems they had encountered with their PŪR ***PowerSurvivor 80*** and complained of poor factory support. I remember being surprised that there seemed to be many people with complaints against ***PowerSurvivor*** watermakers. That was the brand of *our* watermaker!

We were just finishing a six months tour of the Pacific Ocean side of Mexico and had used our ***PowerSurvivor 35*** for *all* of our water. It was still performing well. Sometime in June, while anchored at Cabo San Lucas for a few days before starting the long sail back to San Diego, I had the opportunity to discuss PŪR watermakers and the *Latitude 38* letters with several other watermaker owners, including Tim Schaaf on S/V Casual Water. Tim had owned and used a ***PowerSurvivor 35*** for several years while sailing his boat in the Cabo San Lucas/La Paz area and it was still turning out good water. More important, Tim was highly intelligent, well educated, and wanted to thoroughly understand every piece of equipment on his boat. He knew more about those watermakers than anyone else I had met. It was Tim who filled me in on the content of some earlier letters published in *Latitude 38*.

I never read any letters prior to Johnson's "apologia." I understand that a particularly damaging one was from a cruiser who claimed to have conducted an informal survey of other cruisers with PŪR watermakers. In summary, his results indicated that a substantial number of ***PowerSurvivor*** owners were very dissatisfied with their watermakers.

Whether or not the author of that letter intended any malice toward Recovery Engineering is a moot point but, as a direct result of their comments, there were many derogatory rumors circulating among cruisers during the winter of 1996 as to the functionality of ***PowerSurvivor*** watermakers. By early summer of the same year, almost every cruiser I met had read—or, more often, "heard of"—that infamous survey letter about ***PowerSurvivor*** watermakers.

After discussions with Tim Schaaf and others who had used ***PowerSurvivor*** watermakers with few problems for considerable periods of time, I suspected that the real issue was not a poorly engineered product. I thought that most problems were likely to be caused by poor installations and improper maintenance. Those are the main reasons for almost every other kind of equipment failure on a boat—why not also for watermakers?

In late June, just before reaching our homeport in Santa Barbara, California, our watermaker failed! It quit producing product water. A few days later, after tying up in our slip, I broke out the watermaker manual and repair seal kit and prepared to take apart our watermaker for the first time. Tim Schaaf had told me it wasn't difficult, given a reasonable amount of mechanical ability and good work habits.

Following the manual word-by-word, I carefully disassembled the pump and examined each part, o-ring and seal with a 10X magnifying loupe. Soon I found a broken spring under one of the poppet valves. This defect was more than sufficient to explain the failure and I was delighted to have found the cause so easily. After meticulously cleaning everything, I greased the new seals with silicon and put it all back together, remembering Tim Schaaf's caution about overtightening the manifold fasteners. In a matter of two hours, I had completely disassembled, troubleshot, repaired and reassembled our PŪR ***PowerSurvivor 35*** watermaker.

I bolted the pump onto the drive assembly and returned the entire unit to its designated home under our cockpit combing. A few minutes later, the hoses and electrical connections were restored and our ***PowerSurvivor 35*** was running better than ever. Since we were inside the Santa Barbara harbor, I ran it only long enough to be certain that it was again producing good, potable water.

Tim Schaaf had told me I would have to replace the seals periodically—perhaps every 500 to 1000 hours. Beyond that, with proper attention to the condition of the prefilter element, there was virtually no other maintenance involved. We had made all of our water for the last six months and I quickly calculated that, at a consumption rate of 5-6 gallons per day, we were well beyond the 500-hour mark for watermaker use.

Replacing the seals in the pump once or twice a year was not an unreasonable price to pay for the luxury of having a dependable water supply. New poppet valves and springs were part of the seal kit. The broken spring was obviously a part that wears and would need replacing periodically. On the other hand, I had talked to another cruiser who also had discovered a broken poppet spring. Was that just a coincidence?

The PŪR *Connection*

Later in the summer of 1996, we were preparing to leave for Mexico again in November. Included in that process was an afternoon spent calling distant vendors to order replacement parts for boat equipment. Recovery Engineering was on my list. We needed a new seal kit, having just used the existing one.

On an impulse, when the receptionist answered, I asked to speak with Christian Johnson, then product manager. After a couple of rings, he answered. Much later, I discovered how lucky I was to catch him in—Christian Johnson was a dynamic manager who wore many hats and spent little time at his desk.

I explained that I had called to order some replacement parts and thought I'd offer my comments on the letter he'd written to *Latitude 38*. Yes, he was interested in hearing my thoughts. I told him I thought his letter to *Latitude 38* was well written and convincingly sincere; I thought the magazine's editors had been too one-sided in their comments; that we had used a ***PowerSurvivor 35*** for the whole cruising season with excellent results; that I knew others who had used their watermakers for years with no complaints; and finally that, as a professional technician, experience led me to suspect most problems were caused by user errors.

Christian Johnson had probably braced himself for a diatribe when he took my call. I sensed relief in his voice when he said something like, "Thank you. We think so too." The problem, he went on to explain, was what to do about it. It was clear to me that he believed in Recovery Engineering's products and was willing and able to defend them. He also convinced me that he and the rest of the staff were eager to help any customers who were having problems. At the same time, he'd been frustrated in recent attempts to deal with negative rumors about the company and their product, especially among cruisers in remote parts of the world—like Mexico. The main problem was one of communications—between the support staff of a small company in Minneapolis and their customers on cruising yachts thousands of miles away in the distant reaches of the world.

I thought I could be of some help. It wouldn't be hard to contact other cruisers in each area we visited. All that was needed was an announcement on the local VHF nets, saying that I was available to help people with their ***PowerSurvivor*** watermakers. I could learn what kind of problems cruisers were having and relay that information back to the factory. However, before I made such a suggestion, I decided to fathom Christian Johnson's sincerity.

I told him that several people had trouble with their poppet springs breaking. Was there a problem there? Yes, he admitted, early pumps and seal kits had springs made of a material that could corrode. Newer springs were made from a different alloy. He would provide replacement springs for free. O.K., I thought. That seems reasonable and up front. Engineering mistakes do happen—such problems are normal and to be expected. If the errors are few in number and a reasonable effort is made to track and correct them, there is little room for criticism. I discussed some other installation and maintenance issues with him and felt I got honest answers. I was impressed that he was willing to spend so much time on the telephone with me.

Believing in Johnson's sincerity and integrity, I finally volunteered my plan. I told him we were returning to Mexico for a second season and I would inquire among the cruisers about the kinds of problems they really were experiencing and be a kind of "evangelist" for PŪR watermakers. I felt I could adequately diagnose and correct many of the problems I would encounter, especially if my suspicions about poor installation and maintenance being major culprits proved correct. I said I would let him know what I discovered. I felt Recovery Engineering was being unjustly maligned in the cruiser literature and on the rumor grapevine, and I wanted to get to the bottom of the story, if only to satisfy my own curiosity.

Before I could ask Christian to transfer my call to the parts order desk, he thanked me enthusiastically for my willingness to contact other cruisers. If I were willing to do that, he asked, would I also be willing to take along some repair parts, in case they were needed? Why, yes, I said, I suppose I could do that. He said he'd have them shipped immediately. They'd be in Santa Barbara within two days. We agreed to keep in touch.

When our conversation ended, I decided I wouldn't need the order desk. I hung up the telephone and thought about who was doing whom a favor in this matter—the parts I had intended to order would have cost several hundred dollars. Now it seemed like I'd be getting them for free.

In a couple of days, a six-foot high stack of boxes arrived at our small harbor mailbox from Recovery Engineering, Inc. I lugged them down to the boat, wondering where I could possibly stow so much stuff. After unpacking them, my concerns evaporated. In all those boxes there were a dozen seal kits for the ***PowerSurvivor 35***, a half-dozen seal kits for the **Model *80***, a dozen prefilter cartridges, lots of biocide and cleaning chemicals, a cleaning housing for the **Model *35***, and a generous handful of silicon grease ampoules. Except for the cleaning housing and prefilter elements, I was able to repack all the parts and supplies in one medium-sized box.

As I gazed at the mountain of disused cardboard boxes and popcorn packing, I cursed that part of corporate America that does things that way. I slit the tape on all the boxes, flattened and stacked them in a neat pile near one of the trash bins on the dock, hoping that someone else would have a use for them. I calculated a very rough estimate of the value of all the parts: perhaps a thousand dollars?

The Return to Mexico

We lingered in Santa Barbara just long enough to vote in the elections and took off for Mexico the following day, early in November 1996. We'd already seen much of the chilly, barren, western Baja California coastline so, when we left San Diego after a final provisioning, we sailed straight out around Isla Cedros and down to Cabo San Lucas in six days. I prefer going offshore for several reasons: more consistent wind and sea states, avoidance of fishing boats and commercial traffic, and the comfort of being far from any potential lee shore. (It's nice not needing to make landfalls to take on water during long passages!)

The day after arriving in Cabo San Lucas, I announced on the morning VHF cruisers' net that I was in the area and was being sponsored by PŪR to answer questions and help people with any ***PowerSurvivor*** watermaker problems. I didn't know what to expect. Would I get a flurry of angry watermaker owners ready to vent their spleens on me? I held my breath….

Only one boat responded with a problem. His watermaker was new and was leaking and not producing product water anymore. He estimated it had worked well for about twenty hours. Would I take a look? Yes, I would. He was anchored nearby in the bay. I took our Avon dinghy over to his boat and met the skipper and his lady—a nice young couple, excited about their first cruise. However, the watermaker had failed. The skipper had bought it mail order and installed it himself. He assured me it had never been out of the package before he got it and they had not attempted to work on it. It seemed to work for the first few hours and then had started leaking.

Given my bias and lack of experience, I immediately suspected the installation. But, no luck. Their installation was clean and well plumbed—a quality job. As I applied logic to the problem, it became harder to think of *any* installation error that would cause the pump to leak. I bit the bullet and told him I thought there was something wrong with the pump itself. We'd have to take it apart, replace the seals, and hope to find and/or cure the problem in the process. I said that I could do it for him, but I was willing to supervise and train him to do it, and I would do that for free if he were willing to help and learn. He readily agreed to that arrangement.

He disconnected his watermaker, placed it on a large cloth, and we went at it. I had him follow the manual word-by-word while I watched. I had learned a few subtle tricks and I passed these on at the appropriate times. First, he unbolted the drive unit from the pump assembly. Then he removed the manifold and found nothing wrong. The o-rings looked new, but we replaced them anyway.

The next step involved dismantling the pump body. Using an open-end wrench, he loosened the four large hex nuts on the long stainless steel studs that hold the pump housing sections together. Underneath each nut was a single washer—except there were *two* washers under one of the nuts! All four nuts bore down on the thick metal gland plate that supports the back of the pump body. I asked if he was sure it had never been taken apart and he assured me it hadn't been. It looked as if I'd stumbled on a factory assembly error. The uneven pressure that would be applied to the gland plate—when the drive unit flange was recoupled to those four studs and the nuts tightened—would be considerable, and very likely to distort the plastic pump housing.

We continued with the rebuild and I had him put only a single washer under each nut during the reassembly. Then he tightened the large hex nuts down on the studs with the ½" wrench…and, man, did he tighten! It was quite natural to want to tighten down on such large nuts. However, as I watched him lean on the wrench, I thought I saw the pump body flex. It was done before I could say anything, so I let it go and the reassembly was soon finished.

I left him to reinstall and check it out. An hour later he called on the VHF and said it leaked worse than before. I told him I thought I knew what was wrong and had him bring the pump assembly back to me.

That evening, while listening to Jimmy Buffet, I carefully took apart and reassembled the defective watermaker. I worked slowly, cleanly, and with gentleness—*especially* on those large hex nuts. I realized that all they do is hold the parts of the pump body together under the strains of developing 800 psi. They don't seal anything by their compression when tightened—the rubber seals and o-rings do that. All that is needed is to tighten the nuts finger-tight and then about a quarter-turn more with the wrench and you're home free. Tightening much more than that, like the cruiser had done, will distort the plastic pump body and greatly increase the chances that the manifold o-rings will not seat properly. Then the manifold would leak like a sieve. In a worst case, the pump body could be permanently deformed or cracked.

In the morning, I delivered the reassembled watermaker to their boat and soon heard that it was working fine—and not leaking! I admit to feeling good about that first experience with a cruiser in trouble. I'd solved his problem for the moment and gained a valuable piece of information to echo back to the factory.

And echo I did. I faxed Christian Johnson the serial number of the watermaker and told him what I'd found. Would their QA (Quality Analysis) system be able to isolate this error? One disgruntled assembler could cause a lot of bad product. I leaned on Christian pretty hard and I'm certain he took it seriously.

I was troubled by the fact that the very first watermaker problem I encountered in Mexico appeared to be a factory assembly error. The cruiser's rebuilt watermaker worked well for the rest of the cruising season and then failed again. When the owner contacted me from Mexico via SSB radio, I recommended to the factory that he be given full credit for his ***PowerSurvivor 35*** against any new watermaker he wanted. He elected to get a new ***PowerSurvivor 160E Endurance*** model (6.7 gal./hr.) and has subsequently installed it. It's running well in the Sea of Cortez.

I suspect the initial distortion of the pump body by the extra washer caused enough misalignment of other parts to result in damage to the piston and/or cylinder assemblies inside the pump. For that reason, I recommended (and PŪR granted) full credit under the factory warranty.

The following summer, when I visited Recovery Engineering, I had a chance to describe the extra washer problem to the assembly workers and foremen. They agreed that it sounded like an assembly error and would be likely to cause damage and a malfunction. They were also chagrined at the thought that such a unit had slipped out of the factory. When I left, it was with renewed confidence in the PŪR assembly staff.

Recovery Engineering Inc. Meets the Cruisers

We spent a few days in Cabo San Lucas seeing old friends and then sailed across the Sea of Cortez to San Blas, Nayarit, on the Mexican mainland. Again I announced my evangelical mission for PŪR and got no responses. However, as usual, there was only a handful of boats in San Blas.

It was not until we reached Banderas Bay that we drew a crowd. When I first announced my mission on the local VHF net in Banderas Bay, there was a chorus of responses. Banderas Bay includes many popular cruising areas: Puerto Vallarta, Yelapa, La Cruz de Huanacaxtle, the Tres Mariettas Islands, Punta de Mita. Between the spacious anchoring spots and two large marinas, there are usually several hundred boats in the vicinity. Out of all the cruisers responding to my VHF offer, I sorted out the few who actually had problems to report. It was a relief to discover that most of the responses were from people interested in more information about their watermakers and only a few had real problems.

I helped a couple of cruisers with some unusual, self-produced problems and soon decided that the cruisers in the Banderas Bay area would benefit from a visit by some people from Recovery Engineering. I proposed to Christian Johnson that he consider coming to Puerto Vallarta to give a seminar and personally meet some of his customers. He agreed and on March 15, 1997, Christian and one of the company engineers, Dan Pierstorff, hosted a well-announced gathering at Time Changers Restaurant in Marina Vallarta.

Approximately thirty-five people attended the seminar. There were many questions about installation and maintenance issues. One especially vocal boat owner insisted that his ***PowerSurvivor 35*** was no good. It had quit producing product water. Upon questioning, we learned that he had been running his watermaker for the previous six months while in a slip in Marina Vallarta. He was surprised to learn that his RO membrane was probably ruined due to harmful impurities in the dirty harbor water. That piece of information *is* in the owner's manual, which the man with the problem hadn't bothered to read.

Over dinner, I discussed the seminar and my experiences with Christian and Dan. I informed them of the problems I had found. They assured me they would support me with repair parts and an open communications line to anyone I needed at the factory. They also arranged to have Dave, the owner of Time Changers Restaurant and a diesel mechanic, handle warranty repairs in Mexico.

One of my recommendations was to have repair parts stocked at key locations on the coast of Mexico; e.g., Puerto Vallarta, La Paz, Cabo San Lucas, Mazatlan and, perhaps, Acapulco. Getting replacement parts shipped into Mexico from the United States in an economical and timely manner is very difficult, if not impossible. By the time Christian and Dan flew back to the United States, they had gained a lot of valuable insights through their efforts to meet some cruisers on the latter's own turf.

The Sea of Cortez Crowd

With Christian back in Minneapolis, the rest of the cruising season in Mexico was up to me. I continued to announce my mission everywhere we went. After a few months, people began to know me as the "PŪR watermaker guy" and the word was out on the grapevine that Recovery Engineering had someone in Mexico investigating problems and helping cruisers by giving seminars. As I gained experience in dealing with problems and questions, I was becoming even more convinced that most problems were caused by bad installations and/or poor maintenance or misuse of the equipment. Finally, in April, I was ready for the big test—La Paz!

La Paz is one of two major areas where cruisers intending to spend the summer in the Sea of Cortez congregate in the spring. Mazatlan is the other. The Sea of Cortez Race Week in La Paz is another strong attraction in April. We managed to be there. I got a chance to meet quite a few cruisers with questions when I gave a seminar at the Barba Negra Restaurant a few days before Race Week began.

We attended the Race Week activities at Caleta Partida and gave a second seminar there aboard a trimaran. I demonstrated the rebuild process, working on two cruisers' watermakers. A couple of the people attending owned a different brand of watermaker and had come for general information. Almost 150 boats took part in Race Week and all were advised of the seminar. There were many who were accustomed to spending their summers in the Sea of Cortez. I began to wonder where all the disgruntled owners of ***PowerSurvivor*** watermakers were hiding. About a dozen cruisers attended the Race Week seminar.

Back in La Paz after Race Week, I held a final seminar at the Barba Negra, attended by another dozen cruisers. In addition to answering questions, I used one of the cruiser's watermakers to demonstrate how to replace the seals. Then it was off for Cabo San Lucas and the long sail north to the United States. We had covered many of the major ports and anchorages along Baja California and the mainland coast from Cabo San Lucas to Manzanillo, looking for watermaker problems, questions and comments. In the process, I discussed watermakers with over a hundred cruisers and solved an array of problems. In general, I discovered that the vast majority of cruisers with PŪR ***PowerSurvivor*** watermakers were a "silent majority" who were quite satisfied with their equipment.

Back in the U.S.A.

We returned to Santa Barbara and immediately began making our plans for the next season. After two winters in Mexico, we were finally satisfied with the boat, our equipment and our knowledge. I wrote up a report detailing the seminars, troubleshooting and repairs I had done in Mexico and sent it to Christian Johnson.

A few days later Christian called and invited me to visit the company in Minneapolis—for some training and "to talk." Who was I to say no? Late in August I boarded a plane and headed east over more land than I'd seen in years. They even routed me through Chicago so I could see my oldest daughter and meet my new son-in-law for the first time. (They were married while I was in Mexico.)

In Minneapolis, I was introduced to everybody from top management to the newest shipping clerk. Of special value was the access I was given to key people in the watermaker line—the head design engineer, the top troubleshooting and repair techs, the guy who has the job of shipping parts to remote areas of the world. I asked questions, listened, and learned a lot in a short week. They listened too.

My background in engineering environments allowed me to sidestep what I call "marketing issues" and get to core technical questions; e.g., does the biocide, an antioxidant, cause crevice corrosion of the internal stainless steel components of the pump? Does the watermaker really need to be mounted below the waterline? How long does a membrane live? What can a user expect in high salinity water? How long do seals and other working parts last? Is a TDS meter needed…?

I was particularly edified to learn that, since my seminars in La Paz in April, problem calls to the factory from the Sea of Cortez had dropped to almost zero. This seemed to confirm my belief that many problems were due to poor installation and/or improper use and maintenance. Given a threshold level of information about the product and its proper utilization, problems tended to disappear.

I was able to get a frank answer to almost every question I could think to ask while at Recovery Engineering. In the end, we reached an agreement on a future relationship. I would be available to PŪR personnel as a cruiser-consultant on their watermakers. I would also give a series of seminars and demonstrations at marine stores along the California coast from September to November 1997. After that, I would continue my evangelical work in Mexico.

A Lesson to be Learned

I hope by now it is clear that I believe Recovery Engineering produces a good watermaker. The company is composed of mostly young, energetic midwesterners who believe in what they're doing and try to do it well. However, having a *good* product and having a *successful* product are two distinct things. Recovery Engineering is a rapidly growing company and has experienced some of the pains that accompany success.

For example, during periods of expansion, not everyone hired is guaranteed to be a winner, and a loser in, e.g., customer or tech support can do a lot of damage to the corporate image in a very short time. One technician at a warranty repair station recently complained to me about the "uneven support" he had received from the company over the last few years. "So-and-so was always helpful, but then he left and the new guy was lousy…."

Despite the extremely low warranty return rate of PŪR watermakers (about 2%) and a strong desire to address any legitimate complaints, the logistics of providing service and parts to cruisers in foreign countries are daunting. I know that establishing a workable network of repair/parts facilities outside the U.S. is a top priority for the product manager.

By now I've heard most of the "bad news" about ***PowerSurvivor*** watermakers, whether the source be letters in *Latitude 38* (the West Coast cruiser's Bible), an article in *Santana*, or the drunken testimonial of some skipper under a Mexican palapa. At the same time, I've made a substantial effort to explore the real situation—by visiting both the company and the customers. I hope what I've learned will be of value to other owners of ***PowerSurvivor*** watermakers.

The comments in the following pages are a composite of some "inside" knowledge, lots of actual experiences with cruisers, and my own practical and technical take on matters. I disagree with the "company position" on several important issues and make no bones about it. Here and there, I will also make suggestions for improvements in their products that some may label criticisms. I'm convinced that Recovery Engineering will listen to such comments with a view toward improving an already excellent product line.

In fact, at the time of this writing, the ***PowerSurvivor 35*** and original **Model *80***s have been discontinued by Recovery Engineering. Replacing the ***PowerSurvivor 35*** is the new ***PowerSurvivor 40E***, the **Model *80*** has been supplanted by the ***PowerSurvivor 80E***, and a new, larger-capacity model—the ***PowerSurvivor 160E*** (6.7 gal/hr)—has been added to the product line. The engineering changes across the entire line of PŪR watermakers have been extensive. I was able to see and discuss them with the technical staff at Recovery Engineering. The changes all look like great improvements and, in support of the new designs, the warranty period is being increased from one to three years. At the present time, PŪR is also promoting a generous upgrade offer for current owners of a ***PowerSurvivor 35***. Contact the factory for details.

Only time and many users will tell us how good the new generation of PŪR watermakers is. In the meantime, there are many cruisers with ***PowerSurvivor 35***s who expect them to work well for years to come. This book should prove useful to anyone owning a new PŪR model, an old **Model *35***, or even another brand. Any watermaker on the market will provide years of service if it is properly installed and maintained.

A Look at the Product

BEFORE DIGGING into installation issues in the next chapter, it will be helpful to examine more closely just what it is we want to install. PŪR ***PowerSurvivor*** watermakers are precision-engineered equipment designed to intake clean seawater and produce potable fresh water, utilizing *reverse osmosis* (RO) technology.

All models, despite different specific configurations, are comprised of the same basic functional units. Using the PŪR ***PowerSurvivor 35*** as an example (see *Figure 1*), the major components of any system are (**A**) an electric motor, (**B**) a drive (gearbox) assembly, (**C**) a high pressure hydraulic pump, (**D**) an RO membrane and an intake seawater prefilter unit.

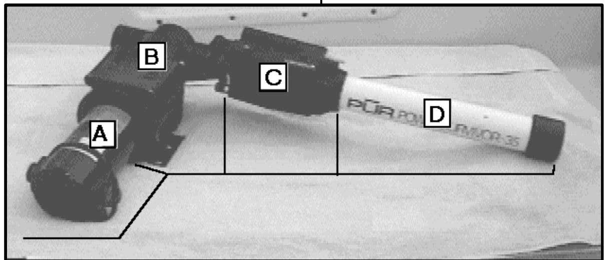


Figure 1: Major Parts of the **PowerSurvivor 35**

Except for the prefilter unit, all the components of the **Model *35*** and **Model *40E*** are bolted together into a single assembly. The larger capacity models (***80E*** and ***160E***), because of their physically greater dimensions, are available in a modular configuration, in which the membrane housing is separate from the motor/drive/pump assembly. The modular models facilitate installation of the larger watermakers in the usually limited spaces available on a small boat. The prefilter assembly is installed separately for all models.

At the heart of every RO watermaker system are the high-pressure pump and the RO membrane. The PŪR *positive displacement* hydraulic pumps are designed to produce about 800 psi (pounds per square inch) of seawater pressure against a semipermeable RO membrane. About 10% of the pressurized water passes through the membrane, leaving viruses, bacteria, and most salts behind. On the other side of the membrane, it is collected as product fresh water. The remaining 90% of seawater flowing across the membrane continues on as salt-enriched waste brine and is rejected.

PŪR claims that, utilizing patented technology, their watermakers recycle approximately 90% of the energy used to drive the high-pressure pump. The result is a significant reduction in the power required to produce useful quantities of water—e.g., the ***PowerSurvivor 35*** will produce 1.4 gallons of water per hour while drawing an average of only 4 amps of current at 13.8 volts DC. The other models have a comparable power-to-output ratio.

Reverse Osmosis

There are a number of useful technologies for purifying or desalinating water, including mechanical filtration, adsorption in carbon, distillation, and reverse osmosis. Which technology (or combination) is best for any particular situation depends on several factors; e.g., cost of equipment, cost of operation, and nature of the contaminants to be removed.

Osmosis and reverse osmosis are complex topics best explained by someone well-educated in physical chemistry talking to someone else who can understand what they are saying. Although I spent two years as an organic chemistry major in college, I know very little about osmosis and would not pretend to give a serious technical account of the process in this book. The only authority I claim is that of a lay-educated, reasonably intelligent owner of an RO machine writing for an audience of similar background.

On the other hand, I don't think a highly technical account is required for our present purposes. Common analogies will suffice. To understand how an RO membrane works, we need only imagine a semipermeable material separating two liquids. An image of a simple mesh screen will do. The material is semipermeable because it has many very small pores or holes in it. The pores are so fine that only the smallest kinds of objects can pass through—objects the size of small molecules and atoms. Water molecules are small enough to pass rather easily. Larger objects, including bacteria, viruses, salt ions and many other chemicals, are "screened out" because of their size.

This would be the perfect analogy were it not for a problem that occurs in the manufacture of the semipermeable membrane material. It is impractical, if not impossible, to make a *perfect* membrane material. Real membranes have a few "pores" that are larger than normal. Larger-sized contaminants *can* get through such pores. In practice, the small water molecules pass rather easily through the membrane, while the larger salt ions and other contaminants can only get through when they confront the larger pores. Since there are very few of the large pores, little of the contaminants get through and the product is *almost* pure water; e.g., the rejection rate for common salt ions (sodium and chloride) is about 98%—but it is *not* 100%!

The next step in the development of our concepts involves the two liquids on either side of the membrane material. Imagine one to be pure water and the other to be saltwater. On the pure water side, water molecules are constantly hitting the membrane and trying to slip through the pores. The same thing is happening on the saltwater side but, since it isn't pure water, not as many water molecules are hitting the membrane as on the pure water side—there are other competing molecules and ions in the way. The result is more water pressure pressing from the pure water side than there is pressing in the opposite direction from the saltwater side. The net effect is a movement of water through the membrane *from* the pure water side *to* the saltwater side. The water pressure created across the membrane surface by this purity imbalance is considerable (approximately 400 psi). Theoretically, the flow should continue until the proportion of water is the same on both sides of the membrane (which would never happen, right?) This process is called *osmosis*.

The main thing wrong with this picture for the purpose of making pure water is that the water wants naturally to travel *from* the pure water side *to* the saltwater side. What is needed is to reverse the flow of the water through the membrane and make it flow from the saltwater side to the pure water side. That is exactly what a *reverse osmosis* system does. An hydraulic pump is employed to develop enough pressure on the saltwater side to overcome the opposing osmotic pressure, and water flows in the "reverse" direction through the membrane—*from* the saltwater side *to* the pure water side. On the pure water side, a tap is installed for collecting the "product" water.

Only ten percent of the input water appears as product water. The remaining ninety percent is expelled as waste brine. One reason for such a large ratio of waste brine to product water is the need to keep the concentration of contaminants on the saltwater side of the membrane as low as possible. This minimizes the percentage of unwanted contaminants that will find a large pore and pass through the membrane.

Seawater

Recovery Engineering explicitly states in their literature that their watermakers are designed to process "clean open-ocean water."

This specification is extremely narrow. Not only must the water be "clean," it must be "open-ocean." Does "clean" mean *no* bacteria, viruses, plankton, or dirt? Does "open ocean" exclude open anchorages like Cabo San Lucas or Punta de Mita and, if so, how far out to sea must one go to find "open-ocean?" Does it exclude waters near icebergs due to reduced salinity? Does this specification mean the watermaker won't work in fresh water situations (lakes, rivers, ground water, etc.) or semi-enclosed "oceans" like the Sea of Cortez in Mexico?

The easy answer to these questions is also the least gratifying: in a court of law, the specification probably would be interpreted to *exclude* all of the aforementioned situations. Intuitively, one can imagine a scale of water quality ranging from hospital-grade saline solution to a waste sump behind a chemicals factory. On such a scale, the PŪR specification would represent a narrow band of acceptable quality input water located very close to the pure 3% saline end of the scale. The official specification is probably the best the company can do, considering it is a U.S. corporation with all the product liabilities entailed by that status. However, it tells us little about what the watermaker can reasonably be expected to do in any number of real-life situations.

Based on the foregoing criteria, I seriously suggest that the vast majority of watermakers in use are not operated in "clean open-ocean water." Most cruising sailboats spend the bulk of their time at anchor, moored, or in a marina. When anchored or moored, they are often close to a surf line with its churning silt and sand, kelp beds shedding microscopic plankton, rain run-off and sewage outflows. This is hardly clean, open-ocean water.

Even when underway miles offshore, the water may not meet this strict criteria. For example, Coal Oil Point on the southern California coast west of Santa Barbara (approximately N 34°24´ Lat., W 119°53´ Long.) has long been known for its natural seepage of petroleum and tar into the seawater. The aboriginal Indians used it to caulk their canoes. Vast slicks of this threatening material, covering many square miles, are frequently encountered well out to sea.

Let's take a closer look at what we *can* learn from the specification. A sample of ocean saltwater obtained far out to sea will normally contain a known range of dissolved and suspended materials, most notably sodium chloride. There are, of course, a rich mixture of other trace elements and compounds in seawater. That's why seawater can be evaporated and the residue packaged and sold as exotic "organic sea salt" at several times the price of common table salt.

Assuming an input source of such water, PŪR watermakers will remove a known high percentage of impurities and yield high quality, potable fresh water for human consumption. In addition, they will do it for a fairly predictable length of time before needing servicing. That's about all the PŪR specification promises the user.

So much for the specs. What we want to know now is: What *other* stuff can an RO watermaker be relied on to remove? That's where things get complicated. The ability of the manufacturer to predict and prescribe for all conceivable situations is understandably limited. In protecting themselves, they have specified a best case scenario for the quality of the input water. Beyond that, users are on their own.

Let's apply a little common sense, and a little more knowledge, to see if we can come up with a better idea of what to expect from our RO watermakers. In the first place, we could improve our "mesh screen" image of the semipermeable membrane by quantifying just how fine the "mesh" is. This will help us in deciding what size contaminants we can expect to remove using the RO membrane.

Published technical literature I consulted indicates that the RO membrane is roughly equivalent to a mesh filter with a pore size of <u>0.001 micron</u>! By way of comparison, we may think of it as *thirty thousand times finer* than the 30-micron cartridge used as the standard prefilter for the watermaker. This is a mesh so fine that only certain atoms and small molecules can pass.

It seems obvious that a quality RO membrane in good working condition will not only reject a very high percentage of sea salt (i.e., sodium chloride) and larger ions and molecules, but it will surely prevent passage of viruses and bacteria. The size of pathogenic bacteria is on the order of 0.5 microns (500 times larger than the membrane pores). Small viruses are about 0.004 microns in size.[*] As small as bacteria and viruses seem to us, they are mega-molecules on an atomic scale. Trying to push bacteria (or viruses) through an RO membrane seems a lot like trying to squeeze an elephant (or cat) through a chain-link fence.

Therefore, the good news about RO membranes goes something like this: as far as I've been able to determine, if the product water is <u>not salty</u>, it is almost certainly also free of viruses and bacteria. I know this is something of growing concern among all users. Major contamination of water supplies, such as those occurring in Milwaukee (1993) and Sydney, Australia (in August 1998) have greatly heightened public awareness of the quality of their water supplies. In this context, it's worth pointing out that RO membranes remove giardia and cryptosporidium cysts.

[*] Thanks to Nate Mueller at REI for this information.

It also seems obvious that, in a functioning system producing non-salty product water, all impurities *larger* than bacteria and viruses will be removed. This leads us immediately to consider the other end of the size scale. What about those atoms, ions and molecules that are small enough to pass through the membrane pores? We know that water is one. What are some others?

Not surprisingly, there is a correlation between the molecular weight of a molecule and its rejection rate by the RO membrane: lower molecular weights correlate rather closely with lower rejection rates. This is simply saying that small atoms and molecules pass through the membrane more easily than large ones. Since there are other factors affecting the actual size of a molecule or atom, the correlation between molecular weight and membrane rejection percentage is not exact—but it is a very good approximation for our purposes.

Let's consider just a few examples of substances whose molecules are small enough to pass through an RO membrane. For purposes of comparison, the molecular weight of sodium chloride is 58 and its percentage of rejection by an RO membrane is 98%. Consider the short list of interesting substances in **<u>Table 1</u>**, their molecular weights and percentage of rejection.[*]

Substance	*Mol.Wt.*	*% Rejection*
Calcium Chloride	**111**	**99**
Sodium Chloride	**58**	**98**
Isopropanol	**60**	**90**
Urea	**60**	**70**
Ethanol	**46**	**70**
Formaldehyde	**30**	**35**
Methanol	**32**	**25**

Table 1: *Sample Rejection Rates*

Without wading too deeply into the world of chemistry, we should note that this list of substances, some of which an RO membrane does a rather poor job of removing, includes some common chemicals. More important, the substances listed are typical of a much wider range of other chemicals of <u>similar molecular weight</u> that are also likely to pass through the membrane. For example, the molecules of the three alcohols listed—*methanol* (wood alcohol), *ethanol* (the kind in Jack Daniels), and *isopropanol* (rubbing alcohol)—are composed of 1-, 2-, and 3-carbon atom chains, respectively. The number of other chemicals based on just three or fewer carbon atoms in a chain is overwhelming. A great many of them are extremely toxic or harmful substances. Some of these chemicals are also potential threats to the integrity of the membrane.

[*] See data on more substances in the Appendix.

As a specific example, the Environmental Protection Agency (EPA) has listed *formaldehyde* as a cancer-causing substance. What is important to understand is that it is possible for a large number of chemicals to pass through an RO membrane—chemicals that are known to be harmful to human beings. Fortunately, "clean open-ocean water" does not yet contain significant amounts of such materials.

We are now in a better position to appreciate the narrow PŪR specification for the source of input water to their watermakers. *It is clearly the user's responsibility to assess the quality of any water intended as an input source for an RO system*, especially any water that is less than the optimum "clean open-ocean water." If there is any question about the suitability of a particular source of input water with known contaminants, the prudent user is well advised to contact Recovery Engineering, or some other source of expertise, for further information. The bottom line here is that it is the sole responsibility of the watermaker user to determine the contaminants likely to be found in the input water. With that understood, it will be discovered that RO watermakers actually work quite well in a wide range of situations.

Known Threats to RO Systems

Having explored the meaning—and limitations—of the PŪR specification for input sources for their watermakers and realizing that actual use situations frequently depart from that high standard, it would be useful to examine a few instances of operating situations that are already known to cause problems. The problems can be categorized into (1) those damaging to the user and (2) those damaging to the watermaker.

Unsafe Product Water: Regarding input water that might yield unsuitable or unsafe product water, the basic rule of thumb is easily formulated: any water which differs in makeup from clean, open-ocean water should be regarded as suspect. It is the responsibility of the user to be aware of what the intake water might contain and, therefore, what needs to be removed.

For example, running the watermaker while anchored immediately offshore from a small town in most third world countries will involve a chance of exposure to high levels of sewage and/or other waste products of human activities. Fortunately, the RO membrane can be expected to do a pretty good job of removing the bacteria and viruses in such intake water. But, how about locally high concentrations of other contaminants—battery acid, old engine oil, paint remover, industrial waste. The list is limited only by one's imagination.

This doesn't mean that one should never run a watermaker when anchored near a village. In fact, we frequently run our watermaker while anchored next to Mexican towns. In most cases, sewer outflows can be located and avoided, if need be. Running a watermaker under any conditions always involves some calculated risk. We've taken that risk while anchored off most Mexican villages and towns and have not yet had a single problem involving the quality of our intake water. On the other hand, we will *not* take the considerable risk involved in running the watermaker when berthed inside a confined harbor or marina, whether in the USA or Mexico.

I have seen some cruisers who anchor needlessly far away from towns (in my humble judgment) "in order to run the watermaker." I suppose it's better to err on the side of caution. I even met one cruiser who was adamant about not running his watermaker if there were any fish in the area. He feared that an excess of fish oil in the seawater would foul his membrane. I doubt this is a problem with which we need be concerned. If it is, I'm not sure how we could know when there are fish in the area. In any case, every watermaker user must calculate the risk factors for the location and make an informed decision about whether or not to run the watermaker. Experience is the best teacher. Performing regular maintenance on the prefilter will tell most of the story about the quality of your intake water. Ask other cruisers about their experiences in specific localities.

The watermaker can also be used in processing fresh water but, again, one must be careful about the source. Are you interested in treating water from a babbling brook high in the Sierras or are you looking at utilizing water from an old well at an abandoned mining camp near a favorite hunting site? If in doubt about the source, find out more before expecting an RO watermaker to do something it wasn't designed to do.

The World Wide Web is an excellent source of detailed information on the suitability of RO systems for purifying water contaminated by various types of chemicals. Literally hundreds of articles are available by searching on keywords like "reverse osmosis" and "desalination."

One of the best known references for the average citizen is the text of the *Safe Drinking Water Act* (SDWA), as passed by Congress in 1974 and amended in 1986. Of particular interest are the tables of known dangerous contaminants and the Best Available Technology (BAT) for removing them. I've included several of the tables in the *Appendix* to this book.

Membrane Damage: A failed membrane or membrane seal can be another source of bad product water. Logically, there are two ways in which a membrane can fail. It may (1) become fouled or plugged up and cease to pass adequate amounts of product water, or (2) deteriorate or suffer a seal failure and become too porous to remove contaminants.

In the first case, the motor will draw more current and work harder, developing more pressure in its attempt to drive water through the plugged membrane. Eventually the over-pressure relief valve will begin leaking as it relieves the excess pressure. Depending on what kind of material has fouled the membrane, an alkaline and/or acid cleaning may cure the problem. In the worst case, a new membrane will be needed. Although expensive to repair, this kind of failure is usually not a health threat because it does not result in contaminated water.

Serious deterioration of the membrane or failure of a membrane seal, resulting in contaminants appearing in the product water, are less common, but potentially more troublesome situations. If undetected, existing potable water reserves aboard the vessel may be contaminated. Such an occurrence could be serious during a blue water passage, many hundreds or thousands of miles out to sea. For a method to avoid such a development, see the discussion of routing product water under *Installation Issues*. (*Note*: It is curious that PŪR does not include a replacement membrane brine seal in their repair seal kit. Adding this item, along with a new o-ring for the prefilter housing, to their repair seal kits would be a welcome improvement.)

While small-molecule toxic chemicals in the input water source are a real threat to the user, the membrane is also vulnerable to strange substances. There are two common cautions to observe. First, the membrane should not be exposed to *any* petroleum-based oils or chemicals. Second, exposure to *chlorine* can rapidly destroy a membrane.

Included among the petro-chemicals are all engine oils and fuels, varnishes, paint removers, resins, etc. A watermaker is *most likely* to be exposed to such substances while being operated within enclosed harbors or marinas.

I've heard some people suggest that there is no threat of damage to the membrane from fuel spills in a marina since fuel floats on the water's surface, while the intake thruhull is well below the waterline. Many times this is true. However, the quiet fuel spill a few boats away, which is quickly and discretely "taken care of" with a squirt of liquid detergent, is the one to worry about. The fuel vanishes from the surface of the water, but it doesn't go away. Instead, it drifts slowly as a cloud through the water, finally reaching the intake thruhull for your watermaker. If that happens, get out your checkbook. You'll probably need a new membrane.

I suspect that most cases of chlorine damage occur when membranes are exposed to municipal water. Water at the dockside and/or municipal water taps is likely to contain chlorine and should not be processed in the watermaker. A common error is to flush or biocide the watermaker with dockside fresh water after arriving in port, in preparation for an extended period of non-use.

Another common source of chlorine exposure is the practice of adding chlorine to the product water in the main holding tank(s) "just as a precaution." If such water is subsequently used to flush, clean or biocide the watermaker, the membrane may be exposed to chlorine.

How serious is the chlorine problem? An informed source told me that membranes are expected to tolerate 1000 ppmh (parts per million **X** hours) exposure to chlorine before suffering significant harm. This seems to mean they could be constantly exposed to water with 100 ppm chlorine for 10 hours, or water with 20 ppm chlorine for 50 hours, etc., before being damaged. Another specification provided by Recovery Engineering indicates less than 0.1 ppm exposure to free chlorine! (See **Membrane Data** in the *Appendix*.) This spec would seem to place a severe limit on the *rate* of exposure to chlorine.

Since the ppm concentration of chlorine in municipal water supplies is fairly low, a couple of accidental exposures of the membrane to such water are not likely to do excessive harm. So, don't panic if you forget and flush with dock water. Just don't do it again!

I think it's worth noting that chlorine is but one of a related group of chemical elements known as *halogens*. They include chlorine, bromine, iodine and fluorine. They are all very active chemicals and I suspect that the precautions about exposure to chlorine apply to these other chemicals as well. In particular, ***Microdyne***, the popular water treatment chemical, is based on iodine. Water treated with ***Microdyne*** or other halogen-containing products probably should *not* be used to flush or treat an RO membrane.

Pump Damage: The hydraulic pump is a precision device designed to develop 800-1000 psi efficiently. In performing this task, it relies on the integrity of rubber seals and o-rings to seal and protect moving parts. These seals have a limited life. Over time, the o-rings lose their resiliency and the seals on moving parts will wear. The ultimate outcome will be reduced output and a leaking pump, indicating the need for installing a new seal kit.

The major threat to the pump and its delicate seals are the suspended particulates in the intake water stream. Assuming a prefilter in good condition, only particles smaller than 30 microns will reach the pump surfaces. In clean, open-ocean water, this is no problem. However, if the intake water contains significant amounts of fine silt or similar substances, the damage done to the pump—especially the cylinder walls and piston seals—can be rapid and substantial.

If the watermaker is to be run in water with questionable silt or other particulate contaminants, PŪR recommends the installation of an additional in-line prefilter with a 5-micron element and a small 12 VDC booster pump to compensate for the added resistance in the intake circuit. (PŪR calls this their "*Silt Reduction Kit*.")

Although the addition of an extra prefilter and booster pump will certainly help prolong the life of a watermaker run with silty intake water, it will *not* remove *all* of the abrasive particles. The owner should expect to have to replace seals more frequently. Keeping a spare piston and cylinder on hand is also a good idea.

Some Basic Electrical Concepts

One doesn't need to know Boolean algebra to understand the electrical operation of a watermaker system—a good understanding of Ohm's Law will suffice. If your background does not include a study of the fundamentals of electrical circuits, your near-term goals *should*. The boat skipper who can't perform basic DC (and usually AC) circuit tracing and troubleshooting is much like a pilot who doesn't know how to operate a parachute. Sooner or later—and usually sooner—something will go wrong with the electrical system on every boat. The consequences of such a failure can range from mere inconvenience (e.g., your favorite cabin light quits working) to threatening (the running lights go out as you're passing under the Golden Gate Bridge) or immediate danger (you smell smoke from an electrical fire).

There is a plethora of books explaining electrical theory and basic electrical systems for mariners. Unfortunately, judging from advertisements I've seen, it would appear that even some vendors of marine equipment don't understand the concepts. I've seen such meaningless phrases as "1 gallon of water per amp" in advertisements from two major vendors of watermakers!* As much as I would like to assume that every reader has a working knowledge of basic electrical theory, I'm afraid I can't. So, let's pause here for a brief review of Ohm's Law and a few of the other fundamentals you'll need to know in order to understand the electrical part of a watermaker.

What is Electricity? For our purposes, we may consider electricity to be, quite simply, the flow of electrons. Electrons are extremely small, charged components of atoms that exist in layers or shells on the outside of the atom. Under the right conditions, they can move or "flow" from one atom to another. Such movements constitute an "electric current."

Lightening is a dramatic example of electric phenomena, in which enormous quantities of electrons jump suddenly from the surface of the earth into the sky. Although lightening is impressive and involves awesome amounts of power, it is an uncontrolled current. All of the electrical devices that we use involve close control of the flow of more limited quantities of electrons.

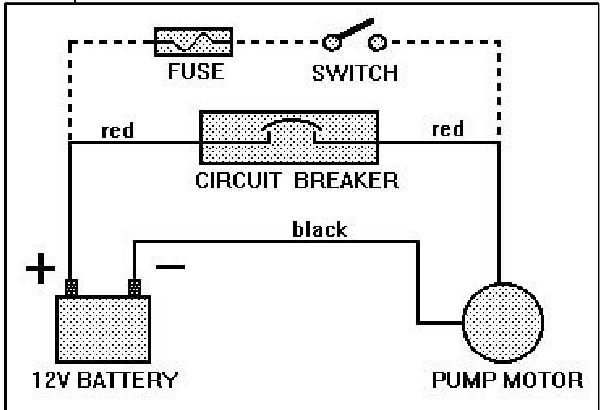


Figure 2: Main electrical circuit componeints

An Electrical Circuit: Practical electrical devices have several properties in common. They all require a "source" of electrons, at least one *complete* path along which the electrons travel to and from the source, and a "load" in which useful work gets done. Despite the obvious complexities of most electrical devices, every one of them can be analyzed and reduced to an equivalent model that is comprised of only these three elements: source, connections and load. If these three elements are present, we may call the overall arrangement an "electrical circuit."

See *Figure 2* for an example appropriate to the present discussion. In the illustration, the battery is the *source* of electrons, the pump motor is the *load*, and the red and black lines are the *connections* between the source and load. Note that the flow path for the electrons must be "complete" in order for the flow to occur; a useful electrical circuit must have both a "send" (red) and "return" (black) line. A break anywhere in the circuit will stop the electron flow. This is the function performed by a switch or circuit breaker.

I should also point out that, for safety reasons, *every electrical circuit should be protected* from excessive electron flow. This is accomplished

* In all fairness, such "technical" mistakes in advertising are usually the work of marketing personnel at the company, who often lack any technical comprehension of the product whatsoever.

by placing a device in the electron flow path that will “break the path” of the electrons if the flow exceeds some predetermined safe amount. This is the role of a fuse or circuit breaker. A circuit breaker actually performs the functions of both a switch and a protection device. Since it usually can be *reset* after interrupting excessive current flow, it is more convenient than a fuse, which must be *replaced* each time it interrupts the electron flow.

The great majority of electrical problems that arise on a boat can be found and corrected with no more knowledge than the basics of electrical circuits and how they work. Before discussing the relationship between the elements of an electrical circuit, we need to establish a few definitions.

Electrical Units of Measurement: There are at least five primitive units of electrical measurement that every skipper should understand:

VOLT — used to express the *voltage*, or “electron pressure,” between any two points in an electrical circuit. The *source* part of an electrical circuit supplies the electrical “pressure,” which we measure in volts. This pressure, or voltage, is what causes the electrons to flow through the circuit

AMP(ERE) — used to express the *rate* of electron flow through an electrical circuit

OHM — used to express the *amount* of *resistance* to electron flow in an electric circuit. The load in an electrical circuit will exhibit a certain resistance to the electron flow

WATT — used to express the *rate* at which *power* is being used by a load in an electrical circuit. The watts being used is found by multiplying the voltage across a load times the current flowing through it

AMP-HOUR — a unit used to express the total *amount* of electric *current* used over time. It is calculated by multiplying the current in amps times the number of hours the current flows

Some of these units of measurement are misused in common practice, even in commercial product advertisements. In particular, the meanings of the *amp* and *amp-hour* are frequently misunderstood and confused.

The *amp* is used to describe the rate of current flow. In simple terms, it is a measure of how many electrons are moving past *any* point in an electrical circuit at a specific time.* If we are interested in the total quantity of current flow over time, we must multiply the rate of flow (the amps) by the amount of time that it has flowed (hours). The result of this simple arithmetic is the *amp-hour*, which is *almost* a measure of the total energy used. (To represent a quantity of energy, amp-hours must be further multiplied by the voltage from the source. See the discussion of the Power Laws later in this chapter.)

Fuel consumption in an engine provides a useful analogy. We speak of the rate at which an engine burns fuel as so many “gallons per hour” (similar to the *amp*: electrons per second). We express the length of a trip in “hours” (the same as the time current flows: *hours*). We can then calculate the total amount of fuel used in gallons (*amp-hours*) by multiplying the rate (*amps*) times the time (*hours*); e.g., 5 gallons per hour **X** 7 hours running time will give us a total fuel amount of 35 gallons. Similarly, an electrical device that draws current at a rate of 5 amps and is switched on for 7 hours will consume 35 amp-hours of battery capacity.

I’m quite certain that much of the confusion about amps and amp-hours derives from the names of the units. In most other situations when we speak of ratios (rates are ratios), we explicitly state the units being used: miles per gallon, feet per second (speed), feet per second per second (acceleration, or *rate* of change of speed), pounds per cubic inch (density, a *ratio* of mass to volume).

Unfortunately, when we speak of the rate of electric current flow, we do not use a descriptive term like “electrons per second.” Instead, we use the name of a much respected, and long deceased, French physicist and mathematician: the *Ampere*, or *amp* for short. The fact that an amp is a unit that actually expresses a quantity divided by time is left implicit.

To make certain that as many people as possible would be confused, some genius went on to create the term “amp-hour” to describe the total *quantity* of electrons that have flowed. Before we applaud this descriptive unit name, we should realize that an amp-hour doesn’t include time as a

* The rate of electric current flow through a complete circuit at any given time is the same at every point in the circuit. Electrons do not flow into the load and remain there or disappear. For every electron that flows into a load, there is another one flowing out. I once had a fellow try to sell me some #22 gauge wire with black insulation for use as the main negative cable from the ship’s batteries to ground. He insisted that the black wire need not be larger because it doesn’t conduct many electrons. According to his theory, almost all of the electrons flow into the load and are dissipated there—there is no need for a large return path! I don’t know if I was able to correct his misconceptions, but at least I wasn’t foolish enough to buy and use the wire for my battery ground.

sub-unit at all. This is clearer when we look at what happens to the units of measurement during our multiplication. When we multiply amps times hours to get amp-hours,

AMPS(electrons/time) x **HOURS**(time) **= AMP-HOURS**(electrons)

note how the time units on the left side of the equation cancel out:

AMPS(electrons/~~time~~) x **HOURS**(~~time~~) **= AMP-HOURS**(electrons)

to produce an answer that is a simple scalar quantity with no embedded reference to time whatsoever. I hope this digression helps the reader to have a clearer understanding of what *amps* and *amp-hours* really mean, in spite of their potentially misleading names.

Ohm's Law: Early in the nineteenth century, a man named George Ohm developed a mathematical equation that describes the relationship between the quantities of current, voltage and resistance in an electrical circuit. The equation is as simple as it is powerful. Perhaps the most common form of Ohm's Law is:

voltage (volts) **= current** (amps) x **resistance** (ohms)

We can greatly simplify the law by substituting single letters for each of the quantities. It we represent voltage with a "**V**," current with an "**I**" and resistance with "**R**," we can re-state Ohm's Law,

(Eq. 1) $V = I \times R$

Using the rules of transposition, we can create several other useful forms of the equation:

(Eq. 2) $I = V \div R$

(Eq. 3) $R = V \div I$

These three equations—Ohm's Law—describe the very useful relationships that hold between voltage, current and resistance in any electrical circuit. It holds for both 12-volt DC (direct current; e.g., the ship's battery) and 120-volt AC (alternating current; e.g., household outlets) circuits. With these equations, if we know the values for any two of the variables, we can find the third.

Power Laws: A very useful equation derived from Ohm's Law is that for calculating the power dissipating in the load part of an electrical circuit. The unit we use for power dissipation is the "watt," and it is a unit of rate.* The watts being dissipated in a load is found by multiplying the voltage across the load (in volts) times the current flowing through it (in amps). If we use a "**W**" to represent watts and retain our previous symbols for current, voltage and resistance, the equation for watts is

(Eq. 4) $W = V \times I$

If we substitute the right-hand member of **Eq. 1** for the **V** in **Eq. 4**, we obtain another interesting formula:

(Eq. 5) $W = (I \times R) \times I$

Combining the two current factors, we have:

(Eq. 6) $W = I^2 \times R$

Finally, we can calculate *watt-hours* in the same way we calculated *amp-hours*—by multiplying the watts (rate of consumption) times the length of time they are being consumed:

(Eq. 7) **watts** x **hours = watt-hours**

Interestingly enough, just like the *amp-hour* unit, the *watt-hour* does not contain any embedded time unit, and for the same reason. The *watts* term in **Eq. 7** has *time* as a divisor. When it is multiplied by the *hours* term, which is also a time unit, the time units cancel out. The watt-hour is a measure of total energy used, a quantity.

If you followed these derivations closely, you may nave noticed that there is a close relationship between amp-hours and watt-hours:

watt-hours = amp-hours x **voltage**

Now let's pull this together into some concepts that a boat skipper can relate to. The watt-hour is probably more familiar to most readers in another guise—the *kilowatt-hour*. The kilowatt-hour is the unit of measurement for electrical energy consumed in a normal household. A kilowatt-hour is 1000 watt-hours.

* The term "power" is another that is frequently misused by laymen, and I will not attempt to clear up the mess in this short essay. The reader is referred to a good primer on physics, where it will be learned that *power* is the first derivative of *work* with respect to time—i.e., it is the rate at which energy is used or work done. The lay world little distinguishes between power, work and energy. The present discussion is for those who think a big battery has more "power" than a smaller battery. In this context, to explain why "potential energy" is the more accurate terminology would extend the discussion unnecessarily, and seems a lot like trying to teach a pig to sing.

The amp-hour is used to express the energy capacity of batteries. Without voltage factored in to give us watt-hours, it is *not* a measure of the total *energy* available from the battery. All it gives us is a measure of how many hours it will provide current at a given current rate. For example, a 200 amp-hour battery, theoretically, will provide 5 amps of current for 40 hours, or 20 amps of current for 10 hours, etc.* On the other hand, a 200 amp-hour 12 VDC battery will store about twice as much *energy* as a 200 amp-hour 6 VDC battery; i.e., twice as many watt-hours. Nominally, the 12 VDC battery would hold (200 amp-hours x 12 volts =) 2400 watt-hours of energy. It could run a 40-watt reading light for (2400 watt-hours / 40 watts =) 60 hours, or it would run a PŪR ***PowerSurvivor 35*** watermaker for (200 amp-hours / 4 amps =) 50 hours.

We'll use Ohm's Law in later chapters to calculate some very useful data for a watermaker system and as an aid to basic electrical troubleshooting.

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* These figures are both rough and nominal. In actual practice, a battery should not be discharged below approximately the 25% charge level; i.e., only about 75% of its rated capacity can be used before irrevesible internal reactions take place that can significantly shorten the life of the battery.

The Importance of the Installation

THE OWNER of a very popular marine supply and outfitting business in San Diego (and a PŪR warranty repair station) recently complained to me: “Almost every PŪR watermaker that comes to me for warranty servicing was bought at West Marine and installed by the owner!”

That was an interesting observation from a dealer and experienced outfitter who had seen more than a few watermakers—and watermaker problems. Implicit in his complaint was the fact that very few of the watermakers installed by *his* outfitting company had failed during the warranty period of one year. We can infer that a proper installation is critical to the success of an on-board watermaker system.

Unfortunately, the PŪR manuals don’t offer the new owner much help in understanding many of the problems that arise during an installation. The PŪR ***PowerSurvivor 35*** Technical Manual (MAN-5/12-93) begins its installation section with a packing list of parts shipped with the watermaker and a couple of brief notes on mounting locations. This is followed by a similarly general discussion of plumbing, storage tanks and electrical connections. The information in the manuals for the other models is equally sparse. Of course, the instructions, cautions and tips found in the PŪR manuals are very important, but they are only a small part of what the informed owner/installer should know.

That PŪR would write their installation instructions in rather general terms is understandable. Boats are quite diverse in their characteristics and layouts. Virtually every watermaker installation will require custom work and unique, on-site considerations. PŪR provides excellent schematic-level descriptions of installations that are known to work and a list of important cautions and considerations in their manuals—but they left the driving to the installer. They made little effort to educate the reader on basic hydraulics and electrical theory—and they shouldn’t!

I’ve mentioned some technical subjects. Perhaps you were a real estate agent before cruising. You majored in drama while in college. Your neighbor was a plumber and your nephew an electronics whiz. They used to help you out with those kinds of problems. Well—there’s no denying that the cruiser who intends to install and maintain his or her own equipment would benefit from a basic knowledge of hydraulics and electrical theory. After all, a watermaker system consists of a hydraulic pump powered by an electric motor. Furthermore, if an installation includes air leaks in the plumbing, some knowledge of pneumatics would be handy.

Nevertheless, there are a few basic concepts that are not difficult to understand and will go a long way toward helping the non- or semi-technical skipper achieve an efficient, trouble-free watermaker installation. The tasks of planning, routing and assembling the plumbing and components of a new watermaker system include three major goals, listed here in *decreasing* order of importance:

1. Make absolutely certain that all connections and fittings are airtight
2. Chose locations for the prefilter and pump that are readily accessible
3. Design the system to minimize the work the motor must do to pump water through the system

If these three principles are followed, there’s about a 95% chance that the installation will be a success. I always predict a 5% failure rate to account for defective materials, Murphy’s Law, and just plain dumb mistakes.

Achieving the first goal is the *sin qua non* of the whole installation. One small air leak can ruin your entire day and, if left uncorrected, can frustrate an entire cruising season.

Accomplishing the second goal will go a long way toward ensuring a good experience with your watermaker. Since the required maintenance will be easy to perform with the major units in accessible locations, it is much more likely to be performed. A properly maintained system can be expected to work well for many years.

The last—and least important—goal involves understanding that the less work the watermaker motor has to do in pumping water into and through the system, the lower the electric current requirements will be. This is primarily an efficiency issue.

A small part of the load placed on the watermaker motor is caused by the resistance to flow in the intake plumbing. The resistance to flow, in turn, is determined by the following factors:

1. *Height of the pump above waterline*: the higher the pump, the farther it must lift water and, therefore, the harder it must work
2. *Inside diameter of fittings and hoses*: smaller diameter hoses and valves restrict flow more than larger sizes

3. *Length of, and bends in, the hose runs*: resistance to flow increases in direct proportion to hose length. Fluids like to flow in a straight path. Curves (bends) increase resistance to fluid flow. Sharp bends and elbows cause more resistance than gradual bends

4. *Prefilter cleanliness*: Accumulation of contaminants in the pores of the prefilter element will gradually increase resistance to flow over time

The last factor will be discussed in a later section on prefilter maintenance. Factors 2 and 3 are, I hope, fairly obvious. It's time to discuss factor 1—an important and controversial issue: the location of the watermaker and prefilter assembly relative to the waterline of the vessel!

Location, Location, Location

There is much confusion and inexpert opinion surrounding the subject of whether or not a PŪR ***PowerSurvivor*** watermaker *needs* to be—or even *should* be—mounted below the waterline of a vessel. The manufacturer has done little to clarify the situation. In fact, there are rumors that certain factory technical support people have told owners that failure to mount their units below the waterline was the probable cause of their problems! It's time to shed some light on this subject.

Let's begin by recalling that the pumps in the ***PowerSurvivor*** watermakers are positive displacement pumps designed to develop 800 psi of pressure. They have no trouble at all pulling the input water up just as high as any other simple positive displacement pump; e.g., an old hand-pump servicing a water well. Its construction and principles of operation are quite simple and well known. *If there are no air leaks or serious restrictions in the intake plumbing, the* **PowerSurvivor** *pumps are capable of lifting intake water well over 10 feet!*

With that understood, one wonders why anyone would want to mount a watermaker below the waterline. Suitable space there is usually at a premium and working areas are cramped and difficult. Eventual exposure of the equipment to seawater from the bilges is much more likely. What are the possible motives for wanting such an installation? I can think of only two questionable advantages to a below-the-waterline installation:

1. Electric current demand should be *slightly* less due to a lighter pumping load on the motor.

2. Minor air leaks in the intake plumbing *might not* cause watermaker failure, due to the positive water pressure in plumbing below the waterline. Such air leaks would *certainly* cause problems in *above*-the-waterline installations.

In my opinion, neither of these advantages is of much importance to a responsible skipper. The amount of work done by the pump lifting its intake supply a few feet above the waterline is very small compared to the work required to pump 10% of that water through the membrane at 800 psi. In other words, the amount of electric power saved by mounting a watermaker below the waterline, as opposed to a more convenient and practical location above the waterline, is hardly worth considering.

The second "advantage" I don't consider an advantage at all. While it is true that a watermaker *might* run successfully if mounted below the waterline when there is a leak in the intake plumbing, this is a very poor way to handle such a problem. At the very least, the leak will cause an accumulation of water in the bilges and—more ominously—it may be a symptom of weak or faulty plumbing that is likely to fail catastrophically at some time in the future. I believe any responsible skipper would agree that such an installation should be corrected.

I discussed the waterline issue with several people at Recovery Engineering during my 1997 visit. The technical staff, including Dick Hembree, the head design engineer, quickly agreed that a PŪR ***PowerSurvivor*** watermaker *could* be mounted above the waterline. It was the non-technical, customer and product support people who seemed to persist in their belief that below-the-waterline installations cured certain evils. The latter were never able to explain to me—in rational, technical terms—what advantages would accrue to the proud owner of a below-the-waterline installation, or why the pump couldn't be mounted above the waterline successfully.

What does the official literature say? Interestingly, the *Technical Manual* for the earlier ***PowerSurvivor 35*** is not forceful in its recommendations: "Install the ***PowerSurvivor 35*** close to or below the water line, if possible." And, concerning the prefilter assembly: "Mount it close to or below the water line." These are very weak recommendations at best and there are no cautions to the effect that the watermaker will not work if mounted higher.

When we look at the manuals accompanying the newer ***Endurance*** models (***40E***, ***80E***, ***160E***), we get a very different set of directions. For example, on page 12 of the ***80E*** owner's manual we are told that "the 80E is a gravity-fed pump; therefore, it must be installed at or below the waterline." I think that statement can be safely ignored. The pumps in PŪR ***PowerSurvivor***/***Endurance*** watermakers are _not_ gravity-fed pumps and all will work just fine mounted above the waterline, given a quality and airtight intake system.

I don't know why there are so many people, including some PŪR staff, who think the watermaker should be installed below the waterline. I have a theory on the matter. I'll call it The Great Waterline Myth and hope it suffices until a better explanation surfaces.

The Great Waterline Myth: Once upon a time, an engineer designed a special water pump to make good water out of bad. The pump was driven by an electric motor. When the design was developed well enough to sell on the market, the engineer hired a marketing expert.

The marketing expert designed an owner's manual. He asked the engineer where the best location was for installing the pump on a boat. Well, said the engineer, it really doesn't make a lot of difference, except the motor will require a little less electric power to run if it is mounted close to, or below, the waterline.

Good, thought the marketing expert. We want to advertise the lowest possible electric power consumption to potential customers. We'll recommend a below-the-waterline installation.

Eventually the original—and minor—technical reason for preferring a low installation became lost and the non-technical customer support people knew only that the company recommended a below-the-waterline installation. They did not know why. It quickly became an easy answer to people with problems who had their watermakers located above the waterline. Customer technical support people reported that some customers who called with problems, when told to move their watermaker to a location below the waterline, never made a second call. The tech support people presumed the problems were solved. Eventually the waterline story became a treasured myth, handed on in an oral tradition at the great company that had grown up around the engineer…or so my story goes.

Figure 3: An Easy-Access Prefilter Installation

A testimonial is in order. Our own ***PowerSurvivor 35*** has been producing well for almost three years. It is mounted underneath the cockpit combing directly below the port jib sheet winch—_about four feet above the waterline_ (and even higher on a port tack!) The prefilter housing is mounted inside a cockpit lazarette (See _Figure 3_) where it is readily accessible, about three feet above the waterline.

My experiences have convinced me that _there is absolutely no need to limit installation plans to a below-the-waterline configuration_ for any of the PŪR ***PowerSurvivor*** or ***Endurance*** watermakers…period! With airtight intake plumbing, there should be no problem mounting the pump *and* prefilter even four or five feet above the waterline. On a related point: don't ever believe anyone who tells you that you have a problem because your PŪR watermaker is mounted above the waterline. If there *is* a real problem, I assure you the cause will be something else. You can quote me on this one. Recovery Engineering makes a better pump than some of their customer support staff are willing to acknowledge.

Prefilter Installation

The installation location and later servicing requirements of the prefilter assembly are intimately related and should be considered at the same time. There is no single component of the ***PowerSurvivor*** systems that will require more attention during actual use than the prefilter. _The most important decision you will make during installation of a watermaker is the choice of prefilter location_! Stop for a few minutes and think the matter over very carefully.

The PŪR owner's manuals might lead you to think that cleaning the prefilter assembly often enough to prevent significant clogging is adequate. Well, it is not. *Long before* enough detriment accumulates in the prefilter housing to cause significant blockage of water flowing through the filter element, the trapped material will begin to decompose. This decomposition will produce, among other things, some small-molecule gases that will easily pass through the prefilter element, through the membrane, and into the product water. The most noticeable is *hydrogen sulfide*, which produces a familiar "rotten egg" smell.

The solution to the "rotten egg" problem is to frequently discard the contaminated water trapped in the filter housing and change the filter element. With the original white, opaque prefilter housing that came with the ***PowerSurvivor 35*** and early **Model *80***s, it is difficult to know when too much crud has collected in the prefilter housing. You must shut down the system, unscrew the housing and examine the trapped material. It is gratifying to learn that the new ***Endurance*** watermakers are shipped with transparent prefilter housings. This makes it very easy to determine at a glance just how dirty the water in the prefilter housing is getting. Someone at the factory was listening to users on this one. The old saw, "out of sight, out of mind," perfectly describes the effect of an opaque prefilter housing on the user. Making it easy for the user to monitor the condition of the prefilter is the single best thing PŪR has done. It should dramatically reduce problems caused by poor prefilter maintenance.

Over time, experience and an intimate familiarity with the equipment become the best guide to how often the prefilter needs attention. While learning the proper timing, it is much better to err on the side of excessive attention than to neglect the matter. Since the prefilter will need regular, frequent attention, it is imperative that it be located in a convenient and easily accessible place. It is difficult to over-emphasize this recommendation. If mounted in an out-of-the-way location, perhaps behind piles of gear or supplies, it is guaranteed to not get the attention it requires.

When I first installed our watermaker, I mounted everything quite neatly in the far corner of a lazarette. I was proud of the way I had utilized some unused space, way back in the dark recesses. It was not until I needed to change the prefilter element for the first time that I realized what a grand mistake I had made. In order to reach the prefilter housing, I had to remove large stacks of gear stowed in the lazarette and climb down into a very cramped space. After moving some more gear, I was finally able to unscrew the prefilter housing, scratching my arms during the process on the rough fiberglass of the inside hull.

After only a couple of prefilter servicing efforts, I tore out the whole installation and relocated the prefilter housing on a bulkhead immediately inside a lazarette (see *Figure 3*). No gear has to be moved to reach it. I have also replaced the original opaque housing with a clear one. Now a quick lift of the lazarette hatch and a glance at the clear prefilter housing tells me immediately what the status is. If it needs changing, the entire process takes less than five minutes.

When mounting the prefilter housing, be certain to leave enough clear room below the unit to allow removal of the screw-on bowl. Also give some thought to what, if anything, will be stowed immediately below the prefilter. Seawater will occasionally be spilled during the process of servicing the filter element and housing. It would be poor planning to have it spill on dry goods, electrical terminal strips or junction boxes, or into an area that has no drain or limber holes.

Pump Installation

The pump, gearbox, and 12 VDC drive motor are fastened together as an integral unit in all PŪR watermakers. In the case of the ***PowerSurvivor 35*** and ***40E***, the membrane and its housing are also attached to the pump assembly. The *enclosed* configurations of the ***PowerSurvivor 80*** contain the membrane and pump assembly in a rectangular enclosure. The ***PowerSurvivor 160E***, because of the larger size of its components, is only available in a *modular* configuration—i.e., separately mounted membrane housing and pump assembly.

As with the prefilter assembly, the user need not worry about restricting the location of the pump assembly to below the waterline. Consider locations that satisfy as many of the following conditions as possible:

Easy Access: Full access to the watermaker itself is seldom needed. Under normal use, an occasional check for pump leaks is the only short-term periodic attention required. However, resist the urge to tuck it too far away. When access *is* required, you'll need room to work.

For example, with the ***PowerSurvivor 35***, an alkaline cleaning procedure will require enough room to change membrane housings. A good installation would allow extra clearance for this to be done comfortably and without having to dismount the entire pump assembly. For all models, adequate working room and comfortable access minimize the chances of damaging a costly membrane when removing or installing it.

Minimize Intake Resistance: To help the watermaker be as efficient as possible, choose a location to minimize the drag on the water coming into the pump. Toward this end,

> a lower location is better than higher, to minimize the distance the pump must lift water
>
> shorter hose runs with bigger ID (inside diameter) are better than long runs and small ID hose
>
> having a separate intake thruhull for the watermaker is better than teeing into a supply that is already serving another device, like the seawater intake for the auxiliary diesel engine

I hasten to add that one has a lot of latitude in juggling these factors. In the first place, the amount of electric current saved by optimizing all the above factors is very small. Secondly, unless hoses are so long and/or small as to cause cavitation at the pump, the system will work. And, of course, there is the skipper who is loath to punch another hole in the hull. Minimizing intake resistance is certainly a consideration, but an easy one to deal with. I'll have more suggestions on these topics in the following section on *Plumbing Considerations*.

Avoid Excessive Heat: It is often tempting to mount the watermaker in an engine room, especially if the engine compartment has been soundproofed. The engine room may also have an available intake water supply and easy access to electrical connections. Unfortunately, engine rooms also tend to get quite hot.

Take a look at the ratings plate on the drive motor of a ***PowerSurvivor 35***. One of the entries is "AMB." This is the *maximum ambient temperature* rating for the motor: it is 40º C (104º F). This rating indicates the maximum temperature the air around the motor can be without causing possible harm to the motor when it is operating. Engine rooms, particularly on smaller yachts, typically get *much* hotter than 104º F. Be aware that it is normal for the watermaker motor to feel quite hot to the touch when running. This is another sign that the drive motor needs to dissipate a considerable amount of heat when operating.

To be honest, I have encountered several engine room installations and none of those watermaker motors has failed—yet. The motors are conservatively rated for their application and should last for many years—even, apparently, when installed in a hot engine room.

Even though an engine room installation may perform well under most conditions, I can imagine a scenario in which they could result in problems. For example, a watermaker running in an engine room for lengthy periods of time when the engine is also running, and all this on a boat in the Sea of Cortez during the summer months, where the intake water temperature might be 90ºF and the high-salinity water is causing an increased load on the watermaker pump. These are, admittedly, extreme circumstances—but not uncommon. For some reason, many cruisers gravitate toward the little, warmer latitudes and tropical climates.

Another possible problem with the heat generated in an engine room is the tendency to dry out the membrane, especially during long periods of non-use. Membranes need to stay moist. If you ever purchase a new membrane, you will notice that it is shipped in an air-tight plastic envelope and is pre-moistened with biocide solution. It is conceivable that a watermaker left unused for a long period of time in an engine room could have its membrane adversely affected by the drying heat.

In summary, engine room watermaker installations are pushing the envelope of tolerable environments for the equipment. If considering a new watermaker installation, I suggest you scratch the engine room off your short list of possible locations. The chances are you and your watermaker will be happier over the long run.

Minimize Noise: Like most pumps, watermakers make a certain amount of noise when running. Depending on your (and your crew's) level of tolerance for the noise, you may want to consider a mounting location that is a comfortable distance away from the main salon and berths. Locating the watermaker in that empty compartment directly under the head of your bunk in the master stateroom is probably *not* an inspired idea.

Look at available spaces in aft lazarettes and compartments. Cut a rubber pad from an old inner-tube to place between the motor mount and the mounting surface. This will go a long way toward damping sound transmitted through the mounting bulkhead to other areas of the boat.

Orientation: The primary caution for mounting all PŪR ***PowerSurvivor*** watermakers is to make sure that the pump and the gear box are in a horizontal line and, in the case of the larger modular units, that the membrane housing is not directly above the drive motor.

The first goal of this caution is to protect the electric motor from seawater leaks at the pump or membrane housing. If the membrane and/or pump are directly above the motor, a leak could drip onto the motor and cause damage. (The electric motors on PŪR watermakers are not waterproof.) The second goal is to minimize the possibility of gear box lubricant working its way downward into the pump and then the membrane, which might happen if the drive unit were to be located directly above the pump. Note that the gear box lubricant is not silicon-based.

Having thus rigidly restricted one axis of the watermaker's orientation to the horizontal, we may experiment with all other positions that are the various angles of rotation about that rigid axis. In effect, we have the option of mounting the drive motor either horizontally, vertically or at some angle in-between.

Mounting the motor horizontally is known to work and is illustrated in the *Owner's Manual*. I can also verify for the ***PowerSurvivor 35*** that vertical mounting with the motor pointing downward will perform well. On the other hand, I have tried orientations that did not work; e.g., mounting the new ***PowerSurvivor 40E*** with the motor pointing *upward*. The best approach to this potential problem is to first determine an acceptable location and orientation and then try it out in that position before drilling the mounting holes—it might not work!

Plan for Leaks: Eventually, one way or another, the watermaker pump will leak. Count on it. It's in the nature of the beast. A failed manifold o-ring, over-pressure due to a plugged membrane, old seals, excessive stress on the Intake/Reject hose barb assembly—all these problems and several others can cause leaks. Consider what you plan to stow directly below the watermaker. Would it be harmed by a dribble of seawater?

One creative approach to those up-and-out-of-the-way locations for the watermaker is to place an old towel in an easy-to-see spot on top of the gear directly below the watermaker. Check the towel frequently for signs of a drip to detect problems early (and protect the gear underneath the towel).

Plumbing Considerations

Before discussing plumbing details, we should define two quite distinct phenomena that occur as a result of faults in the plumbing installation—*cavitation* and *air leaks*.

Cavitation—is the occurrence of void spaces in the water flowing through the pump. If the pump operates to pull water in and there is not enough water available in the intake lines to fill the empty space created by the piston stroke, a vacuum space or "air-less" bubble will be created. The net result is lost effort by the pump and reduced product water flow through the membrane.

The principal cause of cavitation is excessive resistance to the flow of intake water to the pump. Intake hose length, hose and thruhull inside diameters, distance of the pump above the waterline, valves and elbow restrictions, the prefilter element and other in-line strainers—all contribute to the net resistance to intake water flow. At some point, if one runs water through a hose long enough, and of small-enough diameter, to a watermaker mounted high enough, with prefilters dirty enough—cavitation will occur. (*Note*: A very easy way to cause cavitation in an existing installation is to operate the pump with the intake seacock closed!)

Fortunately, few practical installations push these resistance factors to the extreme. For a useful benchmark: using the stock 3/8" reinforced plastic hose provided with the ***PowerSurvivor 35*** and ***40E*** (or the 1/2" hose supplied with the **Model** ***80*** and ***160E***), a run of 10–15 feet from a seacock and coarse strainer to the prefilter housing which, in turn, feeds a watermaker at a height of four or five feet above the waterline—such an installation should work just fine and be well within the allowable limits of the flow resistance factors.

Air Leaks—are the bane of the inexperienced installer. Because air—unlike water—is highly compressible, a small amount of air inside the high pressure, low volume, watermaker pump can cause it to completely stop producing product water. I also have reason to believe that, in certain cases, small pockets of air can become trapped within the ports and passages of the pump and cause it to continue malfunctioning until the air is eventually *dissolved*. Where do air leaks typically occur and how can they be eliminated?

The most common location of air leaks in the standard plumbing hardware provided with ***PowerSurvivor*** watermakers are the three-way valve and attachments at the prefilter housing. It is difficult to get the plastic valve nipples to seal well in the prefilter housing top. The plastic threads need to be tight enough to seal, but it is very easy to *overtighten* them. An excellent solution to this problem comes straight from a factory technician: use *Permatex*® non-hardening gasket sealant on the male threads. This actually works better than teflon tape or any other sealant I've tried.

Air leaks at the connections between the reinforced plastic hoses and their respective hose barbs are rare, unless the hose barb is too small. When using a correct hose barb, the hose should slide onto the barb with some difficulty and be very snug. In fact, these connections should not leak even without hose clamps. If difficulty is encountered in sliding the hoses onto the barbs, immerse the last inch or so of the plastic hose into boiling-hot water for 15-20 seconds and then quickly slide it over the barb. It should glide on like silk.

Another potential source of air intrusion is the o-ring seal between the prefilter housing and its top. If the sediment bowl is not threaded correctly into the cap or is not screwed all the way up to compress the rubber o-ring, the prefilter unit will leak air into the intake water flow. With some practice at screwing the housing on, and a little attention to detail, this source of air leaks is easily eliminated. Of course, in order to seal properly, the o-ring must be smooth and clean. A small chunk of dirt or debris between the o-ring and its mating surface is quite likely to cause an air leak. Inspect, clean and lubricate (with silicon grease) the o-ring in the prefilter housing every time you remove it. Be advised that, if the housing o-ring is torn or missing, an air-tight seal will be impossible!

With the ***PowerSurvivor 35***, a third, and often overlooked, source of air leaks is the input/reject hose barb assembly. The o-rings for this assembly are small and easily distorted or damaged by excessive strain on the hose barbs. The proper solution to this potential problem involves installing the intake seawater and reject brine hoses so they cause little or no strain on the hose barb assembly. To do this will require proper dressing of the hoses as they lead up to the hose barb connections.

<u>*Note*</u>: The seal between reinforced plastic hose and a correctly sized barb is so snug that it is almost impossible to remove the hose from the barbs at a later time. If excess hose (a "service loop") was provided in the original installation, the easiest solution may be to cut the old hose off the barb. Another technique, space permitting, is to dribble boiling water over the hose for awhile and try removing it while the plastic is soft.

It is important to understand the difference between cavitation and air leaks. They are quite separate types of phenomena and have different causes, symptoms, and cures. With this understood, we are ready to discuss the main issues involved with plumbing a watermaker system.

<u>Intake Source</u>: Where will the intake water come from? There are two common choices: either tee into an existing source or install a new thruhull specifically for the watermaker.

In most cases, the easiest solution is to tee into an existing intake line. This eliminates the necessity of adding yet another thruhull to the vessel. Many skippers believe that every hole in the hull of a boat is a potential catastrophic leak. Whatever your philosophy about thruhulls, tapping into an existing facility for the intake seawater supply to the watermaker is a valid and much-used approach.

Some existing thruhulls will clearly not be good sources. For example, many sailboat owners have tapped into the water inlet for their ship's head, only to discover later that the thruhull is relatively high on the hull and often out of the water when under sail in a seaway on a particular tack. If it's the starboard tack that's vulnerable and the vessel is sailing from Mexico to Hawaii, such an installation could present a real problem. If, while sailing your boat, you've discovered that you have to tack when you want to flush the head, the inlet for the toilet is *not* a good choice to reliably feed your watermaker at all times.

Often the best seawater intake source for the smaller watermakers (***35*** and ***40E***) is the line for the seawater intake to the vessel's auxiliary engine. It is typically the lowest thruhull on the vessel, thus almost eliminating the likelihood of sucking air when the vessel is heeling. This is the path we initially took on our boat.[*] The volume of water flow required by a watermaker is actually quite small.[†] The demands of the watermaker will <u>not</u> make a significant difference in the amount of water getting to the main engine. In other words, the watermaker is not likely to make the engine overheat. (If it does, you should conclude that the existing seawater flow to your engine is marginal and needs to be increased.) On the other hand, our watermaker has never had any problem drawing all the water it needs, even when our Westerbeke 27 diesel engine is running at full cruising rpms. The thruhull is 3/4" with a seacock and coarse raw water strainer at the inlet. The intake hose is the standard 3/8" reinforced plastic.

For the larger models—the ***80***s and ***160E***—it is more important to install a separate thruhull. The intake flow requirements for a ***PowerSurvivor 80*** are twice that for the ***40E***, and the requirements of the ***160E*** are four times as great as the ***40E***.

Whether an existing inlet is shared or a new thruhull installed, consider the location carefully. The lower on the hull (the closer to the keel) it can be located, the less the chances it will intermittently suck air in a heavy seaway. As with every thruhull, a seacock should be installed immediately inside the hull and the location should allow easy access to it.

Although 3/8" intake hose is supplied with the ***PowerSurvivor 35*** and ***40E***, installing a larger, 1/2" thruhull and matching hose should be considered during a first-time installation. Among the new ***Endurance*** line of watermakers, only the **Model *40E*** comes with 3/8" hose. The **Model *80E*** and ***160E*** both use 1/2" hose. I've suggested that the manufacturer standardize on 1/2" plumbing for all their watermaker models. It would simplify their lives, and ours—especially if an owner decides to upgrade to a larger capacity watermaker and wants to use the existing plumbing!

One problem I've encountered is difficulty in finding additional 3/8" hose in marine supply stores. Many stores only stock 1/2" and larger. If a 1/2" thruhull is installed in the beginning, you can either install a 3/8" hose barb at the seacock and use the 3/8" hose shipped with the watermaker, or you can run 1/2" hose to the prefilter and adapt the larger hose to the intake selector valve. The latter method involves more cost and a little more work, but it has several advantages:

1. Water flow resistance is less with larger hose. This becomes more important as longer hose runs are considered
2. materials are easier to locate in standard retail stores

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[*] We presently have two watermakers, a ***35*** and ***40E***, in addition to a water-cooled refrigeration system. I've changed our intake configuration to a dedicated 1½" thruhull and an auxiliary booster pump to supply both watermakers and the refrigeration condenser unit.

[†] To produce 1.4 gal/hr product water, the ***PowerSurvivor 35*** pumps approximately 10 x 1.4 = 14 gals of seawater per hour. The specifications for the ***PowerSurvivor 40E*** state 20 gallons per hour. By comparison, even the smallest sump or bilge pumps will have rates of at least <u>400-500</u> gals per hour!

3. a future upgrade to a larger capacity watermaker becomes a simple matter of bolting the new one in place—the existing plumbing will already be adequate

Intake Strainers: Anyone who has spent much time living on a boat offshore can testify to the amazing variety of "things" that can appear in an intake seawater line. I've seen sand, seaweed, squid, octopus, small crabs, wooden sticks—the list is fascinating. Is a coarse strainer in the intake line to the watermaker a good idea?

If your intake source is an existing line—e.g., your engine seawater intake—a coarse strainer may already be installed. In that case, make certain to check and clean it often. This is not to prevent a problem with the watermaker, but to prevent engine overheating. Reduced water flow caused by a clogged intake water strainer will affect the engine long before causing a noticeable problem at the watermaker.

Be aware that the needed frequency of strainer cleaning will vary greatly depending on the kind of water in which the boat is operating. You may go for weeks between cleanings on long, blue-water passages, while motoring near many coastal areas might require daily (or even more frequent) checks.

The purpose of a strainer is to remove relatively large, solid objects from the intake water stream and thereby protect downstream devices from possible malfunction and damage. Good examples are the impeller in the saltwater pump on an auxiliary engine and the valves in a head pump. I personally experienced failures of both these devices before installing coarse strainers in both lines.

On the other hand, the watermaker pump is already protected by an in-line prefilter unit. The prefilter will block everything a coarse strainer will and much more. The bottom line: if you have a separate thruhull for the watermaker, don't worry about including a strainer. If you take proper care of your prefilter, you'll never miss a course strainer.

Hose Runs: Plan the route your hoses will take from the intake site to the prefilter. As much as possible, minimize the length of hose and the number of bends. Where bends are necessary, make an effort to create large-radius curves instead of sharp bends or right-angle elbow fittings.

No installation should be considered finished until the water hose and electrical wire runs have been properly dressed down and secured. A common cause of air leaks and other plumbing problems, especially when working with reinforced plastic or other flexible hoses, is failure to secure the hose along the runs. Undressed hose runs can sag, crimp, and cause stress at the hose barbs and other connections. They are easily kinked or damaged when they shift positions and they are a definite hazard around the moving parts of an engine or other machinery.

Once you've taken the time to carefully plan your installation and crawled through the bilges to route the plumbing, take the little extra time required to secure the hoses and electrical wiring. The first time you proudly show off your installation to another cruiser, you'll be glad you made the effort.

Electrical Considerations: The electrical circuit for the watermaker is about as simple as electrical circuits get. The minimum electrical requirements for the ***PowerSurvivor*** watermakers are two wires of adequate gauge (diameter), a 12 VDC battery, and a circuit protection device (either a fuse or a circuit breaker (See *Figure 2*). Practical circuits will usually have a few other niceties, such as wire terminals and terminal strips. An hourmeter for monitoring running time is a nice enhancement.

Ways to implement the electrical supply for the watermaker vary widely, from the bare minimum hookup to a battery (e.g., something like *Figure 2*) to sophisticated multi-battery systems with voltage and current monitoring. This is not the place for a treatise on yacht electrical design. There are many good books on the subject. However, the following general comments should be useful.

Use electrical materials that are designed or optimized for marine use. The preferred wire is tinned stranded copper. Never use solid copper wire for boat electrical wiring. Vibrations and vessel working cause it to fatigue and fail prematurely.

Personally, for low-voltage, 12 VDC circuits, I usually install a heavier gauge wire than the equipment actually requires. For example, if the manual recommends that "wire runs of under fifteen feet should be 16 ga.," there is absolutely nothing wrong with using 14- or even 12-ga. wire. Larger wire is physically more robust and further reduces DC voltage drop. Don't be afraid to use it, if your budget allows. Consider the wire sizes recommended in the *Owner's Manual* for your model of watermaker as the minimum adequate gauges. Going a size or two larger won't hurt anything.

Watermaker specifications indicate the *average* current drawn by the model. The actual instantaneous current at any given time varies over a much wider range. As an example, the *average* current demand of the ***PowerSurvivor 35*** is about four amps, while the actual current varies from very little to 6-8 amps during each complete cycle of the pump. A 10- or 15-amp 12 VDC circuit breaker is normally appropriate protection for the circuit. In general, a circuit breaker with a current rating of 1½ to

2 times the average current required by the watermaker will provide adequate protection.

Be aware that there are two main kinds of circuit breakers found on boats: *thermal* and *hydraulic*. Hydraulic breakers are the best, but they are expensive and uncommon. Thermal breakers operate by sensing the heat generated as current flows through them. They are the least expensive and most common. In tropical environments, high ambient temperatures can cause premature tripping of thermal breakers, especially if the nominal rating of the circuit breaker is not far above the current rating of the watermaker. If this should occur, try using a next-larger-size breaker (or buy an expensive hydraulic breaker). It may also be necessary to go up a size in the circuit breaker rating if operating in high salinity water, which increases the load on the pump and drive motor.

Terminate the two wires from your 12 VDC power source (the black ground wire and the red wire from the load side of the circuit breaker or switch) at a terminal strip near the watermaker motor. Then terminate the motor leads with ring terminals, run them to the terminal strip, and make the power connections there (red-to-red and black-to-black). Using a terminal strip (instead of in-line butt splices) will be appreciated when it comes time to remove the watermaker for any reason. It is also an excellent test point for monitoring voltage and current at the motor. You won't regret taking the extra time to add a terminal strip to your installation. As with the water hoses in the watermaker system, make certain to dress down all electrical wire runs. Add extra length to the terminal ends of the wires (service loops) to bend into drip loops and allow for maintenance and/or re-termination in the future.

Routing Product Water

Potable water is a critical resource for an ocean cruiser. The greatest care must be taken to insure a supply of uncontaminated drinking water adequate for the passage. Think carefully about how you will handle the product water output from your watermaker.

Most watermakers currently available for cruising boats automate the routing of product water. A typical system involves some type of quality testing device installed in the product water output line. The device monitors the quality of the fresh water output and electronically controls a three-way solenoid valve to direct the product output to either a storage tank or a reject line.

If the water quality is unacceptable to the testing device, the solenoid valve is shuttled to a position to direct output flow to the reject line. Once acceptable product water is detected, the solenoid valve is moved to another position in which the product output is directed to storage.

In theory, the automatic handling of the product water is very attractive—turn it on and forget it. In practice, however, certain problems can arise. *What would happen if the quality testing device or the solenoid valve failed?*

At least one major manufacturer has designed a system in which the *unenergized* position of the solenoid valve is the position that directs water into the potable water storage tank. The advantage, which probably impressed the design engineers, was the lower overall electric power demand of that configuration. Typically the solenoid would only be actuated (and drawing electric current) for a few minutes at the beginning of a watermaker run to divert the initial flow of poor quality water. Then, during the long hours of a run, it would not be actuated, using no current, and directing water into the water tanks. Reversing the logic—requiring the solenoid to be *energized* to route water to the potable water tanks—would require significantly more energy from the batteries.

In my opinion, such sensor/actuator logic is wrong. Any failure to actuate the solenoid—whether a result of a problem in the electrical supply, the solenoid valve, or the sensor/controller module—will result in the valve assuming its *unenergized* position, *which routes water to storage*, regardless of the quality of the product water. Such a failure, combined with bad product water, will quickly contaminate the potable water in the storage tank. Since the product water is typically of bad quality at the beginning of a run, the threat of contaminated water from a defective sensor/solenoid is very real. It's worth noting that the same watermaker model with the faulty logic also had a history of solenoid valve failures!

A more correct engineering solution to this problem would involve reversing the solenoid logic, at the very least. The unenergized position of the solenoid valve should route product water to the reject line. The energized position should route water to the holding tank. That way, if the solenoid valve fails to actuate, all product water will be rejected until the problem is corrected. This outcome is usually preferable to that of having stored potable water contaminated. Only if the solenoid is capable of being energized (i.e., is working correctly) can the valve be moved to route product water to the potable water tanks*. This arrangement uses

* Another failure mode, of course, would be for the valve to remain "stuck" in its energized position even when the solenoid is not energized. This is an unlikely failure mode, but definitely another possibility.

more electric power, as already noted, but is much less likely to contaminate the potable water supply.

Still, things can go wrong. Solenoids, and the valves they operate, can and do fail in a number of ways. It is possible for the solenoid's actuator arm or lever to jam in any position. The valve is also vulnerable to jamming. In the last analysis, there is no *sure* way to implement a 100% reliable automatic water routing system. If you currently use such an arrangement, be certain you understand your vulnerabilities. In particular, if you own one of the older ***PowerSurvivor 80***s, you might want to remove the solenoid valve and sensor from your product water output plumbing. Their intended function is easily performed by a TDS (*Total Dissolved Solids*) meter and a manual three-way valve.

If your cruising plans include only coastal passages from one marina or anchorage to another, you will have less need to be concerned about contamination of your potable water supply. At any time, you are likely to be within one or two days sail of a water supply. Or, if you have multiple water storage tanks that are religiously kept isolated, the threat may not be as great.

On the other hand, many boats—especially smaller ones—make do with a single water tank. In my mind, one of the most important advantages in having a watermaker is the possibility of reducing water tankage, thus freeing up critical space for other storage items. On our boat, we eliminated one of the two original thirty gallon water tanks and used the liberated space for stowing food. However, reducing our tankage to a single tank has forced us to re-think the whole concept of potable water storage. A vessel with only one potable water tank is the most vulnerable to potable water contamination.

In particular, vessels that are being outfitted for long-distance, blue water cruising have additional concerns. They expect to be far from land and potable water sources on some occasions, and must take extra precautions to guard the potable water supply carried aboard the vessel. Again, this is especially true if there is only one main storage tank.

The system we adopted for our boat has worked well. For about five minutes after starting up the watermaker, we reject the product water. Then I manually taste-test the product water, checking mainly for any traces of salt. When the output is good water, I place the small output hose into the mouth of one of the two six-gallon jerry jugs strapped down right below the watermaker in our lazarette (see *Figure 3*).

Later, when the first jug is full, I taste-test the product water again before transferring the hose to the second jerry jug. If the water still tastes good, I assume that the water collected in the first jug is fine, because it was fine when I started to fill and it was fine at the end. When convenient or needed, I manually transfer the water in a full jerry jug to the main water tank by pouring it into the inlet on deck. We run the watermaker often enough to keep the main tank at least half-full (about 15 gallons) and both jerry jugs full at all times. The objective here is twofold:

1. Make sure that water going into the main storage tank is always good by testing it at the *beginning and the end* of the production run before transferring it to the main tank
2. Always keep at least twelve gallons of emergency water (the two jerry jugs) in case of damage to the main tank

This system does not allow for water to be routed directly to the main storage tank from the watermaker. That would not permit testing water quality at the *end* of the production run. In effect, I am recommending that even the manual product water three-way valve *not* be used to direct water to the main tank after it tests good following a startup. What would happen to the water in the main storage tank if a watermaker failure some time later (e.g., a ruptured membrane) caused seawater to appear in the product water output line? Of course, the main tank would be contaminated. This is the reason we make product water in small quantities (6-gal. jerry jugs) and taste it at the end as well as the beginning of the production run.

In summary, I don't believe the prudent skipper should rely on automatic devices to control product water routing. At the very least, understand and think about the problems that can arise and adopt your own system of safeguarding your potable water supply. It's worth noting that none of the new ***Endurance*** line of watermakers from PŪR includes an automatic sensor and solenoid valve in the standard configuration. Instead, they now ship a TDS meter.

The Optional Booster Pump

One of the optional maintenance kits offered by Recovery Engineering for their watermakers is the "*Silt Reduction Kit*." It consists of a high-quality 12 VDC centrifugal water pump and a 5-micron prefilter assembly. The 5-micron prefilter is inserted in the intake seawater line *between* the watermaker and the standard 30-micron prefilter unit. It provides additional—and considerably finer—prefiltering of the intake water supply. Because of the increased resistance to the intake water flow caused by the second in-line filter element, the water pump is added to boost water flow to the watermaker.

Installing the silt reduction kit, especially the centrifugal pump, is not as simple an undertaking as it might seem. Before rushing out to buy one, consider whether you really need to go to the trouble and expense.

When is a 5-micron Prefilter Needed? The standard 30-micron prefilter does an adequate job of filtering the intake water under normal circumstances. A filter element in good condition will be removing everything larger than 30-microns from the intake stream. This assures that anything passing through the prefilter will be smaller than 30-microns. This is a sufficiently small size to allow the particles to be flushed on through the pump interior and membrane passages with the reject brine flow. There is really no need for finer filtering under such circumstances.

A problem arises when the intake water contains silt or other hard, abrasive substances. Potential problem areas include estuaries, tidal plains, coral reefs, and river mouths, to name just a few. If the watermaker will be used to process water with significant amounts of such contaminants, the owner should seriously consider installing the optional 5-micron prefilter. It is important to realize, however, that the finer prefilter merely reduces the size of the particulate contaminants that are passed through the watermaker—it does *not* eliminate them completely.

The problem with such contaminants, of course, is the greatly increased wear and tear on the watermaker's seals and moving parts. More, and larger, particles will cause more rapid and significant damage to the pump. The fewer, smaller particles that are passed when the 5-micron prefilter is added will continue to cause wear, but at a substantially reduced rate. Under such conditions, there is little question that the optional 5-micron prefilter will extend the life of the watermaker. On the other hand, if the watermaker is used to process silty water for extended periods of time, the owner should plan on replacing the seals at more frequent intervals. Also, the watermaker should not be expected to "live" as long as one that has been used only in "clean, open ocean seawater."

When is a Booster Pump Needed? I seriously question the common assumption that adding a second prefilter in the seawater intake line necessarily means adding an auxiliary booster pump, especially with the smaller watermaker models like the PŪR ***PowerSurvivor 35*** and ***40E***. The volume of water flow through these watermakers is so low (approximately 15-20 gallons per hour, or one quart per minute) that, in most cases, cavitation should not rear its ugly head even with both filters in line. Under optimum circumstances, the watermaker can draw enough water to work without the need for a booster pump. I have a lot of faith in those pumps.

Nevertheless, my penchant for imagining worse case scenarios for everything installed on a boat leads me in a different direction. Realistically, I suspect that adding a second prefilter may bring many installation configurations uncomfortably *close* to the point of cavitation. If short runs of over-sized intake hoses are used, if the watermaker is at (or not far above) the waterline, and if the filter elements are kept very clean, I have little doubt that the PŪR ***PowerSurvivor 35*** and ***40E*** would operate well with both filters in line and no booster pump. Given another system with long runs of standard hose, a watermaker mounted high above the waterline, and a moderate accumulation of detriment in the prefilters, I would not be surprised if problems developed.

With this said, it would be my recommendation that one should first seriously consider whether a 5-micron prefilter is really needed. If it is determined that the extra filtration is needed, a booster pump should also be installed at the same time.

Installing a Booster Pump: The auxiliary booster water pump provided by PŪR in its "*Silt Reduction Kit*" is a centrifugal water pump. A centrifugal pump has certain advantages. It can be dead-headed (have its output blocked) without damage and it adapts well to the variable flow rate requirements of a watermaker. On the other hand, the installer should be aware of the potential problems with improperly installed centrifugal pumps.

In stark contrast to the capabilities of the positive displacement pump in the watermaker, a centrifugal pump is not self-priming. If there is air in its intake line, it may fail to pump. It also depends on the fluid it is pumping for lubrication and must not be run dry for very long. The *March* **Model *893-04*** pump shipped by PŪR can tolerate no more than thirty minutes of dry running before damage is likely.

For both of the foregoing reasons, the centrifugal pump in the "*Silt Reduction Kit*" must be installed so that it meets the following conditions:

1. It must be installed so that it is *at least one foot below the waterline of the vessel at all times*. Sailboat owners need to consider both starboard and port tacks under sail
2. The pump should be mounted with the inlet horizontal and the outlet pointing either up, or sideways

3. Both the inlet and outflow hose runs should be slanted upwards, from the inlet to the pump and from the pump to the prefilter. It is especially important to avoid loops or sags that would allow air to become trapped in the intake hose

Recovery Engineering informs me that the same pump is shipped with the *Silt Reduction Kit* for all their watermaker models. Be advised that the input to the pump accepts a 3/8” FPT nipple and the output is a 3/8" hose barb. For ***PowerSurvivor 80*** and ***160E*** models, this will require adapting the stock 1/2" hoses to the pump.

The booster pump, manufactured by *March Manufacturing, Inc.*, of Glenview, Illinois, is a sturdy unit that is submersible. It may be mounted anywhere below the waterline without fear of damage from bilge water. It is warranted for 3000 hours or 12 months by the manufacturer.

Emergency Use

A unique and very attractive feature of the ***PowerSurvivor 35*** and ***40E*** watermakers is their capability of being operated manually, if necessary. This is accomplished by removing the drive motor and gearbox and attaching a long, aluminum handle that is used to operate the pump.*

Manual operation is a highly desirable feature. It is a comfort to know that water can still be produced in the case of a failure in the watermaker motor and/or drive unit or, more seriously, in the ship’s electrical supply. Those are the kinds of problems this feature is designed to address.

If this feature is important to you, give some thought to how you would operate your watermaker manually. Remember that you will still need access to intake water, which will require a hose run from the inlet hose barb to a seawater source. A second hose to route the reject water overboard would be useful, although not absolutely necessary. There are several ways to accomplish all of this.

Mount the watermaker in a location where it can be manually (and comfortably) operated without moving it. This is usually not easy to accomplish, especially in smaller boats. Of course, in order to install and operate the pump handle, the motor drive assembly still must be separated from the watermaker pump

Mount the watermaker where it can be easily unmounted and moved to a nearby location for manual operation. During installation, allow sufficient service length for the intake and reject hoses to permit use of existing plumbing without disconnecting any hoses. This is usually the best compromise and the design we used in our installation

Completely remove the watermaker and use different hoses for intake and reject lines

I suppose the third approach renders the watermaker truly “portable” for use in some imagined emergency. Unfortunately, when operated without an adequate prefilter system, the watermaker membrane is highly vulnerable to fouling, plugging up, and other serious and sometimes permanent damage. I do not recommend the use of the watermaker without a prefilter for any reason whatsoever. If some bizarre situation arises, in which you feel you *must* use the watermaker without a prefilter, or *die!*—don’t let me or this book stop you. Short of that kind of situation, it’s not a good idea.

This is an appropriate place to consider just what kind of emergencies the manual feature of the ***PowerSurvivor 35*** and ***40E*** is designed to address. We’ve already looked at one important type of emergency: power supply failure. How about the big one: *Abandon Ship*! There are a surprising number of cruisers I’ve met who think their ***PowerSurvivor*** watermaker will wind up in the liferaft if they ever have to abandon their vessel at sea.

At a seminar, I met one skipper who asked me how much strain could be exerted on the membrane housing. It seems he wanted to design a mounting bulkhead for his watermaker out of lightweight plywood. In the event that he had to abandon ship, he planned to grasp the watermaker by the long membrane housing and rip it from the bulkhead! Of course, he didn’t want to make the bulkhead *too* weak. That’s why he wanted to know how much strain he could exert on the membrane housing. He would design his bulkhead to be just a little bit weaker than that!

I’m afraid I couldn’t give him any firm figures and I didn’t inquire as to how he planned to handle the quick release of the hoses and electrical wiring. It sounded like he would be taking the pump *and drive motor assembly* with him—a heavy proposition when trying to abandon ship in a nasty seaway. Was the manual handle stowed conveniently nearby? Would he grab the 1/2” wrench he’d need to separate the pump from the drive gearbox later in the liferaft? He’d have to do that before he could attach the handle.…

Let’s be real about this. In planning your abandon ship drills, do not even consider stopping to disconnect and unmount your ***PowerSurvivor***

* REI sells a strictly manual version of the ***PowerSurvivor 35*** watermaker called, logically enough, the ***Survivor 35***. The latter model is still available.

watermaker. There will be many more important things to do first. Of course, if you have the leisure—if the boat goes down so painfully slow that you can unfasten the hoses and the bolts and disconnect the electrical wires, or find the right wrench and unfasten the four hex nuts that hold the pump to the drive housing, and remember where you put the handle—that's fine. However, don't count on having either the time or the mental organization to do it. If you do have that much time, it would be better spent trying to locate and/or plug the hole in the boat's hull. Bottom line—if you have time to dismount, disconnect and remove your watermaker, you probably have time to save the boat, which would make the whole issue a moot point.

If you are truly concerned about having a watermaker in your survival supplies, then you should buy one and dedicate it to that purpose. PŪR offers two small, manual RO watermakers that are a better design for survival packs: the **Model *06*** and the ***Survivor 35***. In any event, do not plan or count on taking your ***PowerSurvivor 35*** or ***40E*** in the life raft.

Some Facts and Figures

LET'S LOOK at some useful facts and do a few calculations. We'll use the PŪR ***PowerSurvivor 35*** for our example and apply *Ohm's Law*.

As stated by Recovery Engineering in their specifications, the ***PowerSurvivor 35*** requires about 4 amps of 12-volt direct current (VDC) under normal working conditions. This is actually an *average* current rating. If you were to connect a DC ammeter in series with one of the power leads, you would notice that the current demand oscillates from about 2 amps to 6 or more. This is because the electric motor draws more current during its power stroke and less during the rest of its duty cycle. The average should be about four amps. A rough estimate of the rate of energy use (watts) can be found by multiplying the average current times the voltage

4 amps X 12 volts = 48 watts

or about 50 watts. That is, the ***PowerSurvivor 35*** watermaker requires about the same amount of electrical power as a 50-watt lightbulb! The ***40E*** requires the same as the ***35***. The ***PowerSurvivor 80*** requires about twice that amount (~100 watts), and the ***160E*** about four times as much (~200 watts).

The reader should note that I am using rough calculations. A more accurate assessment of current and power requirements can be made by considering the voltage/current phase effects of an inductive motor load, using 13.8 VDC as per the spec, adding accuracy to the amperage factor, etc. For our purposes, such accuracy and technical depth are unnecessary.

Again using rough figures, we can estimate the rate of battery discharge when running the watermaker. If we assume a fully-charged 220 amphour battery, we can safely utilize about 75% of that capacity, or

220 amphours X 0.75 = 165 amphours

Next, we obtain the number of hours we can run the watermaker by dividing the available amphours by the watermaker's average current; e.g., for the ***PowerSurvivor 35*** (and ***40E***), with an average current of 4 amps, we get,

165 amphours / 4 amps = 41.25 hours

Thus, theoretically, the ***PowerSurvivor 35*** and ***40E*** can be run for over 40 hours on a 220ah battery system before the battery drops below 25% charge, assuming no other concurrent loads on the battery (knowledgeable skippers avoid discharging their batteries below 25% charge), and it will produce approximately

1.2 gal/hour X 41 hours = 49.2 gals

The careful reader might wonder about the "1.2 gal/hour" production rate used in the last calculation. Why not 1.4 gal/hour as stated in the manual? I used this figure as a reasonable average. As the battery discharges, the DC voltage available to the watermaker motor will decrease and the pump will run slower, producing less output. 1.2 gallon/hour is a more realistic average output over the entire discharge cycle of the battery. It is also a more realistic output figure for vessels running their watermakers without any charging devices (e.g., solar panels, generators, alternators, etc.) constantly replenishing the batteries and keeping the DC voltage high.

We can derive another useful set of values from our data. To produce, for example, five gallons of water, we would need to run the ***PowerSurvivor 35*** watermaker for

5 gal / 1.2 gal/hour = 4.2 hours

and use

4.2 hours X 4 amps = 16.8 amphours

In other words, for every five gallons of water we produce, we must run the watermaker for approximately four hours and use about seventeen amphours of battery capacity. If you need estimates for ten gallons, double the figures; for fifteen gallons, triple the amounts, etc. Or, calculate a different "basic unit" amount of water for your own use.

The average total daily water consumption by the two people on our boat is about 5-6 gals. This figure fluctuates, sometimes dramatically—for example, I've found that rinsing down wetsuits and diving gear consumes a surprising amount of water. But the *average* water use is what matters. The ***PowerSurvivor 35*** and ***40E*** are perfectly suited to boats with an average water use of up to about 12–15 gallons per day.

The Optimum Use Pattern

A PŪR factory technician told me a story about a ***PowerSurvivor 35*** that was returned under warranty just a few days before the one-year warranty period expired. The owner claimed the unit had failed and, indeed, it had. Upon inspection, it was determined that several internal parts were simply worn out. When the owner was questioned more thoroughly, it was discovered that he ran a busy commercial charter boat. The ***PowerSurvivor 35*** had been running continuously since it was installed in order to provide a constant supply of potable water for his passengers!

There is a rumor circulating to the effect that ***PowerSurvivor*** watermakers should not be run for long, continuous periods of time. The implication is that this somehow damages the unit. The truth is more comforting: there is nothing at all wrong with running a ***PowerSurvivor*** watermaker for long, continuous periods of time. The only negative consequence is that you will wear it out sooner rather than later.

Like any other machine, ***PowerSurvivor*** watermakers have a certain life expectancy before needing parts replaced or other servicing. If you find that you are running your ***PowerSurvivor*** watermaker more than 50% of the time (i.e., more than twelve hours per day, on average) to keep up with your water needs, you should seriously consider investing in a watermaker with greater output.

In my opinion, aside from accelerated wear, running the watermaker too much is less a potential problem than not running it enough. Whenever the watermaker is idle, decay and bacterial growth develop and the byproducts of these processes accumulate in the system. Frequent periods of use keep the system flushed and prevent the buildup of distasteful or damaging contaminants. A good use pattern for a ***PowerSurvivor*** watermaker is to run it at least several hours each day it is used, and use it at least every other day. With a ***PowerSurvivor 35*** or ***40E***, and a typical consumption rate of 5 or 6 gallons per day, this schedule is easy to maintain. We try to run our watermaker at least every other day.

According to this idealized use pattern, if your water needs are less than a dozen gallons per day, you should be using a ***PowerSurvivor 35*** or ***40E***. If your needs are in the 12–25 gallon per day range, a ***PowerSurvivor 80E*** would be appropriate. For daily water requirements that exceed 25–30 gallons per day, you should consider the ***PowerSurvivor 160E*** or one of the other watermakers with even larger-capacity that are available on the market. You should also be contemplating an engine-driven unit.

If the watermaker is to be idle for more than three or four days, it should be treated with biocide—a process known as "pickling"—to prevent bacterial growth in the membrane. This is especially important in tropical waters, where the warmer ambient temperatures promote rapid growth of membrane-damaging bacteria. Frankly, when in tropical waters, I biocide our watermaker if I do not intend to run it within the next *two* days!

According to many owners, simply flushing the watermaker out with product water before a few days of non-use is beneficial. This technique works, however, by *diluting* the concentrations of bacteria in the system—*not* by killing them. Thus, bacterial growth is only slowed down—not stopped—and fresh water flushing should not be relied upon for medium- or long-term lay-ups of the watermaker.

The "Big Stick" Philosophy: There is another philosophy about watermaker use patterns that is quite different from mine, and it deserves some comment. It is typically promulgated at boat shows by vendors of large-capacity watermakers, most of which are designed to be powered by the vessel's main engine. It goes something like this:

"Buy our large-capacity watermaker and make a lot of water when you run your engine. After all, you need to run your engine anyway to charge your batteries, keep up with your refrigeration, etc. Why not be stocking up on all the water you'll need instead of running a small-capacity watermaker every day or every other day?"

For a relatively small number of vessels, this approach might be a workable solution. In particular, for many motorboats and large sailboats with substantial fresh water requirements, it could make sense. If your water needs are considerable and you are running the main engine anyway during frequent passage making, you should certainly consider installing a large-capacity, engine-driven watermaker system. In most cases, large water needs are accompanied by other similarly large needs. At some point, a stand-alone generator system, separate from the main ship's engine, becomes desirable.

Producing large quantities of potable water at infrequent intervals also has its disadvantages. Large storage tanks are required, which defeats one of the advantages of having a watermaker. If the watermaker is to remain idle for more than a day or two in the tropics, it should be treated with biocide between runs.

On the other hand, I would argue that this approach is entirely inappropriate for the average cruising boat, especially smaller sailboats. The great majority of cruisers I've met over the years have sailboats in the 30–40 ft. range. They often spend long periods of time at anchor without any need to run the main engine. Almost invariably, they meet their electrical power needs by installing solar panels, wind generators, or small, portable gasoline generators. They do not rely on the main engine to provide day-to-day power for the on-board utilities.

Given this characterization of the "average" cruising boat, we can identify several problems with the "big stick" philosophy. First—and, I believe, most important—is the problem of using the main engine for electrical power. If the vessel is constantly on the move and the engine is being run under a substantial load most of the time, then it certainly makes sense to be recharging the batteries, freezing the refrigeration cold plate, and driving a watermaker at the same time. However, to sit at anchor for weeks at a time and run the engine a certain number of hours every day or every other day only to run the alternator, watermaker and refrigeration, is a bad idea.

Engines are designed to run efficiently under a load, especially diesel engines. Even with a high output alternator, a watermaker and a refrigeration system on line, most sailboat main engines will be running under a very light load and at reduced rpms. The result will be a relatively cold engine and inefficient combustion of the fuel. The latter contributes to "wet stacking," which is the accumulation of carbon particles and other contaminants on the cylinder walls, head and valve surfaces. Wet stacking, in turn, leads to an increased chance of injector fouling and other problems. Incomplete fuel combustion also results in more corrosive acids and other detrimental by-products of combustion reaching the oil in the pan and attacking metal surfaces. This latter problem is even more serious when burning diesel fuel with a high sulfur content (e.g., in Mexico).

According to over a dozen expert diesel mechanics I've contacted, using a diesel engine at less than about 25% of its rated load for extended periods of time is detrimental to the engine. In addition, when using high-sulfur content fuel, the engine oil should be changed more frequently.

In general, for most cruising boats, running the main ship's engine under light load for routine charging of batteries is not a good long-term solution to energy needs. For boats with modest fresh water needs, a large-capacity watermaker makes little sense.

Prefilter Maintenance

As indicated earlier, paying proper attention to the condition of the prefilter unit is the only routine short-term maintenance task required with PŪR ***PowerSurvivor*** watermakers. If this simple job is attended to, a plethora of potential watermaker problems can be avoided. If I sound a bit evangelical about this topic, it is because my experiences have convinced me of its importance.

What the Prefilter Does: Let's sketch a mental picture of what happens at the prefilter as raw seawater enters the system. With each stroke of the watermaker pump, suction is created in the intake plumbing that causes seawater to be drawn from an external source into the intake hose. The hose routes the water to the *intake* side of the prefilter unit, where it is dumped on the *outside* of the replaceable filter element inside the housing. Once the seawater has entered the prefilter housing, it is strained through the polyester filter element and drawn into the watermaker pump.*

The porosity of the standard filter elements shipped with ***PowerSurvivor*** watermakers is 30 microns, which is roughly equivalent to 0.001"—one thousandth of an inch. This means that all contaminants and debris that are larger than 0.001" will be "stopped at the border" of the filter element. Not only will they be stopped—they will remain where they are, trapped between the outside surface of the filter element and the inside surface of the prefilter housing. And they will remain there forever…or at least until the next time the owner services the prefilter.

The trapped material will be composed of everything, as already noted, larger than 0.001". That includes dirt, plankton, kelp, eel grass, squid, small fish, assorted excrement…the imagination reels! Now imagine such a collection of materials brewing in some warm, stagnant seawater for a couple of days. The result is not pleasant to contemplate, let alone smell. Should we expect the watermaker to produce sweet water from such a stew?

Actually, the watermaker will continue to remove salts and larger impurities until the accumulated debris becomes dense enough to impede the flow of seawater through the filter element and cause cavitation at the watermaker pump. That will usually take quite a long time. Long before that point is reached, the putrefying collection of debris in the prefilter will be yielding such an abundance of *hydrogen sulfide*, among other byproducts, that the user will have decided that something is wrong.

Hydrogen sulfide, a gas that smells like rotten eggs, is composed of small molecules—small enough to pass through the membrane and contaminate the product water. Typically, the product water will not taste salty, but it will have a distinct "organic" or "rotten-egg" smell associated with it. When this happens, it may be necessary to run the watermaker for an hour or more before all these byproducts of decay are flushed through the system and reduced to an undetectable level. Nevertheless, as soon as the watermaker is shut down, the contaminants are

* If an optional 5-micron filter has been added to the system, it should be located *between* the standard 30-micron prefilter and the pump.

still trapped and they continue to decompose and the smelly gases accumulate once more.

How much of these byproducts of decay are produced depends on several factors, including the ambient temperature, amount and type of debris, and length of time between watermaker runs (which is when the gases can accumulate). Warm environments, organic debris, and a couple of days of non-use are just about guaranteed to produce an impressive "brew."

Now that we know what kinds of problems can be caused by debris trapped at the prefilter, we should consider some of the problems caused by contaminants that are fine enough to pass through the 30-micron prefilter; i.e., anything *smaller* than 0.001".

Most small sized, soft material will flow on through the system and be expelled in the reject brine flow, doing no harm. The 30-micron filter is fine enough to assure us of that. It's quite another matter with hard, abrasive materials. Fine sand, coral, silt and other insoluble minerals are serious threats to the useful life of many of the working parts inside the watermaker pump. Inside the pump are several moving rubber seals that slide against smooth metal surfaces. Circulating fine silt or other hard contaminants through the pump will cause greatly accelerated wear on the seals and will roughen the stainless steel cylinder walls, which will further accelerate the seal wear.

It is also important to realize that the prefilter only removes *solid* material of a certain size and larger. It does absolutely nothing to remove any substances that are *dissolved* in the water, which includes a large range of undesirable chemicals.

Cleaning the Prefilter Housing: The best solution to the problem of decomposing debris in the prefilter housing is simply to clean the prefilter unit frequently. While first learning how often this is required, I recommend removing the housing and filter element *after each time the watermaker is run*. (Perform this service *after* a run, instead of just before, to eliminate the debris *before* periods of idleness.)

Unscrew the housing and examine the trapped debris. Learn to estimate its quantity and type by look and smell. Then dump it out and clean the inside of the prefilter housing.* Exchange the filter element for a clean one and reassemble the housing. That's all there is to it. If care was taken during the installation to mount the prefilter assembly in an easily accessible location, this should be no more than a five minute job.

If you start out cleaning the prefilter more often than is needed, as I've suggested, you will become intimately familiar with the rate of debris accumulation in your system in a surprisingly short time. This rate can—and will—vary widely, from a minimum rate of accumulation when making blue-water passages to a much higher rate when making water in shallower, near-land waters.

Soon you will know your system and it's likely you will be able to increase the period of time between prefilter servicings. You will have learned that you can go for days, even weeks, without cleaning or changing the filter during a passage from California to Hawaii. On the other hand, you will know to check it daily when making water in the estuary at San Blas, Mexico. You will know to check the prefilter whenever you've processed unusually brackish or murky water, or water with marine flora or fauna obviously present. You will also know when you can kick back and *not* worry about it! Knowing these differences—knowing when to worry and when not to—is guaranteed to be a comfort to the concerned cruiser!

Swapping Prefilters: The alert reader will note that I recommend exchanging the filter element each time the filter housing is cleaned. If the reader has also investigated the cost of replacement filter elements from PŪR, the thought of going through so many filters will raise an immediate red flag. PŪR has a suggested list price on their replacement filter elements of approximately $10 per element! This seems a high price to pay for…what?—guaranteed quality?

Such high prices for important after-market supplies are powerful incentives for users to seek alternate sources—and they do. I know of no reason why a properly-sized, 30-micron, polyester filter element purchased for $3 in a Mexican *ferreteria* shouldn't work just fine. The essential elements are those just mentioned:

> make certain that any third-party replacement elements are the correct size for the prefilter housing
>
> be certain that it is a 30-micron (or slightly smaller) mesh
>
> verify that the material is polyester—filter elements made of paper will break down and clog (= ruin = $350+) the membrane.

If you can't determine the difference between a paper and a polyester filter element, I suggest you cough up the bucks for a stock of replacement filters direct from PŪR (or one of their distributors).

* Be careful not to dump the large prefilter housing o-ring overboard with the foul water—it's very easy to do and those o-rings are hard to replace. A replacement is *not* included in the *Repair Seal Kit*.

With all that said about the high cost of replacement filter elements for the prefilter assembly, the fact is that very few filter elements are needed, if they are utilized properly. In fact, during the last two winters in Mexico, a total of twelve months during which we made water at the rate of about five gallons per day, we used only *three* filter elements!

Cleaning the Filter Elements: What constitutes proper use of a filter element? At the top of the list is frequent cleaning—*very* frequent cleaning. Second on the list is a strong emphasis on *gentle* cleaning. Here's how we make it work:

Each time the filter housing is removed to dump the accumulated debris, examine the filter element. Smell the filter and contaminated water. If you don't like what you smell, replace the filter element with a clean one.

To clean the dirty element, tie a line through the center and throw it overboard. Secure the bitter end of the line to the boat so the filter is suspended underwater. If underway, tow the dirty filter for a few hours. If at anchor, let it bob up and down for a day or two. If in a marina with pressurized water, clean it gently with a hose and sprayhead. In any case, finish the cleaning treatment by drying the element in direct sunlight for a day or two. Store the used, but clean, filter element until the next prefilter servicing. By rotating two or three filter elements in this way, the elements can be expected to last for many months.

It is worth highlighting the fact that this cleaning process for the prefilter elements does not involve any scrubbing or direct abrasion of the filter material. Physical scrubbing is rarely necessary and significantly shortens the life of the filter element by raising and tearing its fibers. On the other hand, filter elements that have accumulated large quantities of debris over relatively long periods of time are much more difficult to reclaim and reuse. Once again, the moral of the lesson is: *clean the prefilter often; exchange and clean the filter elements frequently*.

Pump Maintenance

There is little to be done in the way of routine day-to-day maintenance of the pump assembly itself. Inspect the pump for leaks regularly. If a leak is detected, note its source, if possible. Accumulations of salt deposits are usually good clues to the origin of a leak.

With the ***PowerSurvivor 35***, a common source of leaks is the inlet/reject hose barb assembly that couples the inlet and reject brine hoses to the pump manifold. This assembly is easily damaged and is a potential site of both water leaking from the system and air ingress into the pump.

If a leak appears to be coming from the pump body itself, the source is likely to be a failed o-ring or seal inside the pump. The first attempt at a fix is to install a new seal kit (see the following chapters).

On the ***PowerSurvivor 35***, it is instructive to observe the small white indicator shaft projecting from the over-pressure relief valve on the manifold while the watermaker is running (see *Figure A-6*). Under normal conditions, it should move in and out in pace with the strokes of the pump. While watching it, note its normal range of travel. The pattern of travel of this pressure indicator can be valuable troubleshooting information. Among other things, one can get an estimate of the pressure being developed by the pump by noting the distance through which the indicator shaft moves. If it moves at all, some pressure is being produced. If it moves too far, exposing the red band at its base and possibly leaking water, it indicates that too much pressure is being developed (e.g., from a plugged membrane). If the indicator moves within its normal range, the pump is probably working well.

The owner's manuals for the new PŪR ***Endurance*** line of watermakers all include instructions to replace the seals after every thousand hours of use. In other words, periodically installing a seal kit is considered a routine maintenance matter with the new product line. The same is true for the ***PowerSurvivor 35***, although the owner's manual does not explicitly say so. To maintain any ***PowerSurvivor*** watermaker in good, reliable working condition and avoid most failure modes, you should replace the seals (install a seal kit) every cruising season or one thousand hours of use.

Membrane Maintenance

The best way to keep an RO membrane in good working condition is to feed it clean intake water and use it frequently. Clean intake water will not contain harmful chemicals that attack or clog the membrane. Frequent use will help keep bacterial concentrations low. Bacterial concentrations are also minimized by keeping the prefilter system clean. Occasionally the RO membrane requires extra care above and beyond these routine maintenance tasks.

Biocide Treatment: The watermaker membrane should be treated with a biocide solution before any "extended" period of non-use. In a *temperate* environment, if the watermaker is to remain idle for more than a week, it should be treated with biocide. In a *tropical* environment, I recommend a biocide treatment if the watermaker will not be used within the next *two* days.

What is biocide and what does it do? The biocide supplied with ***PowerSurvivor*** watermakers is the chemical *sodium metabisulfite*, a very common (and usually inexpensive!) industrial chemical. It is a strong anti-oxidant. In effect, when dissolved in water and pumped through the watermaker, the biocide "ties up" any free oxygen in the system (inhibits oxidation). Since bacteria that have entered the membrane with the seawater are normally oxygen-requiring critters, the biocide deprives them of the oxygen they need and they die instead of growing and clogging the membrane pores.

According to published PŪR literature, a proper biocide treatment should be adequate for over a year of non-use or storage of the membrane. Privately, I've been assured by factory personnel that a biocide treatment will normally preserve a membrane for considerably longer than a year.

Directions for mixing the biocide with water and pumping it through the watermaker are given in the ***PowerSurvivor*** owner's manuals. Proportions of the sodium metabisulfite powder to water are not too critical. Completely dissolve a capful of the biocide powder into a quart or two of fresh, non-chlorinated water and feed it into the pump inlet, using either the standard 3-way inlet valve and small hose with strainer or your own plumbing arrangement.

The idea is to thoroughly flush the membrane with the biocide solution. Once that has been accomplished, however, another question arises: should the pump be left full of biocide solution or should most of the solution be pumped on through and out of the pump?

Does it make any difference? Probably not. With either technique, the bacteria in the membrane will be killed and their growth inhibited. Unless fresh seawater (with new, live bacteria) is run through the system, it should make little difference whether the system remains full of biocide or has some air inside—as far as the bacteria are concerned.

Nevertheless, there is a *possible* advantage in pumping the bulk of the biocide on through—and thus drawing air into—the pump. It has been suggested that the biocide, which is an anti-oxidant, may have a detrimental effect on the stainless steel parts inside the pump, particularly the poppet valve springs and the main piston cylinder. Stainless steel is protected from corrosion by oxygen in the environment. The concern is that leaving the stainless steel parts in an oxygen-starved environment (the biocide) *may* contribute to crevice corrosion.

In my opinion, the jury is still out on this one. The issue was raised for me by another cruiser with a knowledge of chemistry. My suspicions were further aroused after encountering three ***PowerSurvivor 35*** watermakers with damaged cylinders. Portions of the narrow lip of metal on each outside end of the cylinders had chipped off. The lips retain the cylinder o-rings and backup seals. They appeared to have corroded at their base.

I took a damaged cylinder with me during my first visit to Recovery Engineering and asked one of the design engineers about this problem. He admitted that the cylinder *might* have been a victim of crevice corrosion. On the other hand, he had not seen enough occurrences of this problem to suspect detrimental effects from the biocide. I was told that parts at the factory had remained in biocide solution for years with no apparent harmful effects.

Although I have encountered three instances of damaged cylinders with what looks like the pitting of crevice corrosion, I have been unable to detect a pattern or any clear correlation with exposure to biocide. I have carefully inspected the cylinder of every watermaker I've disassembled and almost every one has been in excellent shape, regardless of its biocide history. The few cylinders I've found with pitting at the base of the seal lips may have been flawed during the manufacturing process.

In summary, to date I've looked for—and *not found*—any clear evidence that the biocide damages either the stainless steel pump components (through crevice corrosion) or the rubber o-rings and seals. On the other hand, when b襲ociding my own watermaker, I continue pumping air through the pump until the reject line spits air, thus assuring a small supply of oxygen inside the pump. I suspect that it really doesn't make much difference.

Membrane Cleaning: Performing a membrane cleaning process is a little more involved than the biocide treatment, but it is essentially the same for both the alkaline and the acid cleaners. Follow the instructions in the owners manual for using these two chemicals.

Take extra care when removing the regular membrane housing and installing the special membrane cleaning housing on the ***PowerSurvivor 35***. Avoid any sideways torque on the membrane itself. It is very easy to crack the narrow stem on the pump end of the membrane. It is also easy to damage the membrane brine seal (the large lip seal around the pump end of the membrane). Be certain to lube the brine seal and the inside of the housing (which mates with the brine seal) with silicon grease before reassembling them.

The cleaning process is rarely required, especially if the watermaker has been run in relatively clean seawater and run often. Under such circumstances, an annual or cruising-seasonal cleaning with at least the alkaline cleaner is probably a good idea, although not likely to be greatly needed.

The purpose of both cleaning processes—acid and alkaline—is to remove stubborn deposits that have accumulated on the working surfaces of the membrane. Most often, these are organic deposits like bacteria and small organisms. The likelihood that such deposits will form is increased by extended periods of watermaker non-use without biociding, especially in warm environments.

The alkaline cleaner is best for removing organic materials. The process is much like treating a sink drain with caustic soda (*sodium hydroxide*), a strong alkaline chemical. The alkaline cleaner dissolves and loosens organic matter, thus enabling it to be flushed out of the system. The acid cleaner is less commonly needed. It is useful for removing mineral deposits and scaling, which may occur when processing input water with unusually high concentrations of minerals.

The most important gauge of the need for a membrane cleaning is a measure of the product water output. It is an excellent idea to measure the rate of product water output (at a known DC voltage) soon after installing a new watermaker. Later, you can measure the output again (at the same DC voltage) and get a good, quantitative measure of the decline in output, if any. As a rule of thumb, a decline of 15-20% in product water output would probably indicate the need for a membrane cleaning.

When launching the cleaning process, it is usually most convenient to do both the alkaline and acid cleaning processes in sequence—if both are needed. This is especially true with the ***PowerSurvivor 35*** since the installation of the special membrane cleaning housing is required for both processes. Monitor the rate of product water output before cleaning. Then do the alkaline cleaning and again measure the product output rate. Hopefully there will be an improvement. Finally, if needed, flush the system and perform the acid cleaning. Measure the output rate once more.

The cleaning process is useful but can not be expected to revive a membrane that has been seriously neglected or abused. With regard to the health of an RO membrane, "an ounce of prevention is worth a pound of cure." If your watermaker is properly maintained and used frequently, you should seldom need to clean the membrane.

Miscellaneous Maintenance

Record Keeping: As with other types of important equipment requiring a regular maintenance schedule, keeping an activities log is an excellent idea. At a minimum, it should include entries for all servicing, biociding and cleaning procedures. Ideal would be a log documenting the times the watermaker is run, dates of prefilter changes, and an estimate of the amount of water produced. On the other hand, the maintenance requirements for ***PowerSurvivor*** watermakers are so minimal and infrequent that it's easy to dispense with a log and get by quite nicely.

Gearbox Servicing: I'm often asked about the maintenance requirements for the drive motor and gearbox of the ***PowerSurvivor 35***, since there is nothing mentioned in the factory manual. In this case, no news is good news. The gearbox is virtually indestructible (unless water gets inside) and probably will not need servicing during the lifetime of the watermaker.

The gearbox of the ***PowerSurvivor 35*** is stuffed with grease before leaving the factory and should not need additional lubrication. In fact, there is so much grease in the gearbox that it tends to ooze out onto the drive shaft. This grease will try to work its way along the drive shaft and into the pump. If this happens, and the grease finds its way to the membrane, the latter is likely to be damaged. Therefore, once or twice each year, wipe up any grease that has appeared on the drive shaft outside the gearbox housing and lubricate the drive shaft, coupling pin and rubber boot with *silicon* grease. That's not much to ask.

The gearboxes on the new ***Endurance*** line of PŪR watermakers (the ***40E***, ***80E*** and ***160E***) are completely new designs. They are lubricated with a special gear oil instead of the grease used in older models. The gear oil should be changed seasonally, or every 1000 hours, at the same time a repair seal kit is installed.

Motor Servicing: The electric drive motor is probably "over-spec'd" for its application. The motor is beefy, its duty cycle is reasonable, and it should last for many years of normal use. Although the manual doesn't mention the fact, the motor brushes are expected to last about 5000 hours, which is a long time. For extended cruises, carrying a spare set of motor brushes is probably a good idea—contact Recovery Engineering. On the other hand, new brushes and electric motor servicing are usually obtainable, even in underdeveloped countries. Note that early versions of the ***PowerSurvivor 35*** did not have removable brush capson their motors. This prevents the user from easily inspecting and replacing the motor brushes.

Caution: When working with your fingers or tools near the drive shaft and coupling pin of these watermakers, *be absolutely certain that the watermaker can not be accidentally started up*. The drive units are very powerful and the drive shaft can easily cause serious injury or damage. Watch your fingers and tools!

Don’t Worry, Be Happy

IN THIS CHAPTER, we begin the nitty-gritty of providing explicit, detailed instructions for working on ***PowerSurvivor*** watermakers—including disassembly, inspection, troubleshooting, repair and reassembly. The context we’ll use for learning all these skills is the installation of a repair seal kit. As I’ve indicated elsewhere, periodic replacement of the seals should be considered standard maintenance and, eventually, every owner will need to do it (or have it done).

To most people, their watermaker is an intimidating piece of equipment. Any machine that can make fresh water out of seawater using reverse osmosis through a semipermeable membrane…well, it’s just got to be complex, right? For many, the thought of tearing their watermaker apart evokes images of small springs flying like bullets into obscure corners of the room and special-looking fasteners that are dropped and never found or matched again.

It need not be that way, even with complex devices. A good work environment and careful attention to detail make all the difference. Before attempting to install a new seal kit in your watermaker, take the time to choose a good location for the job, somewhere out of the way where you can work undisturbed. Spread out an old towel or large rag for a work surface. Arrange for good lighting—you’ll be inspecting some small parts. Make a cup of coffee or have refreshments (preferably non-alcoholic) on hand while you work. Relax and count on taking your time. There’s a lot to learn.

Now for the good news: ***PowerSurvivor*** watermakers are actually *not* very complicated devices. Following the instructions in the next few pages or the PŪR manual, you should have no trouble completing the job. Better yet, after you’ve done it once, I guarantee you’ll have few reservations about doing it again—it’s a piece of cake!

The Tool Kit: Surprisingly few tools are needed to completely disassemble and reassemble the ***PowerSurvivor 35*** watermaker. Following is a list of the tools and materials I recommend having on hand:

- 5/32" allen wrench
- 1/2" open-end wrench
- needle-nosed pliers
- straight-blade screwdriver
- channel-lock pliers
- adjustable (crescent) wrench
- silicon grease
- 10X magnifying glass or loupe
- small stainless steel wire brush
- clean rags
- old, clean towel for work surface
- good lighting
- wooden toothpicks

Seal Kit and Documentation: As shipped from Recovery Engineering, the repair seal kit for the ***PowerSurvivor 35*** consists of a set of instructions and three plastic bags marked “**A**,” “**B**,” and “**C**.” The parts in each bag are used at different stages of the rebuild process. Leave the seals in their respective bags until needed. This will minimize the chances of getting them misplaced or mixed up.

The directions accompanying the seal kit are important because they are complete, so make sure you have them. Almost identical directions for a “complete overhaul” are included in the ***PowerSurvivor 35*** *Technical Manual* (PŪR Form MAN-5 [12/93]). For some unknown reason, the *Technical Manual* I received with my watermaker does *not* include the directions for disassembly and reassembly of the piston and cylinder section of the pump—nor does it include the full-size drawings of the seals, which are very useful for identifying the parts in the kit.

With the seal kit, tools and directions before you on a clean work surface, you’re ready to dig in. My directions for each step of the procedure are numbered. For the most part, they parallel the steps outlined in the PŪR instructions. Each numbered step includes a single instruction, followed by an elaboration on the instruction and directions for inspecting the involved parts. Special cautions or tips are also noted.

To avoid needless repetition, it will be assumed that *each part will be thoroughly cleaned and inspected as it is disassembled*. Take your time. You’re about to become an expert on an important piece of equipment. Good luck!

Disassembly

Most people wishing to install a ***PowerSurvivor 35*** repair seal kit will start out with a mounted watermaker. I find it easiest to dismount the entire watermaker and get it to the work area before beginning the disassembly.

The seal replacement procedure involves only the pump and membrane assemblies, not the drive motor or gearcase. The latter could be left in place. Unfortunately, the pump assembly must be separated from the drive unit by removing the drive shaft coupling pin and the four hex nuts that fasten the drive unit flange to the pump body. This is usually difficult to do with the limited access available around an installed watermaker.

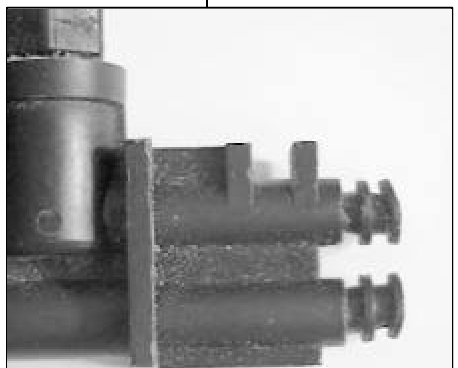


Figure A-1: Damaged hose barbs

The following procedure assumes the entire watermaker will be dismounted and moved to a work area. Before proceeding, turn the intake selector valve to its alternate position and run air through the watermaker until it no longer expels reject water. This will eliminate residual water pressure in the pump and make it much easier to remove the membrane housing.

Stop running the watermaker at a point in its cycle when the piston shaft/drive shaft have traveled farthest *away* from the pump (or, farthest *toward* the gearbox). This will provide ample room for sliding back the rubber shaft-coupling boot in the following procedure.

I suggest you save the old o-rings and seals as they are removed. They could be reused later for emergency repairs, if needed. Put them in a separate bag and mark it as used parts.

Step 1: *Disconnect electrical wiring*

Turn off electrical power to the watermaker at the switch or circuit breaker panel. *If there is any possibility that someone might turn on the watermaker while you're working, secure the switch or circuit breaker handle in the "off" position and/or attach a note indicating that the circuit is being serviced*. The exposed area around the drive shaft and coupling is dangerous. This is a very powerful mechanism that can cause serious personal injury if the watermaker starts running while your fingers or tools are in that area.

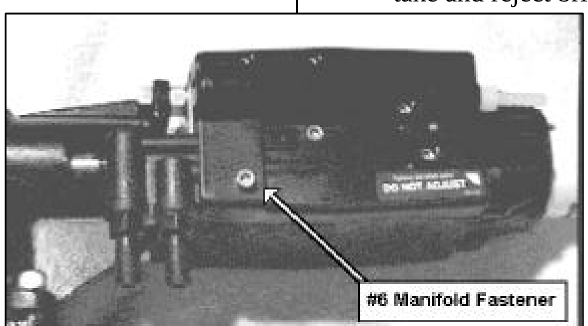


Figure A-2: Location of #6 manifold fastener

Disconnecting the electrical wiring is a simple matter if you had the foresight to install a terminal strip near the watermaker. If you used butt splice connectors, you'll have to cut the wires and re-splice them during the reinstallation. Hopefully, you left enough service loop in the electrical wires to allow for future removals of the watermaker—the wires will get a little shorter each time you cut the splices. If you *are* using butt splices, this is a good time to consider replacing them with a terminal strip and ring terminals.

Step 2: *Remove product water hose*

Carefully pull the small-diameter product water hose from the hose barb on top of the pump manifold. This should not be difficult.

Step 3: *Disconnect intake and reject brine hoses*

Removing these two hoses from the manifold is the single most difficult challenge facing anyone following the factory instructions for installing a replacement seal kit. The PŪR instructions tell you simply to remove the hoses from the barbs.

At best, getting the hoses off the hose barbs is not easy. What is more important—and more difficult—is getting them off without damaging the hose barb assembly and/or its o-rings. If you feel you *must* proceed this way, consider cutting the hoses or dribbling boiling water on them to soften them before attempting removal. In any event, *do not put any serious strain on the hose barb assembly while attempting to remove the hoses*—it is easily damaged!

Take a look at the rounded, unsquare ends of the damaged hose barb assembly in *Figure A-1*. Such damage can easily be caused by pulling on the barb assembly while attempting to remove the reinforced plastic intake and reject brine hoses.

There's a much easier and safer way to handle this challenge. *Don't bother trying to remove the hoses at all*. Instead, use the 5/32" allen wrench to remove the manifold fastener nearest to the hose barb assembly. This fastener is the one labeled number "6" in the PŪR instructions—see *Figure A-2*. (*Note*: very early ***PowerSurvivor 35***s did not have this sixth fastener—there were only five manifold fasteners.)

After the #6 manifold fastener has been removed, the entire hose barb assembly, along with the attached hoses, can be pulled out of the manifold with little

Figure A-3: Preferred way to remove hoses

effort (see Figure A-3). Later, when you have removed and inspected the manifold carefully, you will realize that this fastener has nothing to do with seating the manifold to the pump body. Its main function is to secure the hose barb assembly in place. Remove the four small o-rings on the hose barb assembly.

Step 4: ***Move watermaker to work area***

After removing all three hoses and disconnecting the electrical wires, undo any fasteners securing the watermaker to its mounting surface and move the entire unit (less the hose barb assembly and hoses) to your work area.

When handling and transporting the watermaker, be mindful of its weight and awkwardness. Avoid carrying it by the membrane housing. A good balance point for the unit is about where the drive unit is connected to the pump. Grasp the watermaker by the heavy drive unit flange and it will be easier to handle and balance.

Step 5: ***Remove membrane housing from pump***

Grip the end of the membrane housing and carefully unscrew it from the pump body in a counterclockwise direction. When it is completely unthreaded from the pump body, pull it straight out to expose the yellow membrane element and reject tube. Wash the membrane housing with a mild detergent, rinse in clean water and lay it aside.

If the watermaker has been run recently and you did not remove residual water by pumping air through it, there may be considerable water pressure remaining inside the pump and membrane housing. This can make it very difficult to unscrew the membrane housing. If you encounter this problem, carefully unscrew the five manifold fasteners (see **Step 8**) far enough to relieve the pressure inside the pump. To avoid causing severe uneven forces on the manifold body, unscrew each fastener about a half turn at a time in rotation. At some point during the loosening of the fasteners, the pressure will relieve suddenly, spraying water out the sides of the manifold. Once the pressure has been relieved, the membrane housing should be easy to unthread from the pump body.

Step 6: ***Remove membrane element and reject tube***

Remove the membrane by grasping it at the end farthest away from the pump and pulling it straight out with a twisting motion. *It is very important to avoid putting any sideways stress on the membrane when removing it*. It is easy to crack or break the plastic stem at the pump end of the membrane. Grasping the membrane at its far end minimizes the chances of applying lateral forces. The reject tube runs through the center of the membrane and will be removed along with the membrane.

After separating the membrane from the pump body, pull the reject tube from the center of the membrane. Remove the two o-rings on the membrane stem and the three o-rings on the reject tube. Do *not* remove the large brine seal on the pump end of the membrane. This brine seal is easily damaged and is not included in the PŪR seal kit (although I think it should be—see my list of recommended additional spare parts in the last chapter).

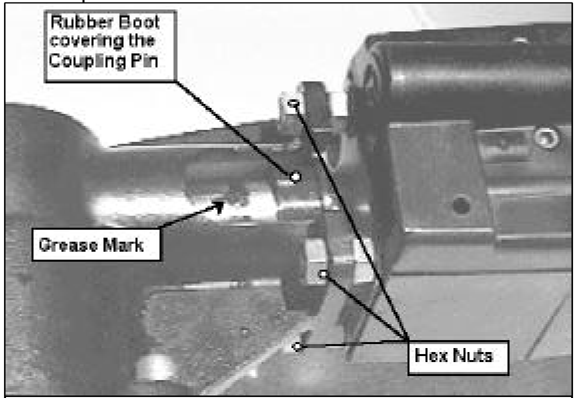


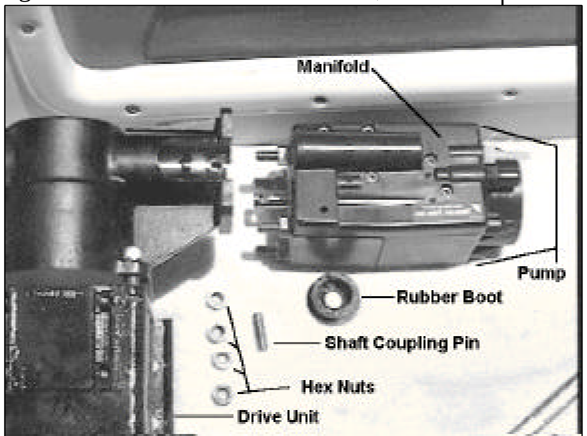
Figure A-4: Drive Unit / Pump Coupling

Wash the membrane in non-chlorinated fresh water and stow it temporarily in a safe place away from sun or heat. *The membrane should not be allowed to dry out while removed from the pump*. If you expect to leave the watermaker disassembled for a considerable period of time (e.g., while waiting for repair parts), store the membrane in an airtight container or plastic bag to keep it from drying out.

Check the reject tube for signs of rust or corrosion. Use a wire brush with bristles made of stainless steel (or a softer metal) to clean up any discolored areas.

Step 7: ***Separate pump from drive unit***

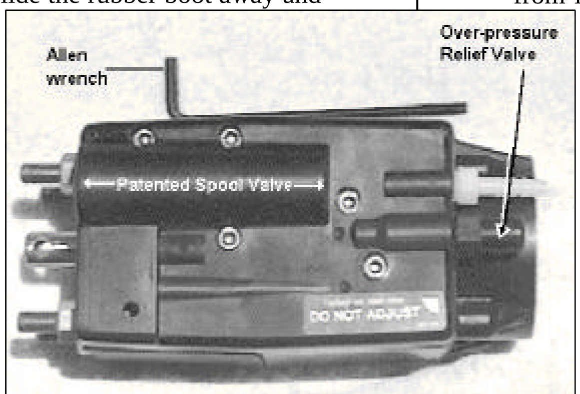
Using the 1/2" open-end wrench, remove the four hex nuts that secure the drive unit flange to the pump. Slide the rubber boot covering the drive shaft coupling *toward* the pump to expose the connecting pin which couples the drive shaft to the pump piston shaft (see <u>*Figure A-4*</u>). Push the coupling pin out of the shaft using the 5/32" allen wrench. In fact, it is a relatively loose fit and may drop out by itself when the rubber boot is moved, so be careful not to lose it. Clean the coupling pin, inspect it for significant wear, and lay it aside.



<u>Figure A-5</u>: Uncoupled Drive Unit and Pump

You may discover that there is not enough space to slide the rubber boot far enough toward the pump to expose the coupling pin. This will occur if the watermaker was last turned off at that point in its cycle when the piston is at or near the end of its stroke *towards* the membrane end of the pump. If this is the case, grasp the pump body and pull it in the direction away from the drive unit. If the four hex nuts have been removed and there is no residual pressure remaining in the pump, this will cause the internal piston to slide back toward the drive end of the pump, thus exposing enough of the piston shaft to enable you to slide the rubber boot away and access the coupling pin.

After the hex nuts and coupling pin have been removed, the drive unit is easily separated from the pump body. Slide the rubber boot off the piston shaft and set it aside (see <u>*Figure A-5*</u>).

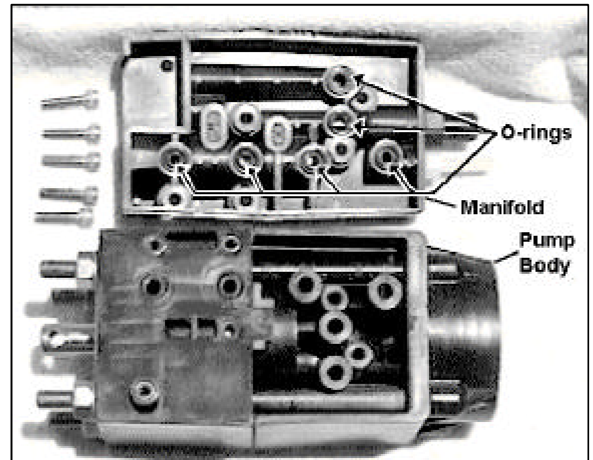


<u>Figure A-6</u>: Manifold top showing five fasteners

Examine the drive shaft coming out of the gearbox and clean off any grease that has worked its way out of the gearbox and onto the shaft (see <u>*Figure A-4*</u>). The grease used in the gearbox is a petroleum-based lubricant and must not be allowed to travel along the pump piston shaft and into the pump, where it could reach the membrane and do damage. Inspect the motor/drive unit assembly for signs of serious corrosion and set it aside.

<u>Step 8</u>: *Remove manifold from pump*

There are actually only <u>five</u> fasteners responsible for seating the manifold and its seals against the pump body. They are the same on all ***PowerSurvivor 35***s. (The sixth fastener was previously removed during **Step 3** and is not present in early ***PowerSurvivor 35***s.)



<u>Figure A-7</u>: Manifold and Pump Separated

Remove the remaining five manifold fasteners with the 5/32" allen wrench. See <u>*Figure A-6*</u> for their locations. When they have all been removed, lift the manifold assembly off the pump body. Turn it over and note the positions of the six o-rings. Usually the o-rings will remain pressed into their sockets in the manifold. If it was necessary to loosen the manifold fasteners to relieve residual water pressure inside the pump (see **Step 5**), one or more of the o-rings may have been dislodged from its seat and fallen into the pump body cavity. In any event, be certain to retrieve and account for all six o-rings.

Take a few minutes to study the manifold (see <u>*Figures A-6 & A-7*</u>). It has three basic components: (1) the main body, which is made of black plastic and has hydraulic passages molded into it, (2) the over-pressure relief valve mechanism, and (3) a patented hydraulic spool valve embedded within the main body.

Gently pry the old o-rings from their seats in the manifold using a fingernail or toothpick. Wipe them clean with a cloth or paper towel, and use the magnifier to inspect each one carefully. Old o-rings will appear flattened and oval-shaped in cross-section, which indicates they have lost much of their resiliency and can not be relied upon to create tight seals.

As they age, the manifold o-rings may begin to leak, perhaps slightly at first but increasing with time. The usual symptoms are reduced product water output and water leaking from around the pump body. Once they have begun to leak, they become much more susceptible to catastrophic failure and should be replaced.

Also look for any nicks, tears or other deformities, especially if the watermaker has been leaking or has quit producing product water. The manifold o-rings are worked hard and are more prone to failure than some of the other seals inside the watermaker.

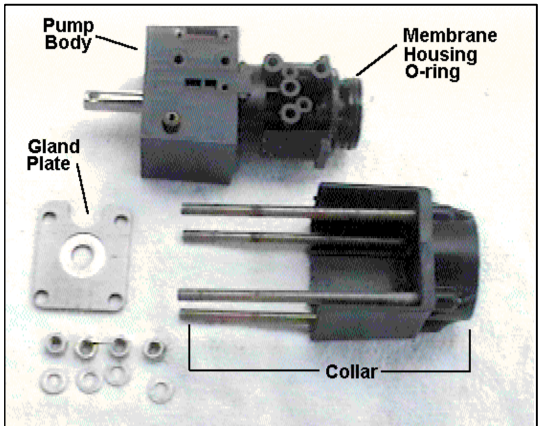


Figure A-8: Collar, Gland Plate and Pump Body

Step 9: *Remove collar from pump body*

Using the 1/2" wrench, remove the remaining four hex nuts and their flat washers from the threaded rods protruding from the drive end of the pump body. When they have been removed, slide the rectangular metal gland plate off the threaded rods.

Unless there is significant corrosion around the threaded rods and gland plate, the latter should be relatively easy to remove. If necessary, use a flat-bladed screwdriver to gently pry the gland plate up and get it started. Be careful not to exert too much pressure with the screwdriver on the plastic pump back.

When doing this, be aware that the gland plate will only slide off the threaded rods easily if it remains perpendicular to them. If you pry up on only one side of the gland plate, it will cause it to bind against the rods and become difficult to remove. Therefore, if a little prying is necessary, work your way around the gland plate, using the screwdriver to lift it just a short distance on each of its four sides in turn.

After removing the hex nuts, washers and gland plate, pull the pump collar away from the pump body. It should be easy to remove. The pump back and front should remain together at this point. Remove any corrosion on the gland plate and threaded rods with the wire brush, wipe the plastic collar clean with a rag, and set them aside. See *Figure A-8*.

Step 10: *Separate the pump front and pump back*

At this stage of the disassembly process, the pump front and back are held together only by the compression of the o-rings on each end of the cylinder. One end of the cylinder is seated in a circular cavity in the pump front and the other end is seated in a similar cavity in the pump back.

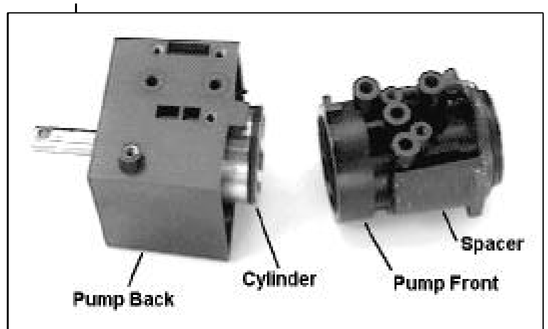


Figure A-9: Pump Front and Back Separated

The PŪR instructions direct the user to use a flat-bladed screwdriver to pry the two pump halves apart. Before resorting to such a heavy-handed technique, try separating them by grasping the pump front in one hand, the pump back in the other, and pulling them apart with firm pressure. While trying to pull them apart, exert a little back-and-forth sideways force on the pump front. This should gradually "walk" the cylinder and its o-rings out of the cavity.

Usually the end of the cylinder seated in the pump front will come out, and the cylinder will remain seated in the pump back. When the two pump halves part, the valve retainer plate in the pump front may fall out, along with the intake poppet valve and its spring. Take care not to lose them. See *Figure A-9*.

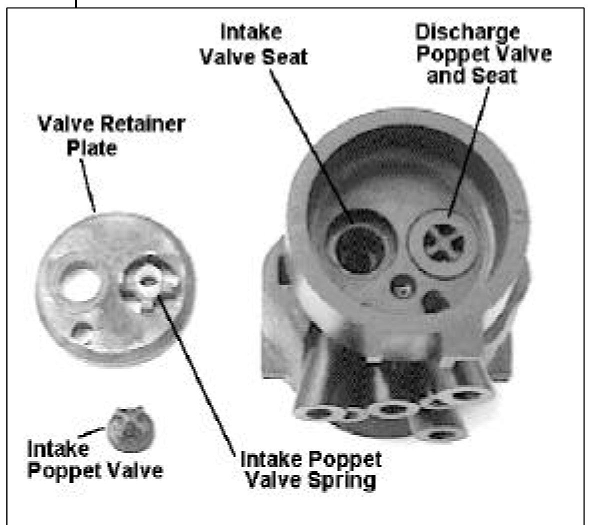


Figure A-10: Intake & Discharge Valve Assemblies

Step 11: *Remove check valves from pump front*

If the valve retainer plate did not fall out when separating the pump front and back, remove it by "pouring" it out of the pump front. It should drop out with no effort required. If necessary, grip it with a pair of needle-nosed pliers and lift it out. The spring for the intake valve will usually remain press-fitted into the valve retainer plate. See *Figure A-10*.

With the valve retainer plate removed, the intake poppet valve can be lifted out if it hasn't already dropped out of its seat. The intake valve seat will remain pressed into its cavity in the pump front. Examine the valve seat with a magnifying glass. Note that there is a beveled edge around the hole in its center. This beveled edge is what the o-ring on the poppet valve seats against. If the surface of the bevel is in perfect shape, with no scratches, nicks or dents, it can be left in place and reused.

If the intake valve seat has been damaged, it must be removed and replaced. The PŪR instructions indicate that this can be accomplished using a "small hook or the head of a nail." Since nails (made of corrodable ferrous metal) are not easy to find on many cruising vessels, consider using a small stainless steel round-head machine screw for this task. Grip the screw by the threaded end and lower the head into the hole in the center of the valve seat. Move it sideways to position the flat of the head beneath the lower lip of the valve seat, and then pull straight up with a firm pressure. The valve seat is held in place only by the compression of an o-ring around its outside perimeter and should come out with little difficulty.

The entire discharge check valve assembly will remain in the pump front. To remove it, use the needle-nosed pliers to grasp the valve firmly by its cross-shaped bottom and pull straight up. The poppet valve and its seat will come out together. Once they are removed, retrieve the valve spring that is underneath them.

Take a moment to study the two check valves. Notice that they were assembled, and operate, in opposite directions. Pay particular attention to the springs. They are especially prone to corrosion and failure. If either of the springs is broken, be sure to retrieve all of the broken portions. If a piece of broken spring is left inside the pump, it is likely to work its way into the cylinder bore, where it is certain to damage the polished cylinder walls and the piston seals. If this happens, you will also need to replace the cylinder.

Step 12: *Remove membrane housing o-ring*

Remove the large membrane housing o-ring at the membrane end of the pump front (see *Figure A-8*). In most cases, this will be the final step in the disassembly of the pump front.

Inspect the metal spacer on the pump front for corrosion and/or salt residue (see *Figure A-9*). If necessary, the spacer can be slid off the front end (membrane end) of the pump front body for cleaning *after* the membrane housing o-ring has been removed.

Step 13: *Remove piston from cylinder*

Remove the piston from the cylinder (which should still be seated in the pump back body) by pushing the piston shaft into the pump back. The piston should slide easily out of the cylinder.

Using a magnifying glass, carefully inspect the two piston seals for wear and/or damage. Also examine the piston shaft for signs of scoring or pitting. Pits or scratches on the piston shaft will cause rapid wear of the shaft seals and cause the pump to leak. If the piston shaft is damaged, the piston should be replaced.

Step 14: *Remove cylinder from pump back*

This step can be a little difficult, especially if the watermaker has been in service for a long time and the cylinder has not been removed before.

Take a look at the o-rings on the exposed end of the cylinder, and the cavity in the pump front where they live. The other end of the cylinder is identical and its cavity in the pump back is similar. There is substantial clearance between the outside diameter of the cylinder and the inside diameter of the cavity in the pump back. The cylinder is held in place by its compressed o-ring seal.

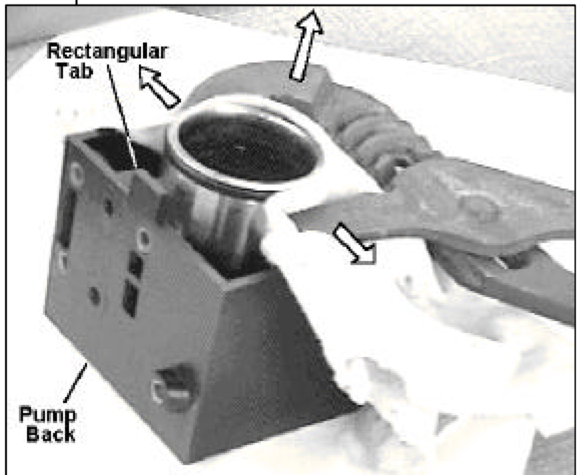


Figure A-11: Removing Cylinder from Pump Back

The secret to removing the cylinder is to take advantage of the clearance by rocking the cylinder back-and-forth sideways, thus slowly "walking" the cylinder out of its cavity in the pump back. Usually this can be done using only your hands. However, sometimes it is necessary to use more force than can be applied with bare hands.

If the cylinder won't budge when you attempt to remove it with your hands, wrap a cloth around the outside of the cylinder and grip the cylinder with a set of channel-lock pliers. Grip it by the main body—do not grip it near the fragile lip of the o-ring groove on the end. Then, while exerting a constant upward force, rock the cylinder from side to side. The sideways movement will be slight, but eventually you should be able to walk the cylinder out of its cavity. See *Figure A-11*.

Before applying the rocking force, identify the top, or manifold, side of the pump back. This is the side with the protruding rectangular plastic tab and the threaded brass inserts for the manifold fasteners. Apply the rocking force in a direction *parallel* to the top side; i.e., sideways, *not* up and down. Trying to rock the cylinder toward the top side is not effective because one of the threaded brass inserts extends into the interior of the pump back body and usually limits cylinder movement in that direction.

After removing the cylinder, inspect it for damage. The inside bore should be smooth and polished. Any scores or pits inside the cylinder will cause rapid wear of the piston seals and premature failure of the pump.

Remove the o-rings on each end of the cylinder. Wipe the o-ring grooves clean and use a magnifying glass to examine them carefully. What you are looking for is evidence of pitting or crevice corrosion, especially at the right-angle corner between the bottom of the groove and the thin lips at the ends of the cylinder. I have encountered several instances of large sections of the thin lip having broken off from the cylinder.

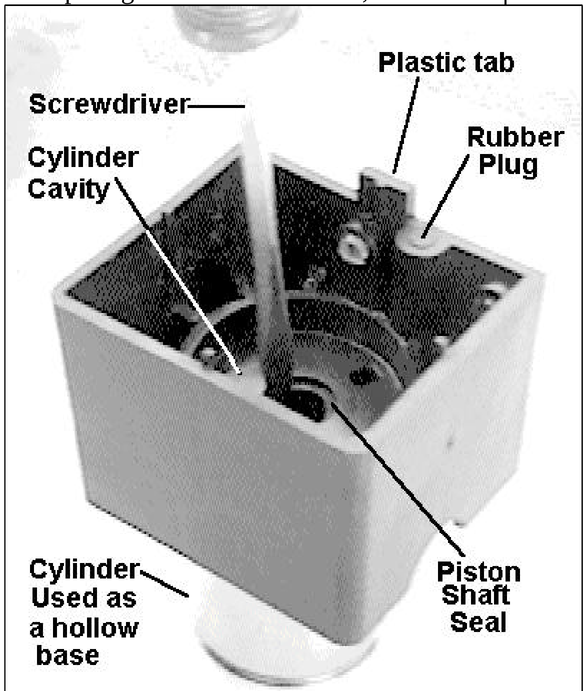


Figure A-12: Removing Piston Shaft Seals

Step 15: *Remove piston rod seals from pump back*

Since it is difficult to remove the piston shaft seals from the pump back without damaging them, only do so if you intend to replace them and have new seals at hand.

You will be removing the two shaft seals, backup washer and shaft bushing, all at one time, by pushing down on them from the cylinder side of the pump back. Place the pump back on a solid surface with its rectangular plastic tab pointing up. Next, you must create at least an inch of open space beneath the pump back body to allow room for the parts to fall out. Two pieces of wood of the same thickness placed under opposite sides of the pump back, with a gap between them under the center of the pump back, will do the trick. The previously removed pump cylinder can also be utilized as a prop. Stand it on end, centered, beneath the pump back (see *Figure A-12*).

Now locate the hole for the piston shaft in the middle of the cylinder cavity. Around the inside of the hole, you will see about 1/16" of the inside lip of the innermost shaft seal, just below the end surface of the cylinder cavity. What is required is to push firmly and straight downwards on the exposed seal with a blunt object. The ideal tool would be a socket wrench, with an outside diameter slightly smaller than the hole in the pump back, mounted on a socket extension. A medium-sized, straight-bladed screwdriver will also work in a pinch. Hold the pump back and its riser base in place and push straight down firmly with the tool. The seals, washer and bushing will fall out the bottom of the pump back.

Again locate the rectangular tab on the top side of the pump back. To one side of it is a small rubber plug about 1/4" diameter (see *Figure A-12*). This plug rarely needs replacing but is included in the seal kit. It can be removed using a paperclip or similar small, stiff probe. Insert the probe into the round opening nearest the plug on the top of the pump back. Angle the probe toward the plug and push it out. Use care in performing this procedure—the round hole is actually an hydraulic port that mates with one of the six o-rings in the manifold. Be careful not to scratch its surface with the probe.

Step 16: *Take a break!*

At this point, you have finished the standard disassembly of the watermaker pump. If it hasn't already been done, take the time to clean and carefully inspect all parts.

If this is your first exposure to the inner workings of the watermaker, try to trace the major paths of water through the pump. Of course, you will not be able to determine the flow through most of the manifold, but try to become familiar with the flow to and from the membrane and the six passages between the pump body and the manifold. The more you understand, the better you will be able to troubleshoot and analyze any future problems.

Now, it wasn't all that bad…was it?

Manifold Servicing

The PŪR *Repair Seal Kit* instructions state: "If the manifold requires service other than replacement of the O-rings provided in [the seal kit], either replace the complete assembly or return it to the factory for repair." In almost every case, I would agree that this warning should be heeded.

One of the best definitions of "cruising" I've ever heard is: "Cruising is the art of repairing boat equipment in exotic locations!" One of the implications is that it is usually difficult—if not downright impossible—to obtain repair parts in many areas of the world. Even if it is theoretically possible to order parts from, or send defective equipment to, original vendors, the cost is typically exorbitant, the time delay prohibitive, and the chances that the parts or equipment will mysteriously vanish somewhere along the line are discouragingly high. Watermakers where along the line are discouragingly high. Watermakers are not exempted from this common state of affairs.

Successful cruisers—those who manage to continue for years and keep their equipment functioning—are usually quite handy at maintaining, troubleshooting and repairing diverse types of equipment. Faced with a broken watermaker in the middle of nowhere, many seasoned cruisers are likely to tear it apart in the hope of finding and fixing the problem before subjecting themselves to the expense, inconvenience and uncertainties involved in an attempt to return it to the factory. It's not that they wouldn't like to have the factory do it—it's just usually impractical or impossible.

In an effort to help the ***PowerSurvivor 35*** owner understand what can and can not be done in the field, I've included the following comments. They are based on my own experiences in servicing dozens of watermakers in Mexico over the last several years. I hope it helps to draw a more accurate line between what is possible and wasted efforts that are likely to result in expensive or irreparable damage to the equipment.

Spool Valve Servicing:

The manifold contains a sophisticated spool valve. It is *not* user-serviceable and should *never* be removed from the manifold. Simply stated, there is nothing that can be done to this component in the field. Servicing of it is limited to replacing the valve stem seal and the o-ring on the spool valve retainer using the seals included in the seal kit. If it is removed, even if only for inspection, it is unlikely that it can be reinstalled without damaging its several special o-rings.

To replace the seal and o-ring, first unscrew the spool valve retainer by grasping its cross-shaped section of plastic with a pair of needle-nosed pliers and turning counter-clockwise until it is completely removed from the manifold. Pull the retainer cap off the inside face of the spool valve retainer. Remove the small seal from inside the retainer cap and the large o-ring on the spool valve retainer. Wipe the retainer and its cap clean with a cloth.

Locate the new seal and o-ring (**Bag A**), lubricate them with silicon grease and install them on the spool valve retainer and in the retainer cap. Press the retainer cap into the retainer and thread the assembly back into the hole in the manifold. Finish screwing the spool valve retainer into the manifold using the needle-nosed pliers until it is just snug and approximately flush with the manifold body. Do not overtighten the retainer. All that is necessary is a firm, clockwise pressure. Realize that it is the seal and o-ring that create the seal—not the tightness of the retainer threads.

In my experience, failure of the spool valve and its associated seals is not a common problem. If you are greatly concerned to be able to repair your watermaker in the rare event of a spool valve failure, consider purchasing an extra complete manifold assembly to include with your repair parts kit at a cost of $505. For what it's worth, I've not yet encountered a defective spool valve—knock on wood!

Replacing the Manifold Plugs:

Also included in the seal kit are replacement o-rings for the two rubber plugs (one large and one small) located approximately in the center of the bottom of the manifold (the side from which you removed the six manifold o-rings—see *Figure A-7*). The PŪR instructions indicate that these need only be replaced if there is evidence of leakage around them. In fact, I've yet to see one that leaked and I would concur with Recovery Engineering on this one. If it ain't broke, don't fix it.

On the other hand, replacing them is not a difficult task. Gently pry them out of their holes. Each plug has a small o-ring around its middle. Remove the old o-rings, correctly identify and lubricate the two new o-rings, install them on the rubber plugs, and push the reconditioned plugs back into their holes.

The Over-pressure Relief Valve:

The ***PowerSurvivor 35*** pump is designed to develop approximately 800 psi across the membrane under normal operating conditions. Cold water, high salinity, a partially plugged membrane, and certain other pump defect modes can cause the pressure to rise higher than 800 psi.

The over-pressure relief valve is factory set to limit the maximum pressure to which the membrane will be exposed. It is adjusted to relieve the pressure when it exceeds 1000 psi. This is an important safety feature designed to protect the membrane against excessive pressure, which can cause permanent damage.

The relief valve itself is a simple, sturdy design and rarely causes any problems. In effect, it consists of a small piston working against a robust spring. The pressurized water developed by the pump is routed through a chamber where it forces the piston outward against the spring. The spring compression is adjusted by screwing the plastic adjusting cap nut clockwise to increase the pressure setting or counter-clockwise to reduce it. The center of the adjusting nut is hollow to provide a path for the relieved water to follow and also to allow the white indicator shaft, which is simply an extension of the piston shaft, to be observed.

The Achilles heel of the pressure relief valve mechanism is a small o-ring that seals the relief valve piston shaft. If it fails, water can exit the pressure chamber. When this happens, water will leak out of the relief valve and the pump will not be able to develop enough pressure to produce product water.

After adjusting the relief valve spring for the correct compression, factory technicians heat-fuse a small spot on the base of the plastic adjusting nut to the manifold body. Not only does this lock the adjustment, but it also serves as an indicator of subsequent tampering with the adjustment. A label is affixed to the manifold that warns the user against attempting to alter the adjustment. This makes sense because the user has no way to measure and calibrate the pressure adjustment.

I have encountered only one instance of a failed o-ring seal in the pressure relief valve. It does not seem to be a common failure mode. Since the factory does not include the relief valve o-ring in its seal kit and cautions against attempting to adjust the pressure setting, there is normally no alternative to shipping the pump (or at least the manifold) back to the factory in the case of a pressure relief valve failure.

If you plan to travel to remote areas, you should consider purchasing the recommended additional repair parts listed in the last chapter of this book. Included in that list is the o-ring for the pressure relief valve. If you have that o-ring on hand and experience a relief valve failure, you can probably get the watermaker working again with the following "emergency" procedure.

Before breaking the factory seal and dismantling the pressure relief valve, make careful measurements of its original adjustment position. First, scratch an orientation mark somewhere on the top of the adjustment nut to help you remember which side of it was up. Next, use some calipers to measure the gap between the base of the adjustment nut and the manifold body. If you don't have calipers, create some other measuring device—for example, use a pad of paper or some pages of a book to determine how many sheets or pages will just fit snugly into the gap. The purpose of this step is to allow you to return the adjustment nut to its original position.

After recording the original adjustment setting, unscrew the adjustment nut and carefully extract the piston shaft and spring. Take your time and <u>note how everything is assembled</u>. (Drawing a diagram is a good idea.) Replace the o-ring, reassemble the relief valve, and screw the adjustment nut up to its exact original position, using your gap measurement and the scratch mark for guides. Although the adjustment may not return to *precisely* 1000 psi, it should be close enough. Later, when it is more convenient, I suggest returning the unit to the factory for adjustment. During the interim, your watermaker will be producing water again.

Reassembly

For the most part, the reassembly of the ***PowerSurvivor 35*** is the reverse of the disassembly process already described. I will be referring to the illustrations in the disassembly procedure for identification of parts, except for those steps that require illustrations unique to the reassembly procedure.

During the reassembly procedure, it is assumed that all components have been thoroughly cleaned and all seals and o-rings, <u>*without exception*</u>, have been lubricated with silicon grease before being assembled. A clean, well-lighted workspace is even more important for the assembly procedure than it was during disassembly.

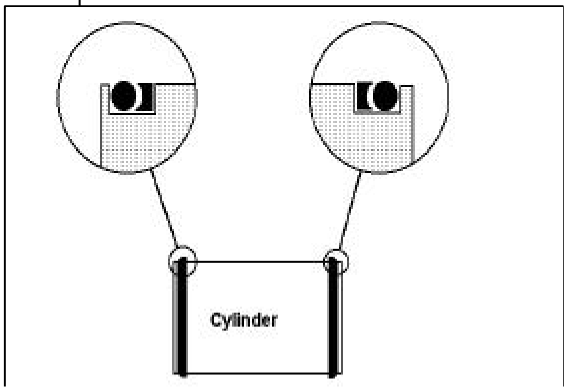
When installing the various o-rings and seals during the assembly process, make certain you are working with the correct parts. If you have any doubt, compare each part with the real-size drawings of the components found in the last few pages of the PŪR instruction set. For the most part, the seal kit components are easy to distinguish.

<u>Step 1</u>: *Install cylinder o-rings and backup washers*

Before proceeding, first coat the inside of the cylinder completely with a thin layer of silicon grease. Also apply a little silicon grease to the o-ring grooves on each end of the cylinder.

For this step (and **Steps 3 & 4**), understand that the two ends of the cylinder, and their seals, are identical. In other words, either end of the cylinder can go into the pump front or the pump back—it makes no difference—and the two sets of seals and backup washers are the same.

Locate the two o-rings and two backup washers for the cylinder in **Bag B** of the seal kit. They are thin in cross-section and 1-3/4" in overall diameter. Distinguish between the o-rings, which have a circular cross-section, and the back-up washers, which are square in cross-section on three sides and slightly concave on the fourth side. The most difficult part to this step is correctly determining the concave side of the backup washers. You'll need to examine the backup wash-



ers closely, preferably using a magnifying glass.

After you're certain you've correctly identified the concave side of the backup washers, use *Figure A-13* as a guide for their installation on the cylinder ends. Note that on each end of the cylinder, the backup washer goes on first, with its concave side facing the near end of the cylinder and the o-ring. Next, an o-ring is installed on each end and the step is finished.

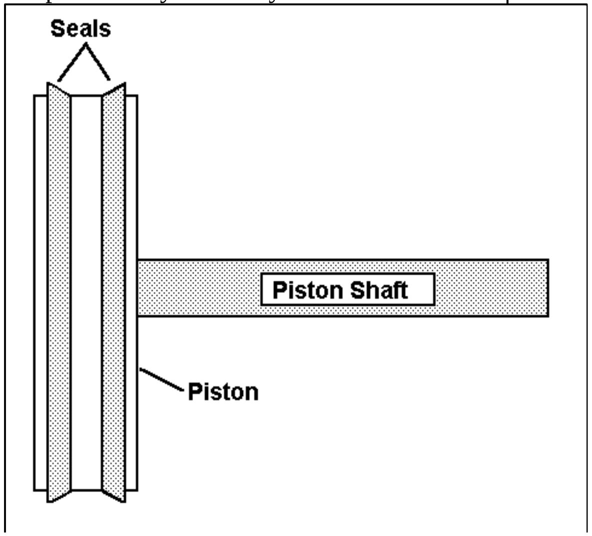
Step 2: ***Install cylinder into pump back***

Again, this is a step that is not difficult, but it must be executed with considerable care. To facilitate the insertion of the cylinder (with its o-rings and backup washers already installed), lubricate the inside surface of the cylinder cavity in the pump back with a thin coat of silicon grease. Center the cylinder over the cavity and make sure it is square to the opening, not tilted in any direction. Then push it into the cavity gently, taking care to keep it square to the opening as you press. It should take only light pressure to start it in.

As soon as the o-ring has just entered the cavity, stop and carefully examine all sides where the cylinder meets the cavity. Look for any part of the o-ring that has rolled out of its groove during the initial insertion. If this has happened, a loop of the o-ring will have rolled up between the outside of the cylinder and its plastic cavity in the pump back. If you haven't pushed the cylinder all the way in, you should be able to see the rolled portion extruding out of the cavity. If this happens, remove the cylinder, re-seat the o-ring and try again (if the o-ring wasn't damaged—examine it carefully).

If the o-ring has rolled, it will become a wedge between the cylinder and the cavity and it will be difficult to press the cylinder any further into the pump back. If you continue to press on the cylinder after the o-ring has rolled, you are certain to damage the o-ring and it will have to be replaced. On the other hand, a cylinder that has been inserted correctly will be easy to push smoothly all the way to the bottom of the cavity.

Take care with this step and at no time use excessive force. The key to success is adequate silicon grease on the o-ring and cylinder cavity and a gentle, straight-in pressure with no tilting of the cylinder.



Step 3: ***Install piston seals***

Locate the two piston seals in **Bag B** and lubricate them with silicon grease. Using *Figure A-14* as a guide, slip them onto the two grooves of the piston. Be careful to note the correct orientation of the seal lips. The higher sides (lips) of the two seals should be facing away from each other.

Step 4: ***Install piston in cylinder***

Before installing the piston into the cylinder, use your little finger to lubricate the piston shaft hole in the pump back with silicon grease in preparation for the following step (**Step 5**). After the piston has been installed in the cylinder, there will not be enough room to lubricate the hole before installing the shaft seals. Also grease the piston shaft.

Insert the piston shaft into the hole in the pump body back from the cylinder side until the first piston seal contacts the end of the cylinder. The lip of this seal will be flared outward, preventing the piston from sliding easily into the cylinder.

While exerting a gentle, but continuous, pressure on the exposed end of the piston, trying to press it into the cylinder, run your fingernail (or other small, blunt object) around the seal where it meets the cylinder bore to work the seal lip into the cylinder. At some point while working your way around the entire perimeter of the piston seal, it should pop into the cylinder with little difficulty. The second seal, being flared in the opposite direction, will slide into the cylinder with no problem. Push the piston into the cylinder as far as it will go.

Step 5: ***Install piston seals, washer and bushing***

Place the pump back assembly on a smooth, solid surface with the cylinder down and the piston shaft pointing upwards.

Locate the two piston shaft seals in **Bag B**. Note that these seals, like the piston seals, are also lip seals, with one side flared slightly outwards. Lubricate the first seal (the two seals are identical) and slip it over the piston shaft *with the flared side down (i.e., toward the pump back)*. Push it down to the shaft bore in the pump back. Continue working it downward into the shaft bore. Make sure that the entire perimeter of the lip enters the bore and then push it down until the exposed end of the seal is approximately flush with the outside surface of the pump back.

Install the second seal in exactly the same manner. It too should be installed with the flared side down and pushed into the shaft bore until approximately flush. This step assures that the seal lips have correctly entered the bore before the bushing and backup washers are press-fitted on top of them.

After both seals have been pushed into the piston shaft bore, slide the new white backup washer (from **Bag B**) over the piston shaft, followed by the larger, white shaft bushing. Note that the piston shaft bushing is *not* included in the seal kit—you will be reusing the old one. Do not attempt to push the backup washer and bushing into the bore at this time.

The next step requires a special technique. What you need to do is push the backup washer and bushing all the way into the piston shaft bore until the outside end of the bushing is flush with the pump back body.

An easy way to do this is to utilize a medium-sized adjustable (crescent) wrench. Open the jaws of the wrench a little wider than the diameter of the piston shaft and position it on top of the shaft bushing with the piston shaft between—but not touching—the jaws of the wrench. The flat sides of the jaws should be lying flat against the top side of the bushing and perpendicular to the piston shaft.

Using both hands, press downward with the wrench against the bushing. This will require a moderate amount of force. Keep the sides of the wrench jaws flat against the bushing and perpendicular to the piston shaft. Continue pushing until the backup washer and the shaft bushing are driven completely into the pump back and are flush with its surface. Take care not to scrape the wrench against the piston shaft. If you are worried about marring the piston shaft, wrap a few layers of cloth around the piston shaft and open the wrench jaws a little wider.

When you are done, set the pump back body assembly aside for the moment.

Step 6: ***Install membrane housing o-ring***

If you removed the metal spacer from the pump front for cleaning (see *Figure A-9*), make sure it is back on the pump front *before* installing the large membrane housing o-ring. The spacer will not slide over the o-ring. Note that the spacer will slide on only if it is oriented correctly—it is impossible to install it upside down.

After the spacer is on, install the membrane housing o-ring on the membrane end of the pump front (see *Figure A-8*). It is the single large o-ring with the fat cross-section in **Bag A** of the seal kit.

Step 7: ***Install check valves in pump front***

All of the components for the two check valves are in **Bag C** of the seal kit. Locate these parts. Notice that there are two pairs each of valve seats, poppet valves and poppet valve springs. If you happen to notice that the poppet valves in your seal kit have the numbers “1” and “2” embossed in their bodies, you can be proud of your attention to detail. However, the poppet valves are identical and those designators can be safely ignored.

Place the pump front body on a flat, level surface with the check valve cavity facing up (see *Figure A-10*). Lower one of the springs into the discharge valve cavity and stand it on end in the small circular recess at the bottom of the cavity. This is easier to do if you use the needle-nosed pliers. Carefully balance one of the poppet valves on top of the spring with its “cross” side facing up. Center one of the valve seats over the poppet valve *with its beveled (seat) side facing down*.

When you’re sure everything is lined up and the spring and/or poppet valve hasn’t fallen over, press the valve seat down firmly with your thumb until it is flush with the surface of the pump front cavity. Test the poppet by pushing it up and down with the allen wrench. It should push down and spring back up smoothly. That’s all there is to it!

Installing the intake valve is less of a balancing act, but still requires a little care. First, stop and think. Did you remove the intake valve seat during the disassembly process? If you did not and the original valve seat is still down there in the bottom of the recess for the intake valve, do *not* install the new intake valve seat on top of it!

If the original intake valve seat *was* removed, press the new valve seat into the recess with your finger as far as it will go. *Make certain you install it with the beveled (seat) side facing up*! The valve seats will not work if the beveled side is not facing the poppet valve.

After installing the valve seat (or if the original seat is still in place), lower the second poppet valve into the hole in the seat with its cross-shaped side facing down. Press the remaining poppet valve spring into its mating cavity in the valve retainer plate. It should snap into place and stay there.

Finally, grip the retainer plate with the needle-nosed pliers and lower it gently into the pump front cavity with the spring facing down. What you need to do here is line up the spring directly over the intake poppet valve, keeping the retainer plate level, and lower the retainer plate carefully so that the spring mates with its matching circular recess on the intake poppet valve.

If this last step is performed correctly, the retainer plate will lie *almost* horizontal, deep in the pump front cavity. When you press it gently with your finger, it will compress the intake valve spring and become exactly horizontal. If, when you press down with your finger, the valve retainer plate remains tilted, you've done it wrong. Play with it, if need be, until you get it right. You'll know when you've succeeded.

Once you have the check valves and valve retainer plate correctly installed, leave the pump front in the same position. If you turn it over, the retainer plate and intake poppet will fall out and you'll have to repeat the process. Proceed immediately to the next step.

Step 8: *Join pump front and back*

This step is similar to **Step 2**. You will be inserting the other end of the cylinder into a mating cavity in the pump front. The same technique and cautions apply.

Lubricate the inside walls of the cylinder cavity in the pump front (above the valve retainer plate) with silicon grease. Being careful not to tip the pump front too far sideways and disturb the retainer plate and intake poppet valve, bring the pump front and back together until the end of the cylinder *just* begins to enter the pump front cylinder cavity. The easiest way to do this without disturbing the valve assembly is to keep the pump front vertical and lower the cylinder into the cavity.

Carefully align the plastic tab on the top of the pump back with its matching notch on the pump front. With the end of the cylinder just barely engaging its cavity in the pump front, the tab and its notch will also be just barely engaged. At this point, stop and make sure the end of the cylinder is square with the cavity in the pump front.

When you are sure everything is square, gently press the cylinder into the pump front cavity. Be very careful not to tilt the cylinder during this process. What you're trying to do is press the entire circumference of the cylinder o-ring into the cavity at the same time. If the cylinder is tilted, the o-ring will slide in easily on the low side. As you continue to press harder, the o-ring will be squeezed and stretched toward the high side. This will result in a loose "loop" of o-ring on the high side which will then roll up and out of its groove and get caught between the outside wall of the cylinder and the cylinder cavity. If this happens, and you continue to press, you will almost certainly damage the o-ring and it will have to be replaced. Do you have another one on hand? Probably not, so take your time and do it right the first time. If the o-ring does roll, stop and pull the cylinder out before you damage the o-ring.

When done correctly, you will feel the cylinder "snap" into its cavity and you'll be able to smoothly slide it in the rest of the way with little effort. Continue to press the pump front and back together until the rectangular plastic tab on the pump back completely fills its notch on the pump front.

Step 9: *Install pump collar*

Slide the collar over the pump front/back assembly. It will only go on one way. Push it on far enough that the membrane housing o-ring on the pump front passes completely through the large hole at the membrane end of the collar and can be seen protruding slightly out of that end of the collar.

This is a snug fit and you may need to look into the membrane end of the collar and align the end of the pump front (and the membrane housing o-ring) with the large hole in the collar to complete the job.

Step 10: *Install gland plate, washers and hex nuts*

This is another critical step. The gland plate should slide easily onto the four threaded studs. Install it with its flat side facing outwards; i.e., the side with the circular recess in the middle should be facing inwards, toward the pump. Slip the four washers over the threaded rods, followed by the four large hex nuts. Screw the nuts down finger-tight. Now, stop and pay close attention to what I'm about to tell you.

The temptation for most people at this point is to tighten the hex nuts with a "dying strain" because the nuts are large. The reason they are large is because they must hold the entire pump assembly together under an internal pressure of 800 psi! The threaded rods and hex nuts don't "seal" anything. They simply keep the parts of the pump from flying apart under high pressure.

If your watermaker pump develops a leak, you will *not* be able to cure it by tightening these fasteners a little more. Leaks are caused by seal failures or damaged pump body components. On the contrary, you are very likely to *cause* a leak by overtightening these fasteners. It is easy to distort the plastic parts of the pump body, making it impossible to properly seat the manifold o-rings and possibly cracking one of the plastic body parts.

So, how tight should they be? Here's what works for me: after bringing the four hex nuts up finger tight, give them each another quarter- or half-turn with the 1/2" wrench. Then, hold the wrench *at its middle using only your thumb and one finger*—don't grip it at the end with your fist. Tighten each nut in turn, using only the force you can exert with the wrench held in the manner I've just described. Strive for a "modestly snug, even torque." That's all that is needed.

Step 11: *Install manifold on pump body*

This is perhaps the most critical step in the whole assembly process. *Stop* for a moment, *look* at the top of the pump body and the mating side (bottom) of the manifold, and <u>listen</u> to what I have to say about this procedure. It is not a difficult task, if certain precautions are observed.

Study the bottom of the manifold (see *<u>Figure A-7</u>*) and notice how little surface area there is that will actually be touching the mating side of the pump body when the two halves are joined. In fact, if you look closely, you should see that the only surfaces that will be touching each other are the o-rings and the circular seats around them, and the opposing lands on the pump front and back. There are two things to realize before attempting to fasten the manifold to the pump body.

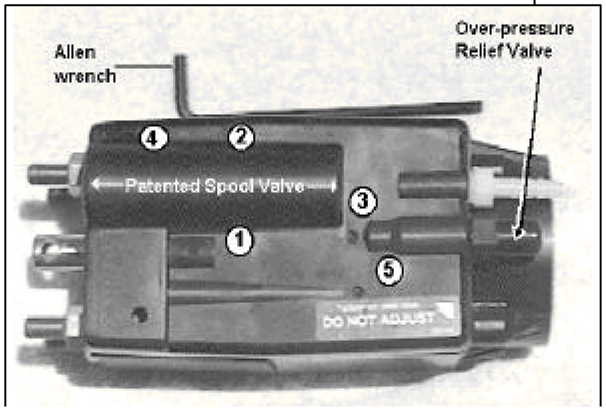
First, it will only be necessary to tighten the manifold fasteners just enough to compress the six rubber o-rings to the point where their seats (in the manifold) and the mating land areas on the pump body <u>just</u> touch. Tightening more than this can distort the plastic bodies of both the manifold and the pump and introduce a real possibility of o-ring failure. It is also possible to damage the threaded inserts for the fasteners by overtightening. Note that the two threaded recesses in the pump front body are plastic and are easily stripped.

Second, it will be necessary to draw the fasteners down <u>evenly</u> in order to assure equal seating of all the o-rings. Don't continue any further until you understand this….

O.K., it's time to do it. Because the stainless steel fasteners tend to bind a little when being tightened, I always prepare the threaded recesses by lubing them with silicon grease. Coat the threads of one of the fasteners with silicon and screw it in and out of each of the threaded holes a couple of times before attempting to tighten down the manifold.

After prepping the threaded holes in the pump body, position the manifold over the pump body, line up the fastener holes in the manifold with the threaded holes in the body and screw the five manifold fasteners into their respective holes. (*<u>Note</u>*: Remember that fastener #6 has nothing to do with seating the manifold—we'll install it later when attaching the hose barb assembly.)

Insert the *<u>long</u>* arm of the 5/32" allen wrench into each fastener in turn and screw them in until you <u>just</u> begin to feel a little resistance. Then begin to tighten each one a little bit at a time, following the sequence shown in *<u>Figure A-15</u>*.



Use only the *<u>short</u>* arm of the allen wrench to apply torque to the fasteners. Remember that all you're really trying to accomplish here is to compress the rubber of six small o-rings—and that doesn't take a lot of torque. Gripping the short arm of the allen wrench will allow sufficient torque, while minimizing the chances that you will tighten too much.

I've assembled many ***PowerSurvivor 35***s over the last several years using only the torque I can apply with the small arm of the allen wrench. None have failed because I didn't tighten the fasteners enough.

<u>Step 12</u>: *Install membrane, return tube and housing*

The following procedure for installing the watermaker membrane and housing differs markedly from the directions in the PŪR instruction set, but it minimizes the chances of damaging the delicate brine seal on the membrane.

Install the two o-rings on the stem of the membrane. The large brine seal should still be in its groove on the pump end of the membrane.

Install the three o-rings (two larger and one smaller) on the membrane reject tube and slide the reject tube through the center of the membrane. The black plastic disk on the end of the reject tube should be at the end of the membrane opposite the white stem; i.e., at the end farthest from the pump end of the membrane.

Lubricate the first inch of the inside surface of the open end of the membrane housing with silicon grease. Make sure to coat the edges of the open end.

Hold the membrane housing in one hand and slide the membrane and reject tube assembly into the housing until the brine seal reaches the open end of the housing. Make certain the brine seal is in good condition and has been lubricated with silicon grease.

Carefully continue to slide the membrane the rest of the way into the membrane housing while paying special attention to the brine seal. This is a critical step. It is very easy to roll the brine seal out of its groove and pinch it between the membrane and the inside of the housing. You may have to work the brine seal with your fingers to prevent it from rolling. With a little care, the brine seal will slip evenly into the housing without damage. If the brine seal starts to roll out of its groove, withdraw the membrane a small distance and try again. If you roll the brine seal, you're very likely to damage it—and there's no replacement in the seal kit. Once the membrane and its brine seal have been successfully inserted into the membrane housing, the critical work is over.

Guide the end of the reject tube into the hole in the pump front, thread the membrane housing into the pump front until it will go no farther and you're home free. It is not necessary to tighten the membrane housing in the pump front with a dying strain. However, it should screw completely in without leaving a gap between the slight flange on the end of the housing and the mating surface of the pump front.

Step 13: *Attach pump to drive assembly*

If the piston shaft is not fully extended out of the pump back, insert a small screwdriver (or similar rod) through its coupling hole and pull the shaft out. At the same time, twist the piston shaft until the coupling hole is vertical. Lubricate the piston shaft with silicon grease and slide the rubber boot onto the piston shaft with its large opening facing away from the pump.

Guide the four threaded rods through their respective holes in the flange on the drive unit. The piston shaft should slide easily into the hollow center of the gearbox drive shaft. Continue to slide the piston shaft into the drive shaft until the two coupling holes are aligned. Then push the coupling pin through the holes while holding a finger underneath to prevent the pin from dropping out the bottom of the drive shaft. After the coupling pin has been inserted, slide the rubber boot over the pin to keep it in place.

Push the pump toward the drive unit until the drive unit flange is against the four nuts that are securing the gland plate and pump halves. Install the four remaining hex nuts and tighten firmly with the 1/2" wrench.

Step 14: *Mount the watermaker*

Remount the watermaker and reconnect the product water hose and electrical wiring. Replace the four o-rings on the hose barb assembly and insert the latter into its cavity in the manifold.

Screw the #6 manifold fastener into its hole to secure the hose barb assembly in place. Be careful to not overtighten this fastener. Overtightening it will distort the manifold body and can pull the threaded brass insert in the pump back body upward toward the manifold and crack the top of the pump back.

Step 15: *Test the watermaker*

Open any seacocks and/or valves that are necessary for normal operation and turn the watermaker on. Run it long enough to determine that it is operating correctly, making good product water, and there are no leaks.

Step 16: *Relax. Have a Pacifico!*

With a little bit of luck, you will have succeeded in returning your ***PowerSurvivor 35*** watermaker to near-new working condition. In fact, if you've been diligent in following the instructions in the preceding pages, you can rest assured that you've done as much for this valuable piece of equipment as many repair stations would do—probably more. And you've done it with more love and care than most strangers would have given. After all, you're the one who depends on the watermaker to make your life a lot easier.

Finally, you now know what it's all about. It's not that hard. If you encounter any problems down the road, you'll have a lot more confidence in your ability to handle the situation. Your watermaker is no longer a "black box"—it's an old and familiar friend!

Before You Begin…

BEFORE COMMENCING WORK on your ***PowerSurvivor 40E*** watermaker, read the first few paragraphs of the previous chapter—“*A. Servicing the PowerSurvivor 35*.” Then at least skim through the rest of the present chapter to get an overview of the entire disassembly process. It is assumed that the reader has the *Owner’s Manual* and other original documentation for the ***PowerSurvivor 40E***.

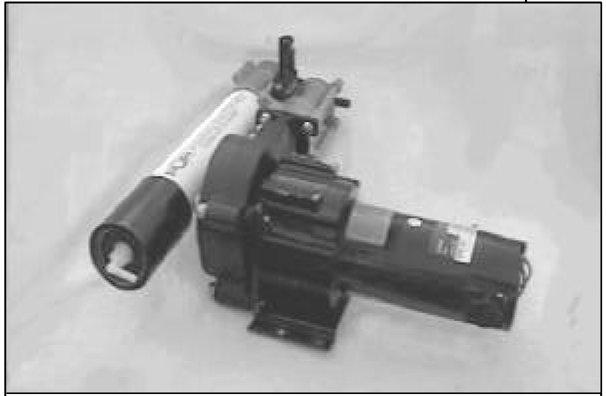


Figure B-1: The **PowerSurvivor 40E** *watermaker*

All of the current watermakers from PŪR reflect a number of important design engineering advances. This is especially true when we compare the ***PowerSurvivor 40E*** with its predecessor, the ***PowerSurvivor 35***. In this case, the advances include a simplified design and a substantial reduction in internal seals and working parts. As a result, the disassembly, servicing and reassembly of the **Model *40E*** is easier than working on the **Model *35***.

The **Model *40E*** has replaced the **Model *35*** in the PŪR watermaker line. The ***PowerSurvivor 40E*** is available in marine stores and the ***PowerSurvivor 35*** is no longer sold. I’ve been assured that Recovery Engineering will continue to support the **Model *35*** well into the future. At the time of this writing, PŪR is offering a generous policy for current ***PowerSurvivor 35*** owners to upgrade to a ***PowerSurvivor 40E***. The offer includes a complete new ***PowerSurvivor 40E*** pump and drive assembly, without the electric motor or membrane. The latter items are to be salvaged from the original **Model *35*** being upgraded. Interested ***PowerSurvivor 35*** owners should contact Recovery Engineering about the offer.

The Tool Kit: Very few tools are needed to completely disassemble and reassemble the ***PowerSurvivor 40E*** watermaker. Following is a list of the tools and materials you should have on hand.

Piston seal installation tool (supplied in kit)
1/2" open-end wrench
5/8" open-end wrench
1/4" allen wrench
5/32" allen wrench
small flat-bladed screwdriver
needle-nosed pliers
channel-lock pliers
small scissors or razor blade
silicon grease
10X magnifying glass or loupe
small stainless steel wire brush
clean rags
old, clean towel for work surface
good lighting

Seal Kit and Documentation: As shipped from PŪR, the *Repair Seal Kit* for the ***PowerSurvivor 40E*** consists of a set of instructions and one plastic bag of parts. Illustrations detailing the overall system configuration for the **Model *40E*** can be found in the *Owner’s Manual*. Installation instructions for the *Repair Seal Kit* are in the kit and also in the *Owner’s Manual*. Both versions of the documentation include actual-size drawings of all the seals in the kit.

Both sets of seal drawings show a *membrane brine seal*. However, there have been no brine seals in any of the **Model *40E*** *Repair Seal Kits* I’ve seen. On the other hand, all of the kits I’ve seen were early issues. Perhaps PŪR currently ships a brine seal in their kits, as per the documentation. They definitely should! The membrane brine seal is one of the most often abused and easily damaged seals in the whole system—especially with the ***PowerSurvivor 35*** (the membrane brine seal is the same for both the **Model *35*** and ***40E***). Be sure to check your *Repair Seal Kit* to see if you have a replacement brine seal before manhandling the old one.

Fortunately, it is not necessary to remove the membrane from its housing for a standard seal replacement procedure. For the most part, the instructions that follow are the same as those to be found in the PŪR documentation. But, as Cannonball Adderley once said, “…sometimes things don’t lay the way they’re supposed to lay!” To address that issue, I’ve added my comments and tips on procedures, where appropriate.

Refer to the PŪR documentation for exploded parts drawings, part numbers, actual-size seal and o-ring drawings, and similar information.

Disassembly

The seal replacement procedure involves only the pump assembly—not the drive motor, gearcase, membrane, or system plumbing. Before proceeding, I suggest turning the intake selector valve to its *alternate* position and running air through the watermaker until it no longer expels reject water. This will eliminate residual water pressure in the pump and make the disassembly job less messy.

The following procedure assumes that the entire drive, pump and membrane housing will first be removed as a unit. With some installations, where there is ample working room around the watermaker, it may be possible to separate the pump from the drive unit without dismounting the latter.

Step 1: ***Remove membrane end cap (not recommended)***

If the membrane does not need to be removed—and a standard seal replacement servicing does *not* require it—do *not* perform this step. To remove or replace the membrane, it is not necessary to remove the end cap on the end of the membrane housing. The membrane can be accessed from the pump body behind the check valve plate.

The end cap is often quite difficult to remove. The easiest way is to pump it off while the watermaker is still installed. To do this, remove the stainless steel spiral retaining ring at the end of the membrane housing. Work it out of its groove with a small, flat-bladed screwdriver, or grasp the end with needle-nosed pliers and pull toward the center and up.

After the retaining ring has been removed, turn on the watermaker. It should require no more than a couple of strokes to develop enough pressure to push the end cap out of the membrane housing. After the end cap has emerged, turn the watermaker off and continue with its removal and disassembly.

Step 2: ***Disconnect electrical wiring***

Turn off electrical power to the watermaker at the switch or circuit breaker panel. *If there is any possibility that someone might turn on the watermaker while you're working, secure the switch or circuit breaker handle in the "off" position and/or attach a note indicating that the circuit is being serviced*. The exposed area around the drive shaft and coupling is dangerous. This is a powerful mechanism that can cause serious personal injury if the watermaker starts running while your fingers or tools are in the area.

Disconnecting the electrical wiring is a simple matter if you had the foresight to install a terminal strip near the watermaker. If you used butt splice connectors, you'll have to cut the wires and re-splice them during reinstallation. Hopefully you left enough service loop in the electrical wires to allow for future removals of the watermaker—the wires will get a little shorter each time you cut the splices. If you *are* using butt splices, this is a good time to consider replacing them with a terminal strip and ring terminals.

Step 3: ***Remove three water hoses***

Carefully pull the small-diameter product water hose from the hose barb on the end of the membrane housing. This should not be difficult. Loosen the hose clamps on the seawater *intake* and *reject* hose barbs and pull the hoses off the barbs.

Step 4: ***Move watermaker to work area***

After removing the three hoses and disconnecting the electrical wires, undo any fasteners securing the watermaker to its mounting surface and move the entire unit to your work area.

When handling and transporting the watermaker, be mindful of its weight and awkwardness. Avoid carrying it by the membrane housing. A good balance point for the unit is about where the drive unit is connected to the pump. Grasp the watermaker by the heavy drive unit flange and it will be easier to handle and balance.

Step 5: ***Disconnect motor/drive assembly from pump***

Use a 1/2" open-end wrench to remove the four hex nuts securing the gearbox flange to the pump back plate. A 1/4" allen wrench may be required to loosen the two 5" sockethead capscrew bolts running through the check valve plate and back plate. Remove the two capscrew bolts.

If necessary, pull the pump away from the drive unit to expose more of the plunger rod. Slide the black rubber boot away from the coupling pin (toward the pump body) and push the pin out of its hole in the drive shaft. Set the motor and gearbox assembly aside. See *Figure B-2*.

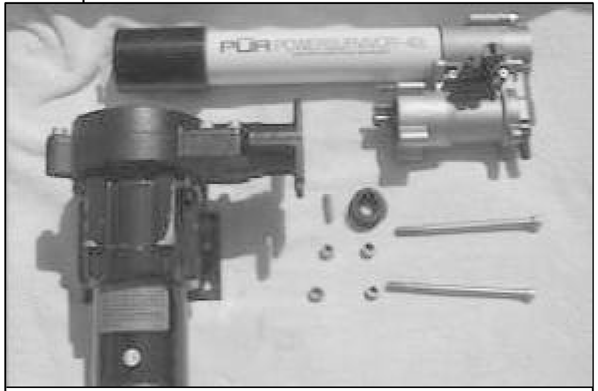


Figure B-2: Pump separated from drive assembly

Step 6: ***Separate back plate from pump body and remove piston***

Using the 1/4" allen wrench, remove the two 3" sockethead capscrew bolts holding the back plate to the pump body. Separate the back plate from the pump body. Remove the large o-ring from the inside face of the back plate. Grasp the plunger rod and pull the piston out of the pump body. It may be necessary to wiggle the piston back and forth to get it out. See *Figure B-3*.

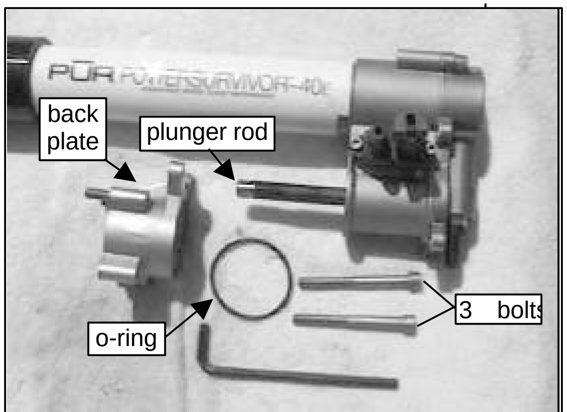


Figure B-3: Back plate separated from pump

Step 7: **Remove cup seal and PIP ring from piston**

Carefully work a small, flat-bladed screwdriver or similar tool underneath the PIP ring on the piston. Pry the ring up far enough to cut it off with a small pair of scissors or a razor blade. Repeat this procedure for the cup seal. Discard the old PIP ring and cup seal.

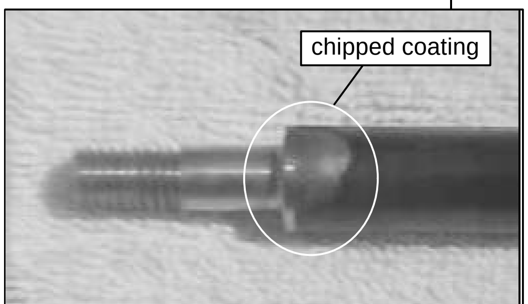


Figure B-4: Defective coating on plunger rod

While you have the piston assembly in your hands, inspect the plunger rod carefully. Look for any signs of roughening or chipping of the dark, ceramic-looking coating on the surface of the plunger rod. Early in the history of the ***PowerSurvivor 40E***, a small number of watermakers were shipped with defective coatings. The coatings begin to flake off after a few hundred hours of running. The flakes cause accelerated wear of other seals, and the roughened plunger rod rapidly destroys its shaft seals (see *Figure B-4*). Early symptoms include gradually increasing seawater leakage around the plunger rod. The seawater comes out of the back plate around the plunger rod.

I've been assured that very few—if any—of the units with defective plunger rods ever reached end-users. The problem was discovered while most units were still in vendors' warehouses. The defective watermakers were returned to Recovery Engineering. Anyone possessing a new **Model *40E*** watermaker with this defect in the piston plunger rod should contact the MROD Product Manager at PŪR to arrange for its replacement. This defect can be expected to cause problems well before the first 1000-hour routine seal replacement servicing.

In any event, always inspect the condition of the plunger rod surface when disassembling the watermaker. It and its seals undergo a lot of wear. Small surface flaws on the plunger rod surface will act like sandpaper and chisels against the shaft seals, greatly accelerating the rate of wear.

Step 8: ***Remove wiper block and seal***

Figure B-5: Removing plunger rod seals

Retrieve the large plastic wiper block from the back plate. You should be able to shake it out. Inside the center hole in the wiper block is a rubber seal. Grasp the inside lip of the seal firmly with needle-nosed pliers and pull the seal out. Pull it sideways first, and then up. It is seated in a groove in the inside of the hole in the wiper block.

Step 9: ***Remove plunger rod seals, backup washers and bushing***

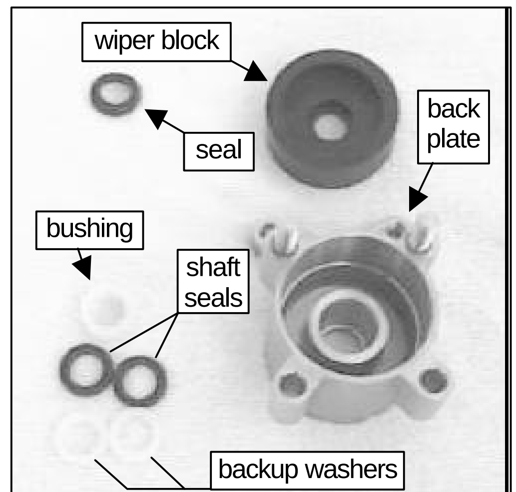


Figure B-6: Wiper block, back plate and seals

Insert a flat-bladed screwdriver into the plunger rod hole in the inside face (o-ring seal side) of the back plate. Align the tip of the screwdriver blade against the white backup washer just inside the plunger rod hole (see *Figure B-5*). Push straight downward with the screwdriver, and both backup washers, both shaft seals, and the bushing, will fall out the other side of the back plate (see *Figure B-6*). A socket wrench just slightly smaller than the plunger rod hole also works well to push out the shaft seals and washers.

<u>Step 10</u>: *Separate check valve plate from pump body and membrane*

Use a 1/4" allen wrench to remove the remaining two sockethead bolts (3/4") still holding the check valve plate to the pump body. At this point, the instructions from PŪR simply say: "…the Check Valve Plate will come off the Membrane Housing and Pump Body." Well…,

Figure B-7: Rotating check valve plate

The check valve plate doesn't simply fall off. Even with the two capscrew bolts removed, the check valve plate will remain tight against the pump body. It is being held in place internally by the compressed o-rings of the membrane tube plug. Carefully wedge a flat-bladed screwdriver between the check valve plate and the pump body. Gently twist the screwdriver blade and pry the check valve plate about 1/8" away from the pump body. Be careful not to damage the faces of the check valve plate or the pump body. Then rotate the entire check valve plate part-way (e.g., 90°) around the membrane axis. In that position it is possible to grip the check valve plate well enough to wiggle it off the single o-ring on the end of the membrane tube plug. See *Figure B-7*. Remove the large o-ring seal (#137) from the pear-shaped groove in the check valve plate.

The reason for prying the two pieces apart a little bit before rotating them is to avoid cutting the large o-ring (#137) on some of the internal sharp edges and holes. Prying the two pieces apart a small distance provides room for the o-ring to rotate with the check valve plate without tearing.

<u>Step 11</u>: *Remove membrane tube plug from pump body*

Illustrations in the PŪR instructions show the membrane tube plug remaining in the check valve plate when the latter is separated from the pump body. In fact, I've never known that to be the case. Instead, the membrane tube plug remains buried in the pump body, tightly held by three o-rings and presenting little surface to grip for pulling it out.

Figure B-9: The membrane tube plug

Remove the o-ring (#920) from the groove in the membrane tube plug. Carefully line up a knife blade (preferably dull) with the inside edge of the white plastic membrane tube plug. With a slight wiggling motion, press down on the knife blade just until it wedges between the lip of the membrane tube plug and the fiberglass membrane housing (see *Figure B-8*). After the knife has wedged between the two edges, wiggle the knife sideways—*without* pressing down—to work the tube plug out of the membrane housing. At this point, a flat-bladed screwdriver is better for working the tube plug the rest of the way out. When it's off, remove the remaining three o-rings on the tube plug: two small (#-012) and one larger (#920).

In the PŪR documentation, the membrane tube plug is only illustrated as inserted into the check valve plate. There is no illustration or exploded view of the whole membrane tube plug. To aid the installer in understanding what is involved in removing the part, *Figure B-9* shows the membrane tube plug in all its naked glory, with o-rings installed.

Figure B-8: Removing membrane tube

Note that the stem of the membrane tube plug (and the two smaller o-rings) insert into one end of the membrane itself, while the upper large o-ring lives between the plug and the fiberglass membrane housing. Only the lower large o-ring lives in the check valve plate. It's not hard to see why the membrane tube plug stays with the pump and membrane when the check valve plate is removed.

<u>Step 12</u>: *Remove poppet valves from check valve plate*

Use a 5/8" open-end wrench to unscrew the inlet valve seat fitting in the top of the check valve plate. Be sure to loosen the <u>metal</u> hex fitting, and not the plastic hose barb that is screwed into it.

Remove the o-ring seal on the inside end of the valve seat fitting. Lift the first poppet valve, spring, and valve retainer out of the check valve plate with the needle-nosed pliers. Note that the first poppet valve may have already come out with the inlet valve seat. The spring and retainer will usually come out together, because one end of the spring is lightly pressed-fitted into the retainer.

Beneath these parts is a second poppet valve assembly. Removing it can be a problem, and almost any procedure is likely to damage the old valve components. Removal should only be attempted if replacement parts (e.g., a *Repair Seal Kit*) are available.

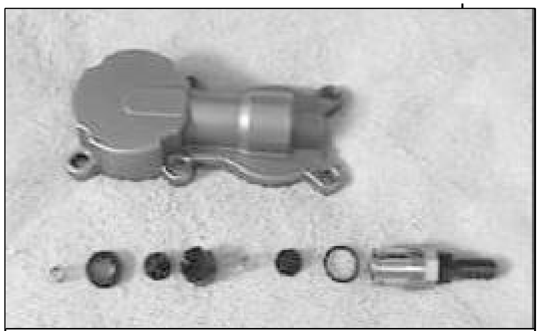


Figure B-10: Check valve components

First, clean and lubricate (with silicon grease) the upper part of the valve bore in the check valve plate. Get the grease all the way down to the second valve seat. This will make it easier for the valve seat to slide out. Then try reaching into the hole with the needle-nosed pliers to grasp the second poppet valve by its cross-shaped center. Pull straight up with the pliers. If you're lucky, the poppet valve, along with its seat, will come out. Lastly, retrieve the small spring at the bottom of the hole.

At this point, you should have removed the inlet seat fitting and its o-ring, two poppet valves, two valve springs, one valve seat and one valve retainer (see *Figure B-10*).

It's possible that the foregoing method of removing the second poppet valve assembly won't work. When all else fails, the second valve seat can be "burned out." If you have a hot knife small enough to reach the valve seat, burn through the seat on one side to release it's tension.* It then should be easier to remove with the needle-nosed pliers.

Figure B-11: Removing end cap

After removing the second valve assembly, clean the valve bore in the check valve plate and coat it with a thin layer of silicon grease. Next time the seat may come out with less effort.

Step 13: *Remove membrane and end plug (optional)*

If you need to remove the membrane for servicing or replacement, you should now do so. If you pumped the end cap off before dismounting the watermaker (see **Step 1**), you're home free. In fact, the membrane probably came out with the tube plug. If not, push it out of the housing.

If the end cap was left installed, you can pull the membrane out of the membrane housing from the open end of the pump body with some needle-nosed pliers. Wash it down with fresh water and put it aside until reassembly. *Do not let it dry out!*

Alternate method: The membrane *can* be removed without tearing down the entire pump, via the end cap end of the housing. In this case, the end cap needs to be removed. To do this, remove the stainless steel retaining ring on the end of the membrane housing. See **Step 1** for tips on doing this. *Note*: Although the membrane can be removed from this end, I advise against inserting it from this end, for reasons cited elsewhere (see **Step 4** of the reassembly procedure).

Trying to remove the end cap by pulling on it with the weak nylon product water fitting in the end cap—the method described in the PŪR instructions—usually will *not* work. The nylon fitting is too weak and is quickly deformed by vice-grips or any similar tool.

The method I've devised for removing the end cap requires a 3/8" NPT pipe nipple at least a couple inches long. Unscrew the nylon product water nipple from the end cap and screw the pipe nipple in its place. Secure a tight grip on the pipe nipple close to the end cap with a pair of vice-grips. Then use a flat-bladed screwdriver to lever the vice-grips away from the end cap, as illustrated in *Figure B-11*, working the end cap out at the same time.

You might be surprised at the force required to pull the end cap out of the membrane housing. When it does come out, the membrane may come out as well. Be careful not to break the membrane stem while it is embedded in the end cap. If the membrane has stayed inside the housing, pull it out carefully with some pliers.

If the membrane came out with the end cap, pull the end cap off the membrane stem. If you'll be replacing the membrane, remove the brine seal on the other end. Be aware that a new brine seal has *not* been included with any **Model *40E*** *Repair Seal Kits* I've seen to date, but may be included in current kits. Check *your* kit.

Step 14: *Take a break!*

You have now completely disassembled a PŪR ***PowerSurvivor 40E*** watermaker. Clean all the parts, stow the old seals in a bag of used parts, and have a refreshment. Next, we'll put it all back together again.

* A hot-knife substitute is any thin strip of metal held with pliers and heated over a flame; e.g., a chunk of old hacksaw blade.

Reassembly

For the most part, the reassembly of the ***PowerSurvivor 40E*** is the reverse of the disassembly process already described. I will be referring to the illustrations in the disassembly procedure for identification of parts, except for those steps that require illustrations unique to the reassembly procedure.

During reassembly, it is assumed that all components have been thoroughly cleaned and all seals and o-rings, *without exception*, have been lubricated with silicon grease before being assembled. You should also lubricate all seal bores in the back plate, pump body and check valve plate, including the piston cylinder, check valve bore, and wiper block hole. A clean, well-lighted workspace is even more important for the assembly procedure than it was during disassembly.

Step 1: *Install poppet valves in check valve plate*

Lube the inside of the valve bore with silicon grease. Lube a new poppet valve spring and lower it into the valve bore in the check valve plate. Press it into the indent at the bottom of the bore. It should snap into place and stay upright, without falling out. You may have to play with it a little to get it right.

After the spring is in place and pointing straight up, lower a poppet valve on top of the spring, with its cross-shaped side facing up (away from the spring). The PŪR instructions refer to this part variously as "poppet,' "poppet and o-ring," and "poppet/o-ring combination." Note that each poppet valve has an o-ring around its widest perimeter. For the PŪR ***PowerSurvivor 40E***, these o-rings are pre-installed. These o-ring/poppet valve "combinations" are what PŪR is referring to in their documentation. You needn't be looking around for another o-ring to install with the poppet valve.

Next, lube the plastic poppet valve seat and push it down the bore and over the poppet valve, *with its beveled edge facing down* (i.e., facing the poppet valve). Push down hard with your finger to make sure it is fully seated. Look down the bore to see that the cross on the poppet valve is centered in the hole in the valve seat. Insert a chopstick or the eraser end of a pencil into the bore and press the poppet valve up and down a few times. It should travel a small distance downward and spring back into place smoothly. If the poppet valve doesn't appear centered in the seat, or it can't be operated with the probe, pull the poppet valve and seat out together and start over.

After the lower poppet valve, seat, and spring have been successfully installed, lubricate the valve retainer and the other valve spring. Press the spring into the small, circular land that is in the center of one side of the retainer. Make sure the spring stays in place and is pointing straight up. Then lower the spring and retainer combination into the bore on top of the first poppet valve assembly. The spring should remain pointing upward.

Figure B-12: Assembled check valve plate

Gently lower the second poppet valve on top of the spring with its cross-shaped side facing up. Finally, lube and install a new o-ring on the inside end of the inlet valve seat fitting and screw it into the bore after the poppet valve. Note that the inside end of the fitting is the seat for the second poppet valve. Screw the fitting all the way in until it bottoms. The outside shoulder of the fitting should be approximately flush with the top of the hole in the check valve plate. Do not use any pipe joint compound or tape for this inlet seat fitting. The o-ring on the end of the fitting creates the seal.

Use the pencil or chopstick probe to reach into the inlet seat opening and operate the second poppet valve. It also should operate freely.

Step 2: *Install tube plug and o-ring in check valve plate*

PŪR documentation never shows the membrane tube plug removed from the check valve plate, and gives no instructions for replacing the second large (#920) o-ring installed on it. Nevertheless, the *Repair Seal Kit* drawings indicate there are two of these o-rings included in the kit, presumably to replace both large o-rings on the membrane tube plug. Since our disassembly procedure describes complete removal of the tube plug, replacing both o-rings is no problem and that's what we will do.

Install both large o-rings (#920) on the membrane tube plug. Also install the two smaller o-rings (#-012) on the stem of the membrane tube plug. Insert the wide end of the membrane tube plug into the cavity of the check valve plate and line it up square. Using firm finger pressure, press the tube plug into the check valve plate until the o-ring snaps into place and the plug bottoms in the cavity.

Generously lubricate the pear-shaped o-ring groove on the inside face of the check valve plate with silicon grease. Press a new o-ring (#137) into this groove and work it around until all of it lays smoothly in the groove. The o-ring may seem almost too large for the groove but, once it has been evenly distributed around its path, the silicon grease should hold it in place. The assembled check valve plate should now look like

Figure B-12. Notice how deeply the membrane tube plug is seated in the check valve plate. Set the check valve plate assembly aside.

Step 3: *Install end cap in membrane housing*

If the membrane housing end cap was removed, reinstall it now. Clean and lube (with silicon grease) the o-ring on the end cap. Since there is no replacement in the *Repair Seal Kit* for this o-ring, the old one should be reused. Note, however, that this is the same o-ring (#920) that is used on the membrane tube plug at the other end of the membrane housing. If you save your old o-rings, you will have an emergency replacement for the end cap o-ring, in case it is ever damaged.

Look inside the membrane housing and identify the inside surface of the fiberglass housing where the end-cap o-ring will be sliding. Use a dab of silicon grease on a finger to lubricate those surfaces. Remove the nylon product water hose barb fitting from the end cap, if it isn't already out.

Slide the end cap into the membrane housing until you encounter resistance. Then, stand the membrane housing, end cap down, on a flat, firm surface and press down hard. Continue inserting the end cap by pressing down until the end cap is flush with the membrane housing. You should feel the end cap slip into its bore in the housing tube.

It will be necessary to tap the end cap farther in with a soft mallet or the plastic handle of a screwdriver. Continue driving it into the membrane housing until its outside face is just below the groove for the spiral retainer ring in the housing.

Install the stainless steel spiral retainer ring. Coat the threads of the nylon product water nipple with a thread sealant or teflon tape and screw it into its hole in the end cap.

Step 4: *Install reverse osmosis membrane*

Clean and inspect the two small o-rings on the membrane tube stem and the larger brine seal on the opposite end of the membrane. Be especially careful when handling these seals, as replacements are not included in the *Repair Seal Kit*. If you are installing a new membrane, it should have arrived with a new brine seal and stem o-rings already installed.

Lubricate the membrane brine seal and stem o-rings and slide the membrane, stem first, into the pump end of the membrane housing. Continue pressing until the brine seal is about to enter the membrane housing tube. While continuing to press gently inward on the end of the membrane, make sure the brine seal enters the housing smoothly and completely. After the brine seal has entered the housing, press the membrane all the way in until it will go no farther.

In my opinion, the preceding procedure is the best way to install a membrane into the membrane housing. When servicing (or installing) *only* a membrane, the PŪR instructions direct you to remove the end cap and pull the membrane out from that end of the housing. Their directions for re-installing the membrane are, at best, amazingly succinct: "Reassemble in reverse order of disassembly."

I take issue with these factory directions for two reasons. When the membrane in inserted into the housing from the end opposite the pump, the delicate brine seal must travel the entire length of the membrane housing with its flared side pushing first. If the seal is working correctly, when pushed in this direction, it should be "sealing all the way." This long travel greatly increases the chances of rolling or damaging the brine seal during insertion.

The second reason I avoid the PŪR method of membrane insertion is my experience with replacement brine seals I've seen in the field. Some are significantly larger in diameter than others. The larger brine seals are sloppy-loose on the membrane, and so large that they can barely be coaxed into the housing without damage. They want to roll and pinch. Although they can be made to work (if sufficient care is exercised in their installation), they are a problem.* Trying to slide one of these larger o-rings up the entire length of the membrane housing is, in my opinion, an invitation to disaster.

If the membrane is inserted as I've directed, i.e., into the pump end of the housing, the brine seal can be "coaxed" into the membrane housing, if necessary, and then need slide only a short distance down the membrane housing tube. Further, it will be *trailing* its flared edge as it slides—a much more natural direction of travel, and one that is much less likely to result in a pinched or rolled seal.

For these reasons, I recommend partial disassembly of the ***PowerSurvivor 40E*** watermaker pump whenever a membrane is to be inserted. All that is required is removal of the back plate, piston, and check valve plate. Once the check valve plate has been removed, the membrane tube

* When I brought up the problem of over-sized brine seals at REI during a recent visit, I was told by the customer support staff that, indeed, there did seem to be a substantial variation in the size of brine seals they had seen. Nevertheless, they assured me, the brine seals are all within specifications and should work. Personally, I don't believe that. Industrial seals and o-rings are manufactured to tight—often critical—specifications. My guess is that REI received a batch of "close-but-wrong-sized" seals that slipped by QA. In any event, be especially careful when installing membrane brine seals.

plug and membrane can be removed per the instructions earlier in this chapter. An added benefit to this approach is the lack of need to remove the troublesome membrane housing end cap.

Step 5: ***Prepare back plate for assembly***

Prepare the back plate for assembly by lubricating the hole for the plunger rod and its seals, and the cavity for the wiper block.

Insert one of the (new white plastic) plunger rod backup washers into the plunger rod hole from the outside face of the back plate. Press it down with a finger or pencil eraser until it will go no further and is lying flat at the bottom of the hole.

The reason for installing a single backup washer at this time is to have a guide for later insertion of the plunger rod through the back plate. This technique minimizes the chances of damaging the inside surfaces of the back plate hole by hitting it with the plunger rod during assembly.

Finish preparing the back plate by generously lubricating its pear-shaped o-ring groove. Install the large o-ring (#137) into the groove, working it around until it is evenly distributed and is held in the groove by the silicon grease. If necessary, use more silicon grease. The back plate is now ready for assembly. Lay it aside.

Step 6: ***Assemble piston and plunger rod (optional)***

The installation of a standard *Repair Seal Kit* in the **Model *40E*** does *not* involve separating the plunger rod from the piston. This step will only be necessary if the plunger rod and/or piston need to be replaced.

If disassembly is required, use a 1/2" socket wrench to loosen the hex nut on the end of the plunger shaft. The hex nut should have been assembled using a thread-locking compound. It will be necessary to apply moderate force to loosen it. Secure the other end of the plunger rod by inserting a medium-sized Phillips screwdriver through the coupling pin hole. Remove the hex nut, washer and piston from the plunger rod.

Behind the piston, at the base of the threads on the plunger rod, is a small o-ring seal. Because of the torque applied to the hex nut when it is installed on the plunger rod, the seal is severely compressed and usually damaged *after one use*. It should be removed and replaced with a new plunger rod seal. If you order a new piston or plunger rod, be sure it comes with a new seal.

After installing the plunger rod seal, slide the piston back on to the plunger rod. Coat the threads on the end of the plunger rod with *Loctite*® (or equivalent thread lock compound).* Slide the washer on, screw on the hex nut, and tighten it firmly with the socket wrench.

Step 7: ***Install PIP ring and cup seal on piston***

Place the piston assembly on a firm, flat surface with the piston down and the plunger rod pointing up. Slide the insertion tool (supplied with the *Repair Seal Kit*) over the plunger rod with its wide end against the piston. Lightly grease the outside surfaces and seal grooves on the piston with silicon grease. Also grease the outside surface of the insertion tool. This latter step is the key to having the PIP ring and cup seal slip easily down the tool and onto the piston.

Lubricate the PIP ring and cup seal with silicon grease. Slide the PIP ring over the insertion tool with the ribbed (non-smooth) side of it *facing up*. Referring to *Figure C-11* (in the following chapter), use your fingers to press the PIP ring down the insertion tool, over the sides of the piston, and into its groove.

This step will require a fair amount of force. If you have trouble, try pushing the ring part way down and then backing off, to get a feel for the elasticity of the PIP ring and the force that is required. You should observe that the purpose of the insertion tool is to spread the seals wide enough to slip over the outside perimeter of the piston. From there, it's an easy trip to snapping the PIP ring into its seat in the piston groove.

After the PIP ring has been installed, repeat the same procedure to install the cup seal. The cup seal should be slid on with its ribbed side *facing down* (facing the PIP ring). The secret to success with installing these seals is the lubrication of the seals, the piston, and the insertion tool with silicon grease. Take your time, do it right, and it'll happen.

Step 8: ***Install piston in pump body***

Set the piston on a clean, flat surface with the plunger rod pointing upward. Lower the pump body cylinder over the piston assembly with the membrane housing pointing up. Gently slide the pump body cylinder down and over the piston until the piston face is approximately flush with the bottom side of the pump body cylinder. At this point, the piston and piston seals should be just inside the pump body cylinder.

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* Note that a thread *locking* compound is needed here. This is not the same as a thread *sealant*. A sealant only "seals" a joint to prevent it from leaking (e.g., pipe joint compound, teflon tape). A thread-locking compound "glues" the joint to keep it from working loose. *Loctite*® #272™ (red) is recommended, although #242™ (blue) would also probably work.

Inserting the piston from the described direction is relatively easy. If it had been first assembled to the back plate and then inserted from the other side of the pump body cylinder, the flared lip of the cup seal would catch on the pump body cylinder and be quite difficult to work into the cylinder.

<u>Step 9</u>: *Install back plate, plunger rod seals, backup washers and bushing*

Lower the back plate onto the plunger rod, using the previously installed backup washer to guide the plunger rod through the middle of its hole in the back plate. Slide the back plate down the plunger rod until it is almost flush with the mating surface of the pump body. Take care that the large (#137) o-ring doesn't fall out of its groove in the process.

Slide one of the plunger shaft seals over the end of the plunger rod and down to the hole in the back plate. The seal should be installed with its <u>*flared side facing down*</u>. Be careful when sliding the two seals over the coupling pin hole at the end of the plunger rod. The sharp edges of the hole can cut a seal. A good technique is to squeeze the seal between thumb and forefinger on an axis perpendicular to the axis of the hole and then slide the seal past the hole. Squeezing the seal in this manner will cause it to bulge slightly outward on the sides that pass over the hole, lessening the chance of damage from the sharp edges of the coupling pin hole.

Work the first seal into the back plate hole until it's approximately flush with the hole. Then install the second (and identical) shaft seal in exactly the same manner, with its flared side also facing down. Work it into the back plate hole on top of the first seal until the second seal is approximately flush with the back plate. Next, slide the second (white plastic) backup washer onto the plunger rod. Finally, slide the thicker (white plastic) bushing onto the plunger rod.

Slide the installation tool over the plunger rod, small end down. After making sure that the piston and pump body are well supported, press straight down with the insertion tool and drive the two seals, the second backup washer, and the bushing, into the back plate. Continue to press them in until the bushing is flush with the back plate.

<u>Step 10</u>: *Install wiper block and seal*

While holding the back plate against the pump body, push the piston into the pump body cylinder (toward the back plate) as far as it will go.

Identify and lubricate the new wiper block seal. Notice that it has a lip on one side. Examine the wiper block. One side has a raised land in the center. Place that side down on a flat surface. Squeeze the wiper block seal into an oval with your fingers. Press one end of the oval seal into the groove in the hole in the wiper block. After getting one edge of the seal into its groove, work the rest of the seal down into the groove. This seal should be installed with its raised lip facing up.

Slide the wiper block onto the plunger rod. The side from which you installed the seal should be facing up. When done, check the large o-ring seal in the back plate to be sure it hasn't been dislodged from its groove. At this point, the assembly should look like <u>*Figure B-13*</u>. Notice that in the illustration, the back plate has been moved away from the pump body a short distance to show the piston and plunger rod.

<u>Step 11</u>: *Install check valve plate*

It is time for the final grand assembly, during which the prepared subassemblies are bolted together. The back plate has just been installed and the piston should be moved as far toward the back plate as it will travel. This provides maximum extension of the plunger rod out of the pump, making it easier to connect the drive assembly later.

<u>Use extra care in handling the back plate and pump assembly</u>, especially when moving the piston. The back plate is held to the pump body only by the compressed piston seals. It is very easy to accidentally pull the piston and back plate assembly out of the pump body cylinder. If this happens, go immediately to the next step, **Step 11x**, for special instructions before continuing this assembly procedure.

Lubricate all mating seals and surfaces of the check valve plate and the pump body with silicon grease. Line up the check valve plate with the open end of the membrane housing, with the tube plug stem ready to enter the hole in the membrane. Insert the tube plug stem (with its two o-rings) into the hole in the end of the membrane and press it in until the large o-ring on the tube plug just meets the edge of the fiberglass membrane housing.

Stop here and make sure the check valve plate is closely lined up with the pump body. Examine the large (#137) o-ring seal on the check valve plate to be sure it is still in its groove. When everything is ready, hold the pump body (and back plate) securely and hit the check valve plate sharply with the heel of your hand or a soft mallet. This should drive the large o-ring on the membrane tube plug the rest of the way into the membrane housing and seat it. The check valve plate should now be *almost* flush against the pump body.

If the large (#137) o-rings on the check valve plate and the back plate have not slipped out of their grooves, the clearance gap between the check valve plate (or the back plate) and the pump body should be approximately 0.020-0.030". A gap significantly larger than that (e.g., 1/8" or more) would probably indicate that the o-ring has jumped out of its groove somewhere and is keeping the check valve plate farther away from the pump body. Take it apart and check it out. It is very important that the #137 o-ring seals stay in their grooves, both in the back plate and in the check valve plate.

Step 11x: *Reassemble back plate and plunger rod seals (optional)*

If you inadvertently pulled the piston out of the pump body cylinder while working on the piston/back plate assembly, you have two ways to proceed.

1. Push the piston away from the pump back to provide some working room. Insert the piston back into the cylinder until the piston cup seal is stopped by the pump body cylinder wall. Then use a smooth, thin tool (e.g., feeler gauge blade, chopstick, etc.) to gently work the lip of the cup seal into the cylinder. Start at one point and work around the perimeter of the seal, pushing down lightly on the plunger rod. This technique is the easiest, but requires patience and a steady hand.

2. Pull the piston out of the back plate and repeat **Steps 8–10** of the preceding instructions. Unfortunately, the plunger rod should *not* be pushed back through the back plate while the plunger rod seals are still installed. The coupling pin hole is almost certain to damage the seals in the back plate if pushed in this direction. The plunger rod seals, backup washers and bushing must first be removed. Then **Steps 8–10** can be repeated.

Step 12: *Install capscrew bolts*

Insert the two 3/4" sockethead capscrew bolts through the ears on the check valve plate and screw them into the pump body fingertight. Slide the two 3" capscrew bolts through the ears in the middle of the check valve plate and screw them into the threaded holes in the back plate fingertight. Slide the two 5" capscrew bolts through the check valve plate and back plate ears. The pump and membrane assembly is now ready for the final step.

Step 13: *Attach drive assembly to pump*

Position the pump/membrane assembly next to the drive unit, with the pump plunger rod facing the slider shaft on the gearbox. Visualize how the plunger rod must slide into the drive slider shaft and what the final orientation of the pump to the drive assembly will be. Then insert a narrow screwdriver blade through the coupling pin hole at the end of the plunger rod and rotate the rod until the coupling pin hole will line up correctly with the hole in the drive unit slider shaft. Lubricate the black rubber boot with silicon grease and slide it onto the plunger rod. Its widest side should be next to the pump.

Lift the pump/membrane assembly and guide the plunger rod into the hole in the end of the drive unit slider shaft. Insert the plunger rod until the coupling holes in the slider shaft and the plunger rod line up. Push the stainless steel coupling pin through the holes. Slide the rubber boot over the coupling pin to hold it in position. Install the four hex nuts on the two studs from the back plate and the two 5" capscrew bolts, all fingertight.

The tightening process is important. The object is to draw the check valve plate, pump body, back plate, and drive unit together evenly. Start with the four fasteners that are holding the check valve assembly to the pump body; i.e., the two 3/4" and the two 3" capscrew bolts. Using the 1/4" allen wrench, tighten these four bolts a little at a time, using a criss-cross sequence, until they are comfortably snug. They do not require a dying strain. All sealing is done with o-rings and seals. The bolts only have to be tight enough to not work loose later. It is entirely possible to strip the threads by overtightening.

Finally, tighten the four hex nuts at the drive unit flange. Again, tighten them snugly a little at a time in an alternating pattern, but don't overtighten.

Step 14: *Replace relief valve/cleaning assembly seals (optional)*

The seals underneath the relief valve/cleaning valve assembly aren't likely to need replacing and can be skipped during a routine *Repair Seal Kit* installation. If you elect to replace them, use a 5/32" allen wrench to remove the two small sockethead fasteners that hold the assembly to the pump body. Pull the valve assembly off, replace the large and small o-ring inside, and re-install.

Step 15: *Mounting and final checkout*

Mount the assembled watermaker in its running location. Attach the product water, intake, and reject brine hoses, and reconnect the electrical wiring. If you have access to acceptable seawater for intake, make sure all necessary seacocks are open and run the watermaker for awhile. Check for any leaks or unusual sounds. Also check for good quality and quantity of product water output.

When you're sure everything is working well…pat yourself on the back for a job well done and kick back.

Before You Begin…

BEFORE COMMENCING to work on your watermaker, read the first few paragraphs of the earlier chapter, "*A. Servicing the PowerSurvivor 35*." Then at least skim through the rest of the present chapter to get an overview of the entire process and what to expect. We'll be learning how to disassemble a PŪR ***PowerSurvivor 80E***, install a *Repair Seal Kit*, and reassemble the unit. This is the best way I know for an owner to gain confidence about how the watermaker works and how to attempt fixing it if it doesn't work.

The hydraulic pumps in the new PŪR ***Endurance*** watermaker models (***PowerSurvivor 80E*** and ***160E***) and the older **Model *80***s (with all-stainless steel pump bodies) are virtually identical in design. For this reason, the following instructions for the installation of a *Repair Seal Kit* in a **Model *80E*** should be sufficient for servicing the new ***Endurance 80E*** and ***160E***, or any of the older configurations of the **Model *80***.

It is assumed that the reader has the *Owner's Manual* and other original documentation for the specific watermaker being serviced. The latter will best document the overall system configuration. Configuration differences (e.g., *modular* vs. *enclosed* models of the PŪR ***PowerSurvivor 80***) do not affect the installation of a *Repair Seal Kit*, since the pump assembly is the same in all configurations. Of course, parts and tool sizes may differ somewhat for the ***160E***.

The Tool Kit: Very few tools are needed to completely disassemble and reassemble the ***PowerSurvivor 80E*** watermaker. The following is a list of tools and materials you should have at hand:

- Piston Seal Installation Tool (supplied with the *Repair Seal Kit*)
- 1/4" allen wrench
- 7/16" socket wrench
- 1/2" open-end wrench
- 11/16" open-end wrench
- 7/8" open-end wrench
- straight-bladed screwdriver
- needle-nosed pliers
- 10X magnifying glass or loupe
- silicon grease
- small stainless steel wire brush
- clean rags
- old, clean towel for work surface
- good lighting

Seal Kit and Documentation: As shipped from PŪR, the *Repair Seal Kits* for the ***PowerSurvivor 80II, 80E,*** and ***160E*** consist of a set of instructions and one plastic bag of parts. Refer to the PŪR documentation for exploded parts drawings, part numbers, actual-size seal and o-ring drawings, and similar information.

Quite naturally, the documentation shipped with PŪR ***PowerSurvivor*** watermakers and optional kits (e.g., the *Repair Seal Kits*) has undergone changes over the years. This is especially true of the different **Model *80***s. Most of the changes have been minor corrections, but they can be confusing during a first-time effort at working on the watermakers. In particular, you are likely to have at least two of the following three different sets of directions for installing the *Repair Seal Kit*:

1. the version that is in the *Service Manual* that came with the ***80-II*** watermakers. This manual was separate from the *Owner's Manual*
2. the version that is in the *Owner's Manual* that comes with the 80E watermakers. This manual combines the material from the original *Owner's Manual* and *Service Manual* into one volume
3. a third version that accompanies the *Repair Seal Kit* itself

There are some differences between these versions. For example, the *Repair Seal Kit* instructions specify needing a 5/32" allen wrench for the disassembly, while the *Owner's Manual* for the ***80E*** contains an explicit list of needed tools, including a 1/4"—*not* a 5/32"—allen wrench. The *Service Manual* for the **Model *80-II*** has no explicit list of tools, but a 1/4" allen wrench (the correct size) is mentioned in the text of the instructions.

For the most part, the instructions in this book are the same—and in the same sequence— as those to be found in the PŪR documentation. I've added comments and tips on procedures, where appropriate. I've also tried to identify potentially confusing errors in the factory instructions.

All of the current watermakers from PŪR reflect a number of engineering advances, especially in comparison with the older ***PowerSurvivor 35***. The advances include a simplified, sturdier design and a substantial reduction in the number of internal seals and working parts. As a result, the disassembly, servicing and reassembly of the **Models *40E, 80*** and ***160E***, are easier than the **Model *35***.

The photos accompanying the following instructions were taken at the Recovery Engineering factory during an afternoon with Rob Lazore, a technician with the MROD* assembly and repair departments. The hands in the photos—and some of the good tips below—are his. Thanks, Rob! Any errors, of course, are mine.

Now it's time to dig in. Good luck!

Disassembly

The seal replacement procedure involves only the pump assembly, not the drive motor, gearcase, membrane, or system plumbing. The latter can be left in place. Before proceeding, I suggest turning the intake selector valve to its *alternate* position and running air through the watermaker until it no longer expels reject water. This will eliminate residual water pressure in the pump and make the disassembly job less messy.

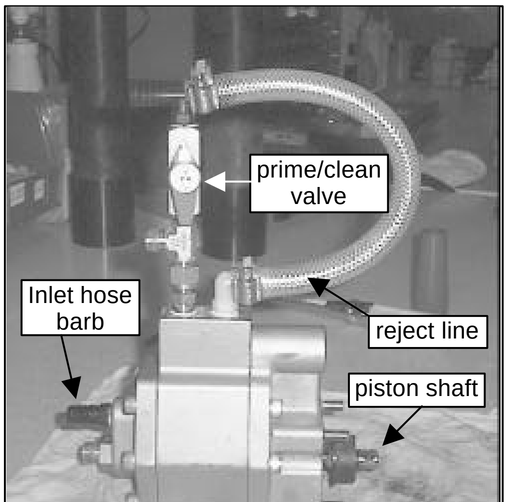

Figure C-1: Model 80E before disassembly

__Step 1__: ***Disconnect plumbing to watermaker pump***

Using the 11/16" wrench, disconnect the two high-pressure lines (coming from the membrane housing) at the pump check valve plate and at the prime/clean valve assembly. Depending on the model, these lines may be flexible hoses or rigid metal tubing.

Loosen the hose clamp and remove the plastic seawater intake hose from the check valve plate. Disconnect the plastic reject hose from the prime/clean assembly. This step will be slightly different in the *modular* vs. *enclosed* configurations, but the disconnect points should be obvious.

__Step 2__: ***Disconnect pump from drive assembly***

Use the 1/2" wrench to remove the four nuts holding the pump to the drive and motor assembly. Then pull the pump away from the drive unit to expose as much of the piston shaft as possible. Slide the rubber boot on the piston shaft toward the pump to expose the shaft connecting pin. Be careful that the pin doesn't fall out and get lost. It is not a press fit and should either fall out, or be easy to remove by pushing on it with a small screwdriver or allen wrench.

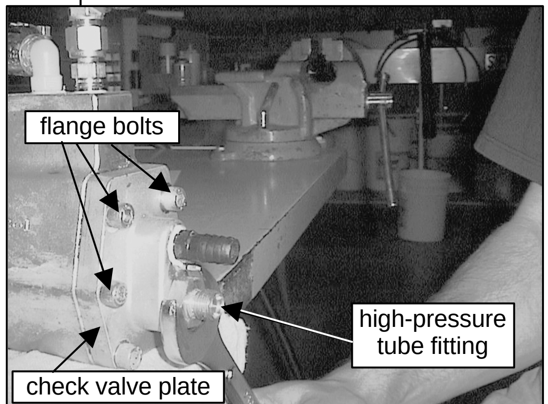

Figure C-2: Loosening large tube fitting

Occasionally, the drive shaft and connecting pin become rotated far enough that the connecting pin does not appear within the small access opening in the gearbox housing. In that case, after pulling the pump as far as possible away from the gearbox, rotate the pump or gearbox until the connecting pin appears in the opening and can be pushed out.

Once the four hex nuts and the drive shaft connecting pin have been removed, the pump unit should be removed to a clean work surface. See *Figure C-1*.

__Step 3__: ***Loosen the high-pressure tube fitting***

Before proceeding to the next step of dismantling the check valve plate from the pump body, use a 7/8" wrench to loosen the large, high-pressure tube fitting that is screwed into the check valve plate (see *Figure C-2*). It must be removed later to access the discharge poppet valve and it is easier to apply the necessary torque while the check valve plate is still bolted to the pump body. Loosening it after the check valve plate has been separated from the pump body is much more difficult.

* MROD: Marine Reverse Osmosis Device.

Step 4: ***Separate check valve plate from pump body***

Use the 1/4" allen wrench to remove the six flange bolts holding the check valve plate to the pump body (see *Figure C-3*). When the check valve plate separates from the pump body, remove the large o-ring seal between them.

Step 5: ***Remove intake check valve***

The *intake* check valve assembly is accessed from the inside of the check valve plate; i.e., the side that was facing the pump body. It is the valve assembly that is behind the plastic intake hose barb. You should note that "*Figure 36*" in current versions of the *Owner's Manual* for the ***Power-Survivor 80E*** incorrectly shows the *discharge* poppet valve assembly for this process.

If the intake valve retainer did not fall out when the check valve plate and pump body separated, lift it out of its cavity using the needle-nosed pliers. Beneath it, you should find a small spring and the poppet itself. Remove both of them.

At the very bottom of the intake valve cavity is the seat for the valve. It is a circular piece of plastic with an o-ring around its perimeter and it will remain pressed into the cavity. There are two methods for retrieving it:

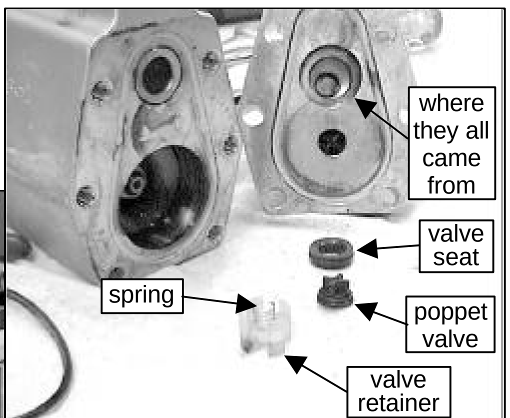

Figure C-4: *Intake poppet valve assembly removed*

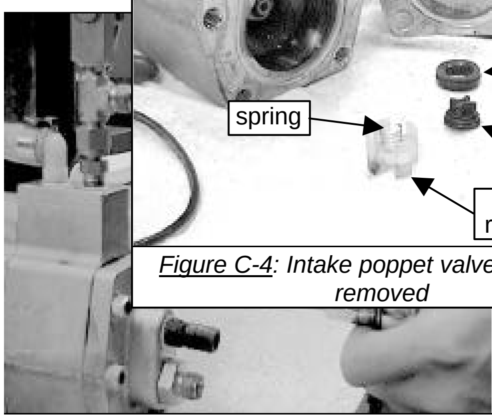

Figure C-3: *Removing check valve plate*

1. lower the head of a small machine screw into the cavity, hook the flat edge of the screwhead under the lip of the valve seat, and pull the seat straight up and out, or
2. remove the plastic hose barb for the seawater intake and push the seat out using a screwdriver blade from the barb side of the check valve plate

Either method should enable you to retrieve the intake valve seat. If you elect to access the seat by removing the intake hose barb, you can reinstall it later using some *Permatex*® non-hardening gasket sealer. When you have finished, you should have retrieved the parts shown in *Figure C-4*.

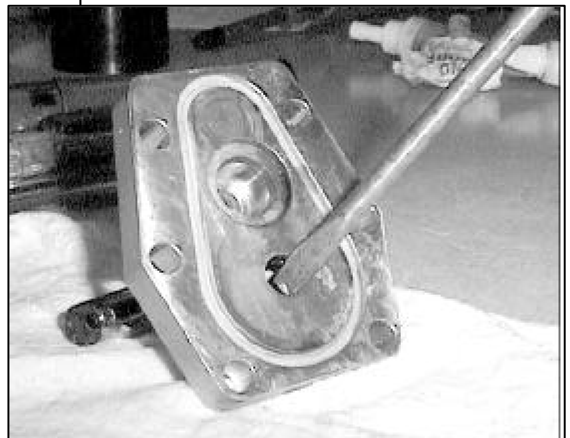

Figure C-5: *Removing discharge valve seat*

Step 6: ***Remove high-pressure tube fitting***

Now is the time to completely remove the high-pressure hose fitting on the outside of the check valve plate, next to the intake hose barb. You may need the 7/8" wrench. This is the large fitting that was loosened in **Step 3**. Underneath it is the discharge check valve assembly.

Step 7: ***Remove discharge check valve***

The parts comprising the discharge check valve assembly are identical to those in the intake valve assembly. Using the needle-nosed pliers, retrieve the valve retainer, the spring, and the poppet valve.

The valve seat can be removed using the same methods as for the intake valve assembly. Probably the easiest is to push it out through the bore in the inner face of the check valve plate using a screwdriver (see *Figure C-5*).

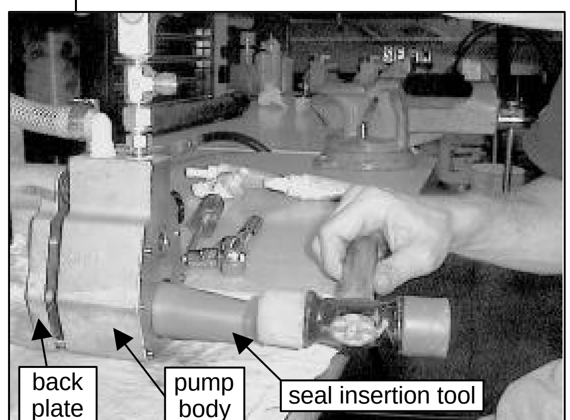

Figure C-6: *Separating back plate from pump body*

With both check valve assemblies removed, carefully inspect each of the valve springs for integrity. If either is broken or incomplete, try to locate the missing parts. The springs are a vulnerable component. If they break, broken pieces are likely to work their way into other areas of the pump and cause serious damage.

Step 8: ***Separate back plate from pump body***

Use the 1/4" allen wrench to remove the four flange bolts securing the pump back plate to the pump body. Then try to pull the back plate apart from the pump body. They may separate easily. If not, retrieve the piston seal insertion tool from the *Repair Seal Kit* bag. It is the large, tapered, hollow dowel among the seals. Using a soft mallet and the insertion tool, tap on the piston head to drive the back plate apart from the pump body, as illustrated in *Figure C-6*. This method is preferable to prying the back plate and pump body apart with screwdrivers, as suggested in the instruction sets for the older **Model *80***s.

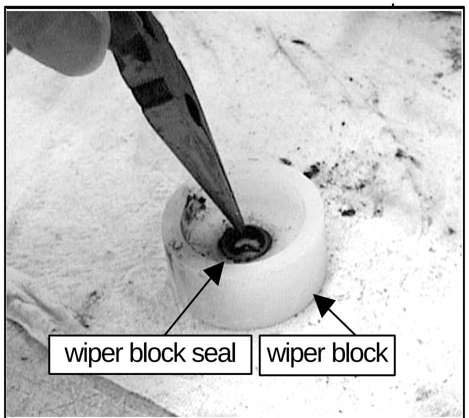

Figure C-7: Removing wiper block seal

After they have parted, remove the two o-rings (one large and one small) on the inside of the back plate and save them in your bag of used parts. Be careful not to lose the large spring for the pressure relief valve. Set the pump body aside.

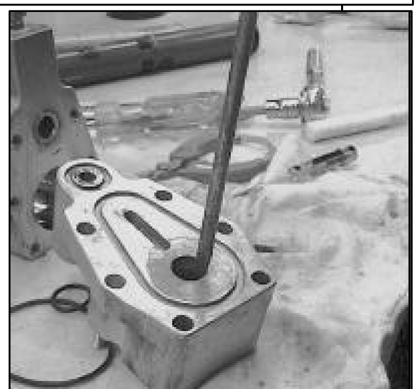

Figure C-8: Removing shaft seals

Older PUR instructions that accompany most **Model *80*** *Repair Seal Kits* caution the installer to save the large #31 o-rings for reuse during the reassembly procedure. Check your *Repair Seal Kit* carefully—there should be two #31 o-rings, one for each side of the pump body. Both should be replaced during a seal kit installation, and neither need be reused. Of course, you should save the seals in your used parts bag for emergency use. In most cases, all of them will still be usable.

Step 9: *Remove piston assembly*

Pull the piston out of the back plate. If necessary, tap the other end of the piston plunger rod to drive it past the seals in the back plate.

Step 10: *Remove piston cup and PIP ring seals*

Make certain you have replacement piston seals before performing the following procedure for removing the cup seal and PIP ring from the piston. The following procedure involves destroying the old seals.

If there are no replacement seals at hand, the old seals should be left in place. Attempting to remove them is likely to do more harm than good. Clean them, inspect them with a magnifying glass for wear or defects, and don't disturb them further until replacements can be obtained.

The easiest way to remove the cup seal and PIP ring from the piston is to squeeze the seal hard from one side of the piston, to form a slack loop on the other side. Use a small screwdriver or similar tool to wedge under the seal, if needed, and cut the seals with a small pair of scissors or a razor blade. Discard these damaged seals.

Step 11: *Remove plunger rod o-ring seal (not recommended)*

At this point in the disassembly process, the instruction sets with the *Repair Seal Kit* and the older **Model 80-II** *Service Manual* direct the installer to disassemble the piston from the plunger rod. This allows access to the small o-ring seal between the rod and the piston.

As a matter of fact, the o-ring seal seldom fails or needs replacement. More problems have been caused by improper reassembly of the piston and plunger rod than by a failed o-ring. Unless the watermaker has been malfunctioning and there is reason to suspect failure of the plunger rod o-ring, the piston and plunger rod should not be disassembled.

If it is necessary to take them apart, use a 7/16" socket wrench on the piston lock nut. Insert a drift pin or screwdriver through the coupling pin hole to hold the other end of the plunger rod. Loosen and remove the lock nut. Slide the piston off the plunger rod and remove the o-ring seal on the plunger rod.

Step 12: *Remove wiper block and seal*

Lift the large plastic wiper block out of the back plate cavity. Around the inner bore of the wiper plate will be a black seal. Grasp the inside lip of the seal with a pair of needle-nosed pliers and pull it out. See *Figure C-7*.

Step 13: *Remove plunger rod seals, washers and bushing*

Using a straight-blade screwdriver, reach through the plunger shaft hole on the pump side of the back plate. Align the screwdriver blade against the lip of the shaft washer, and push straight down. This should eject both shaft seals, both backup washers, and the bushing that are pressed into the back plate. See *Figures C-8* and *C-9*.

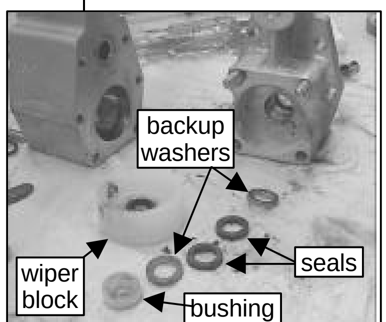

Figure C-9: Plunger rod seals

Step 14: *End of the disassembly*

Have a Pacifico! The basic disassembly of the watermaker pump unit has now been completed.

In the early ***PowerSurvivor 80-II*** *Service Manual*, an additional step directs the owner to remove the shuttle valve assembly in order to replace the o-rings on the spool sleeve. This is not a good idea. This step has been omitted from the *Repair Seal Kit* directions and the *Owner's Manual* for the **Model *80E***. The shuttle valve is a delicate mechanism and seldom needs servicing. It consists of an outer, hollow metal sleeve (with four o-rings) and a spool (shuttle) valve that slides inside the sleeve. The spool valve also has four o-rings and four seals. There is a slight taper to the valve and the o-rings are different sizes, although very similar. Reinstalling the shuttle valve with new o-rings is an error-prone operation.

Note that none of the o-rings for the shuttle valve assembly are included in the *Repair Seal Kit*. Do not remove the shuttle valve assembly unless you intend to install a *Spool Valve Kit* or a complete *Pump Rebuild Kit* and have the kit on hand. The latter kits are available as special options from PŪR. If these kits are ever ordered, special instructions should be obtained from PŪR on their installation.

Reassembly

Before beginning to assemble the watermaker pump, clean and carefully inspect all parts for wear and damage. This should be done with a magnifying glass, if possible. Pay particular attention to the o-rings and seals. Examine the plunger rod surface for scratches or nicks that could damage the shaft seals. Inspect the inside cylinder surface for smoothness.

Deposits of black sludge inside the pump are usually a mixture of silicon grease and pulverized rubber from the worn seals. Large amounts may indicate abnormal wear on nearby seals. However, a certain amount of black sludge should be expected, due to normal seal wear over time.

When all parts have been inspected and cleaned, break open a few ampoules of silicon grease (supplied with the *Repair Seal Kit*), identify and organize the new seals, and put the pump back together. It is assumed in the following instructions that all parts and seals will be lubricated before assembly. Be sure to use *only* silicon grease—do not use petroleum-based grease of any kind on the watermaker pump. Doing so will damage the RO membrane.

Step 1: ***Install discharge check valve in check valve plate***

Locate one of the check valve seats in the seal kit. Identify the side with the bevel on the lip of the center hole. Press this seat down into the discharge hole (the larger one) from the outside face of the check valve plate. Use your finger to push it all the way into the hole until you feel it bottom.

Next, lower one of the poppet valves into the valve seat. The poppet valve should have its "cross" side facing the valve seat and should settle flat into the valve seat. Lower a new poppet valve spring into the hole and position it in the recess in the center of the poppet valve. Finally, lower the white plastic check valve retainer into the hole, on top of the spring.

Screw the high-pressure tubing fitting into the hole finger-tight. You will tighten it later after securing the check valve plate to the pump body.

Step 2: ***Install intake check valve in check valve plate***

Repeat the sequence of operations given in **Step 1** to install the intake check valve components, which are identical to the discharge check valve parts. The valve for the intake circuit is installed from the inside face of the check valve plate (the side which faces the pump body) in the hole for the intake seawater. Again, be certain that the valve seat is installed with the beveled side facing the poppet valve (facing outward). The valves will not work if the seats are reversed.

Step 3: ***Install o-ring seal in check valve plate***

There have been two different o-rings used in the ***PowerSurvivor 80*** for the main seal between the check valve plate and the pump body. Very early models (serial #0854 and lower) used a different size than later models (serial #0855 and higher). Be sure you know which model you have. There are replacement o-rings included in the *Repair Seal Kit* for both models. If in doubt, compare the old one you removed to the new ones. The sizes are different enough to be obvious.

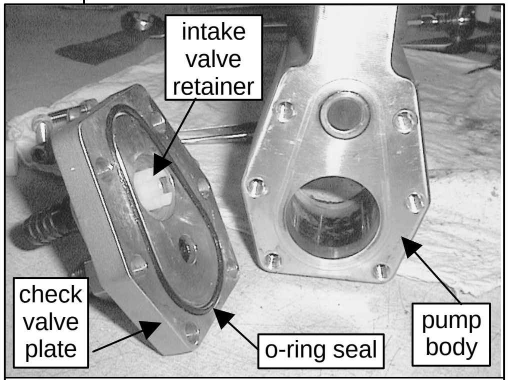

Figure C-10: Check valve plate and pump body prepared for reassembly

Once the correct o-ring has been identified, generously lubricate the large, pear-shaped o-ring groove in the check valve plate with silicon grease. Press the new o-ring into the groove. The object here is to have enough silicon grease in the groove to hold the o-ring in place while it is bolted to the pump body in the next step.

Step 4: ***Attach check valve plate to pump body***

During this step, don't let the intake check valve retainer fall out and be careful not to disturb the large o-ring. See *Figure C-10*.

Position the check valve plate against the pump body and screw in the six flange bolts finger-tight. When they've all been screwed in, check around the gap between the check valve plate and the pump body for any indication that the large o-ring has slipped out of its groove.

If the o-ring is still properly seated in its groove, tighten the flange bolts with the 1/4" allen wrench. Tighten each a little at a time, using an alternating sequence. The object is to draw the check valve plate against the pump body evenly and avoid squeezing the o-ring out of its groove on one side.

Use only moderate force during the final tightening round. The faces of the check valve plate and the pump body should appear to touch, but it is the o-ring that seals the joint, not the power in your wrist. If you have a torque wrench, tighten the flange bolts to about 120 in-lbs.* If not, tighten until the fasteners are "snug." Remember that the bolts and castings are stainless steel, which is a relatively soft metal. It is not too difficult to overtighten them and strip the threads. Then you have another kind of problem!

Step 5: *Reassemble the piston assembly (not recommended)*

If you disassembled the piston and plunger rod assembly in **Step 11** of the disassembly procedure, you should now rebuild it. If not, skip this step.

Clean the parts and lubricate everything with a thin coat of silicon grease. Install the new o-ring on the threaded end of the plunger rod and then slide the piston on. Clean any silicon grease off the plunger rod and *coat the machine threads on the end of the plunger rod with Loctite®*. Install the locknut (and washer, if your piston has one) finger-tight.

Using a drift pin or similar tool to hold the other end of the plunger rod, tighten the lock nut securely with the 7/16" socket wrench. You don't want this assembly to work loose. Read the instructions for the thread lock compound and allow adequate curing time before running the watermaker.

Step 6: *Install PIP ring and piston seal*

Even some Recovery Engineering factory technicians warn that this step is difficult. I've had no problems installing the PIP ring and piston seal using the following procedure:

Place the piston assembly on a firm, flat surface with the piston down and the plunger rod pointing up. Slide the insertion tool (supplied with the *Repair Seal Kit*) over the plunger rod with its wide end facing the piston. Thoroughly grease the outside surfaces and seal grooves on the piston with silicon grease. Also generously grease the outside surface of the insertion tool. This step is the key to having the seals slip easily down the tool.

Lubricate the PIP ring and piston seal with silicon grease. Slide the PIP ring over the insertion tool with the ribbed (non-smooth) side of the PIP ring *facing up*. Then slide the piston seal over the insertion tool with its ribbed side facing the PIP ring (i.e., *facing down*). Everything is now ready for the big push!

Referring to *Figure C-11*, use your fingers to press the PIP ring and piston seal on down the insertion tool, over the piston and into its groove. This will require a fair amount of force. If you have trouble, try pushing the seals part way down and then backing off, to get a feel for the force that is needed. You should observe that the purpose of the insertion tool is to spread the seals wide enough to slip over the outside perimeter of the piston. From there, it's an easy trip to snapping them into their seats in the groove.

The secret to success with this step is the lubrication of the seals, the piston, and the insertion tool with silicon grease. Take your time, do it right, and it'll happen. If you encounter difficulty, try installing the PIP ring and cup seal one at a time.

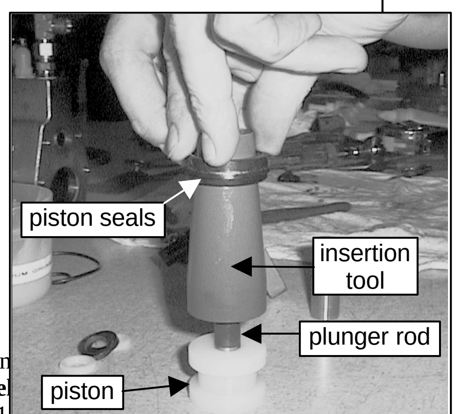

Figure C-11: Installing piston seals

Step 7: *Insert backup washer and plunger rod in back plate*

I deviate slightly from the factory directions for this step. To prevent possible nicking or scoring of the shaft seal bore when inserting the plunger rod, first press one of the new white plastic backup washers into the shaft bore from the outside of the back plate. Push it all the way into the bore until it bottoms.

Now insert the plunger rod into the pump back through the center of the previously installed backup washer. The washer will keep the plunger rod centered so it won't mar the inside of the shaft seal bore.

Step 8: *Install plunger shaft seals, backup washer and bushing*

Turn the back plate over so the piston is on the bottom and set it on a firm surface. The plunger shaft should be protruding upward out of the back plate. Since one of the backup washers was already installed during the previous step, we can proceed to installing the shaft seals.

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* Several torque values for these fasteners have been
Owner's Manual: 80-120 in-lbs. The older **Model**
80-150 in-lbs. A factory technician told me that 1
sounds like at least 120 in-lbs is about right—and

Note that the two shaft seals are identical and are flared outward on one side. Slide one of the seals onto the plunger shaft with its flared side facing down (toward the back plate). Then slide the second seal on, facing the same way (flared side down). Slide the insertion tool over the plunger rod with its narrow end toward the back plate. Carefully press both seals into the hole in the back plate until they are flush with the surface of the back plate. Installing the seals together avoids the possibility of creating an air pocket between them.

Slide the second backup and then the larger white bushing onto the plunger rod. Again slide the insertion tool over the plunger rod with its small end toward the back plate (see *Figure C-12*). Using a firm pressure, press the second backup washer and the bushing into the hole in the back plate with the insertion tool. Continue pressing them inward until the bushing is flush with the back plate surface. Remove the insertion tool.

Step 9: *Install wiper block and seal*

Pinch the new wiper block seal into an oval and work an edge into its seat in the bore in the wiper block. Once you have an edge into the groove, work the rest of the seal into the bore until it snaps into place. Slide the wiper block over the plunger shaft with the seal side facing up. It should slide easily into its cavity in the back plate.

Figure C-12: Insta

Figure C-13: Back plate and pump body ready for assembly

Step 10: *Install o-ring seals in back plate*

As with the o-ring for the check valve plate, early **Model *80*** watermakers used different sized o-rings in the back plate. One set of o-rings was used in units with serial #0854 and lower, and a different set for units with serial #0855 and higher. Both sets of o-rings are shipped with the **Model *80*** *Repair Seal Kit*.

Determine which seals your watermaker uses before proceeding. If in doubt, compare the new ones with the old o-rings you removed during the disassembly. They are different enough to be easily identified. For the back plate, two o-ring seals are used: a smaller diameter o-ring (#32) for the small, circular groove, and a much longer o-ring (#31) for the large, pear-shaped groove.

Generously lubricate the two o-ring grooves in the back plate with silicon grease. Apply enough grease to hold the o-rings in place during the assembly. Then press the two o-rings into their respective grooves. They should stick in place.

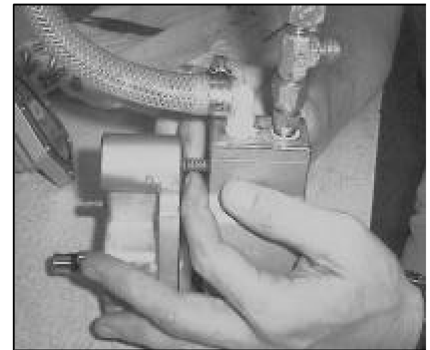

Figure C-14: Sliding back plate towa pump body

Step 11: *Attach back plate to pump body*

Be certain that the relief valve spring is still in position. It should be projecting out of the pump body facing the back plate. Also make sure the o-rings on the back plate remain in place.

Line up the mating sides of the pump body and the back plate (see *Figure C-13*). Gently guide the piston into the pump body. The piston seals and the cylinder walls in the pump body should be well lubricated with silicon grease.

After the piston has started into the pump body bore, carefully push the back plate against the pump body (see *Figure C-14*). Install the four flange bolts and bring them up finger-tight. Inspect the joint between the back plate and the pump body. Make sure the o-rings have not slipped out of their grooves.

Finally, tighten the flange bolts with the 1/4" allen wrench. Tighten each a little at a time, using an alternating sequence. As with installing the check valve plate, the object is to draw the back plate against the pump body evenly and avoid squeezing the o-rings out of their groove. Torque the bolts to about 120 in-lbs. If a torque wrench is available.* Otherwise, tighten them "snug." *Do not overtighten the flange bolts*.

Step 12: *Attach pump to gearbox*

If the seawater intake hose nipple was removed from the check valve plate for access to the intake valve seat during disassembly, reinstall it using a little *Permatex*® non-hardening (or similar) gasket sealant on the nipple threads.

Pull the pump plunger rod out of the back plate as far as it will come. Slide the black rubber boot over the plunger rod with its flat side toward

* I'm especially fond of the instruction for these bolts that is printed in the ***PowerSurvivor 80E*** *Owner's Manual*: '…If a torque wrench is used, tighten the Bolts until snug." That's straight from the horse's mouth.

the back plate. Line up the gearbox flange with the pump back plate and slide the gearbox drive shaft over the plunger rod. Adjust them until the coupling holes in the drive shaft and plunger rod line up. When they are aligned, insert the coupling pin into the hole and slide the black boot over the pin to hold it in place.

After the drive shaft is coupled to the piston plunger rod, push the pump body toward the gearbox. The four threaded rods projecting from the pump body should slide through the matching holes in the gearbox flange. Install the four hex nuts and tighten snugly. If a torque wrench is available, tighten these nuts to about 50 in-lbs.

Attach the two high-pressure lines to the pump. Reconnect the seawater intake and reject brine hoses. Finally, run the watermaker to check for leaks and proper operation. You're done!

A Parting Sermon

THIS SEEMS an appropriate place to pull out the soapbox and deliver a brief sermon on watermaker use and abuse. This book began as a personal quest for more information about the PŪR ***PowerSurvivor 35*** watermaker and potential problems with it. Over the course of two visits to the Recovery Engineering factory, three years of cruising, numerous seminars, and countless discussions with watermaker owners, I've come to the conclusion that most problems with watermakers—*all brands*—involve poor maintenance and/or misuse of the equipment. Since these are the same factors that cause problems in many other areas, I have a few general comments on the subject.

The mariner who refuses to take an active interest in how his or her equipment works (and, perhaps more importantly, how it can *fail* to work) is well advised to stay close to a home port or technical support. For such a skipper, venturing beyond readily available support facilities is an invitation to serious inconveniences and, possibly, disaster.

Each year, early in November, literally hundreds of boats leave the safety and modern conveniences of the west coast of the United States and Canada, headed for Mexico and points south. Many depart with plans to continue east through the Panama Canal or west to the South Pacific. Although I don't have accurate data to support my contention, I estimate that more than half of these vessels return home having never completed their projected itinerary and with no desire to make a second attempt.

The neophyte cruiser is often unaware that along with the "freedom, adventure and romance" of the cruising lifestyle goes an awesome measure of personal responsibility. A good friend of mine, a very experienced delivery captain, once commented: "They don't realize that cruising is hard work!"

My friend didn't mean that the rewards are not out there—if they weren't, very few of us would make that second trip or even keep going the first time. He meant that many first-time cruisers are blissfully ignorant of the wide range of practical skills and knowledge the cruising skipper needs in order to keep the vessel's support systems functioning. When things break or go wrong—and Murphy's Law assures us they will—the inexperienced mariner's "freedom" can become a prison, the "adventure" turn to travail, and the romance metamorphose into thoughts of divorce and selling (or even abandoning!) the boat at the earliest opportunity.

The reader should not misconstrue my comments as a diatribe against novice cruisers or skippers who decide to abandon the cruising life. There are many good reasons for not continuing—family emergencies, lack of funds, a desire to do other things. And even the most experienced skipper was a novice at one time or another.

My intention here is only to *identify*—not *condemn*—a specific type of personality or attitude. In short, if you are the kind of person who is accustomed to hiring (or asking) others to solve problems that are outside your particular area of expertise, *and you are unwilling to change that attitude*, it's unlikely you will succeed at, or have an enjoyable experience, being a cruiser.

I'm reminded of a story about a personnel manager at an engineering company. When conducting job interviews, he asked each candidate a simple question: "If your electric razor suddenly quit working one morning, what would you do—spend a few hours taking it apart to see how it works and if you could fix it, or would you walk down the street and buy a new one on sale?" Implicit in the interviewer's question is the fact that the cost of a new razor is considerably less than several hours' wages for an engineer at the company. Nevertheless, the engineer who admits he would "waste time" tearing into the broken razor is the one the personnel manager adds to his short list for the job. Most successful cruisers I've met are the kind who would tear apart their razor.

I've included these comments for a specific reason. As I stated in the first chapter of this book, there were some derogatory rumors about PŪR watermakers circulating within the cruising community a couple of years ago—rumors that peaked my curiosity about their source and validity. I also indicated that, as a result of my travels and inquiries, I discovered these rumors have their source in a few highly vocal individuals whose talent for complaining far surpasses their interest in the proper installation, use and maintenance of their watermakers. Not surprisingly, many of these individuals also have "problems" with their auxiliary engines, boat electrical systems, outboard engines, etc.

In summary, what I've found is that people who are not inclined to understand and maintain their equipment are typically the most adept at whining about their problems—and problems they surely have. For these individuals, projecting blame is much easier than seeking realistic solutions to challenging situations as (and *before*) they arise.

With that said, it's time to turn our attention to the kinds of problems the responsible owner of a ***PowerSurvivor*** watermaker is most likely to encounter, along with some general approaches to dealing with them. The following discussion—and, indeed, my comments throughout this book—are based on the premise that PŪR ***PowerSurvivor*** watermakers are, in fact, well-engineered products. If properly installed and maintained, they can reasonably be expected to give their owners many years of useful and trouble-free service.

Comments on Troubleshooting

Troubleshooting defective equipment is an acquired skill. To be successful at it requires *some* basic understanding of how the equipment operates, along with an ability to logically analyze what can be observed about that operation.

The best preparatory training available to the average owner of a ***PowerSurvivor*** watermaker is to perform a *Repair Seal Kit* installation, as documented in the PŪR manuals and this book. After performing this procedure at least once, you will have gained much valuable knowledge about the internal organization and operation of the watermaker. Perhaps more important is the self-confidence to be gained. Therefore, my first recommendation for those who really want to be able to keep their watermakers operating is: install a seal kit.

As I've indicated elsewhere, replacing the seals in your watermaker should be considered a regular maintenance task—something to be done after every 1000 hours of use, more or less. Resist the temptation to consider your watermaker a turn-key, install-it-and-forget-it, piece of equipment. It is not. It requires maintenance just like any other piece of mechanical equipment on a sea-going vessel.

Occasionally, despite the best efforts to properly install and maintain a watermaker, things will go wrong. Even the best of equipment can fail from time to time, regardless of the diligence of the owner. It is my goal in this section to familiarize the reader with some of the more common problems I've run into and offer some suggestions for diagnosing and dealing with them.

Armed with the knowledge and confidence you will gain from disassembling your watermaker, inspecting it, installing a seal kit, and reassembling the unit, you will be able to tackle most problems as they arise with reasonable expectations of success. Knowledge is power.

The Motor and Drive Assembly: There is little to go wrong with the motor and gearbox assembly. If the drive shaft is moving in and out and still coupled to the pump plunger rod, a problem is not likely to be associated with the motor or gearbox.

Unless you detect growling noises or other unusual sounds or symptoms directly associated with the gearbox, leave it alone. The only case of a defective gearbox I've run into was one which had been submerged in seawater for awhile as one result of a boating accident. In that case, the skipper had many other problems to deal with in addition to a damaged watermaker.

The electric drive motor also causes little trouble. The two most typical failure modes are non-operation and excessive current draw. If the motor doesn't run, even though there is 12 VDC power available at its electrical connections, the motor probably needs servicing. In this case, first try disconnecting the pump assembly from the drive unit slider shaft and again running the motor. If the slider shaft now works, the problem may be a stalled pump. If the slider still doesn't move, a defective motor or gearbox are the most likely culprits.

Excessive current draw is another kind of problem. The main symptom will usually be repeated tripping of the circuit breaker (or fuse) for the watermaker. If the circuit breaker trips immediately, i.e., as soon as it is turned on, the problem is acute. Eliminate the possibility of a short circuit in the wiring to the watermaker before condemning the motor. If the circuit breaker only trips after a period of running, the problem is more subtle. It may be the result of motor overload—perhaps a combination of restrictions in the intake line (e.g., dirty, plugged prefilter), higher than normal salinity, or a plugged membrane. If possible, use a DC ammeter to determine how much current is being used. The problem could also be a faulty circuit breaker. Obtaining a reading of the actual current being used will help eliminate the latter possibility and provide useful information if and when it becomes necessary to contact the manufacturer, vendor or other service provider.

After about 4000 hours of use, it would be a good idea to unscrew the brush caps (if your watermaker has them) holding the brushes in place and inspect the brushes. If they're getting short, have them replaced. This can usually be done locally by any competent electric motor service shop.

At the same time, inspect the motor commutator (the metal surfaces that the brushes press against) for wear, pitting or excessive carbon dust from the brushes. If you decide to replace the brushes, it would be wise to have the commutator serviced at the same time, although it will probably not be absolutely necessary. In any event, replacing the brushes and having the commutator cleaned should not be a very expensive project.

The new ***Endurance*** line of watermakers from PŪR (***40E***, ***80E***, ***160E***) have redesigned gearboxes which use a light gear oil instead of heavy grease. This oil should be changed at the same time a seal kit is installed, i.e., after about every 1000 hours of use. During this servicing, I recommend that the motor and drive unit be inspected for chipped paint. If necessary, use some standard enamel paint to touch up exposed metal areas on the motor and drive unit.

The Membrane: As vulnerable as it is, the membrane seldom causes problems unless it has been abused. Almost every damaged membrane I've seen has been the result of poor maintenance or mishandling.

A membrane's susceptibility to damage from certain kinds of contaminants (e.g., chlorine or petroleum products) has already been discussed, and adequate cautions are included in the owner's manuals. Most people I've met who have experienced this kind of problem have not bothered to read the manual and, therefore, are not likely to be buying and reading this book. There's little I can do for them, so I won't try.

There are instances, however, of accidental damage beyond the control of the responsible owner. These things happen. If the product water becomes salty, it *could* be the result of a damaged membrane, although the more likely cause would be a failed seal. The other failure mode possibly caused by a bad membrane is leaking of the over-pressure relief valve, which may indicate a plugged membrane.

If the latter situation arises (over-pressure valve relieving), try cleaning the membrane first with the alkaline and then the acid cleaner. Beyond this, the only reasonably certain way to determine if the membrane is the problem is to replace it with a known good one. If you carry an extra membrane with you, this is a simple solution. Swap out the membranes and see if the problem goes away. If it does, then reinstall the old membrane and see if the problem returns. If your tests clearly associate the problem with the membrane, you can be pretty sure you'll need to replace it.

Pump Failure Modes: I've already mentioned most of the problems that can occur with the pump itself. The usual symptoms are either a failure to produce product water, or leaking, or both.

If the watermaker quits producing product water but doesn't leak, the first step is to eliminate the possibility of an air leak in the intake plumbing. If it fails intermittently, especially if it only fails when you are underway, suspect an intake thruhull that is out of the water on a particular tack or in a rough seaway. If the intake is teed off of the intake to another piece of equipment, it could be getting air from the other plumbing. For example, if a manual seawater pump is plumbed into the same line, it is possible that air is being sucked in from the faucet opening, regardless of any check valve(s) that should be preventing this. Remember that it takes very little air in the watermaker to cause it to quit producing product water.

A good technique for determining whether the fault lies with the pump or the plumbing is to use a separate hose to temporarily feed the intake, thereby bypassing all of the intake circuit. Run the hose directly into a seawater source (e.g., a bucket of seawater). If the pump now works, look for the problem in the intake plumbing. If it still fails, turn your attention to the pump itself.

If there is evidence of leaking from the pump, there is definitely a problem with the pump itself. In some cases, the watermaker may leak and still produce product water. Nevertheless, a leak indicates a problem that should be addressed before it becomes more serious.

With the ***PowerSurvivor 35***, before tearing into the pump, examine the intake/reject hose barb assembly that connects to the pump at the manifold. This is a common source of leakage and air ingress. The latter can cause failure to produce product water by admitting air into the pump. Remove the hose barb assembly and check for damaged o-rings or deformation of the barbs, especially near the ends that are hidden within the manifold. Make sure there are no strains on the two hoses connected to the hose barbs. (Because of new designs, air ingress at the intake hose is less likely with the newer watermaker models.)

If the hose barb assembly and o-rings are in good condition, the next step is disassembly and careful inspection of the pump components, seals and o-rings. Follow the procedure described in the preceding chapters. Use a magnifying glass to examine the o-rings and seals. Be aware that flaws are sometimes small and not obvious. I've seen o-rings that looked normal until they were squeezed between two fingers to reveal a slit in the rubber. A small nick in an o-ring is sufficient to produce a substantial leak and cause the watermaker to fail.

Look for flaws in the pump body parts. Pay special attention to the inside surface of the cylinder (and the cylinder o-rings and backup seals in the Model 35), the piston seals, and the plunger rod seals. Is anything scored, chipped or cut? The poppet valve springs are known to be vulnerable. Are they whole and in good shape?

Field Parts Swapping: The tips I've mentioned up to this point are sufficient to troubleshoot most of the problems I've seen arise. On several occasions I've failed to identify the specific cause of a problem, but have returned the units to working order by replacing the seals. This is a category of problem and repair which experienced technicians sometimes refer to as “FM.” If it works, it ain’t broke!

What about a problem that isn’t fixed by installing a seal kit, and where no defective or damaged parts were found? This gets a little tougher. Frankly, there are two alternatives:

- Return the watermaker to the PŪR factory
- Swap pump parts with known good ones

Neither choice is an easy one. In the first case, returning a watermaker to the factory is often impractical or impossible for a cruiser. If it isn’t impractical for you, then do it, by all means.

If the first option won’t work, you are stuck with the second. To the extent that you already possess major replacement parts for your watermaker, you can proceed. However, most cruisers do not carry a spare manifold, pump piston and body parts, membrane, etc. What is really needed is a second watermaker in known good condition.

Used ***PowerSurvivor 35*** watermakers in good condition can sometimes be purchased at marina swap meets and marine used equipment stores, usually at quite reasonable prices. The long-range cruiser with this model of watermaker should seriously consider buying one for backup parts. Redundancy of critical equipment is not exactly a new idea.

Lacking the components or a second watermaker, the last resort is another cruiser. If you are lucky enough to meet another cruiser in the fleet with the same model of ***PowerSurvivor***—someone who is familiar with the disassembly procedure and not afraid to swap parts—you could exchange components in a patient effort to isolate the problem to the lowest possible level of sub-assembly. Realistically, however, finding someone who would be willing to let their installed and functioning watermaker be disassembled to troubleshoot another unit may be expecting too much. On the other hand, it never hurts to inquire.

I’ve used this troubleshooting procedure with good results many times. I use my own watermaker as a source of known good parts and swap them out with a defective unit, one assembly at a time. For example, if servicing a **Model** ***35***, I would swap manifolds and then test run each of the watermakers. The next exchange might be pump body backs, or membranes and housings.

I continue with the swapping until the “problem” is transferred to my good watermaker and disappears in the defective unit. Then I’ve isolated the problem to a sub-assembly—an important step. Individual parts of the sub-assembly can then be examined and/or swapped in a further attempt to identify the cause of the failure. At worst, this technique identifies a replaceable component, which can be ordered from the factory or the nearest repair facility. That’s a lot better than having to ship the whole watermaker to and from the factory. Good luck!

My own most trying instance of using the swapping technique involved a ***PowerSurvivor 35*** watermaker that leaked and did not develop enough pressure to produce product water. A seal kit job didn’t reveal or solve anything. I began swapping components from my own watermaker. I finally isolated the problem to the pump back body, which *looked* just fine, but simply failed to work with either watermaker. The whole process took most of an entire day—I completely disassembled and reassembled both watermakers seven times! Since I had a spare pump back body, I installed the new one and the unit was returned to service. The owner was extremely grateful. We shared a couple of Pacificos.

The TDS Meter

As mentioned in an earlier chapter, PŪR has discontinued their automated salinity monitor/solenoid valve approach to routing product water. Instead, they now ship a hand-held TDS meter with their watermakers, leaving it to the user to manually monitor the salinity of the product water and route it to an appropriate storage location. Personally, I consider this a major improvement, for reasons cited in my comments on routing product water.

Although using a TDS meter to assess the quality of product water is a more reliable method than earlier automated systems, it has its limitations. The user needs to be aware of how a TDS meter works and, more importantly, what it does *not* do.

How a TDS Meter Works: “TDS” is an abbreviation for *Total Dissolved Solids*. Unfortunately, this name is very misleading. From the name alone, it would be natural to assume that the meter provides a measurement of all the solids that are dissolved in a sample of water. This is not the case. To better understand what a TDS meter really does, we need a little knowledge of basic chemistry. To avoid getting too complicated, we’ll limit the discussion to a single solvent material, water, and two common soluble materials, table salt and sugar.

When a solid substance dissolves, the atoms of the solvent “attack” the molecules of the solid material and break them apart into single atoms or molecules that gradually disperse throughout the solvent, eventually producing a homogeneous “solution”.

Solid substances dissolve in different ways, depending on the kinds of chemical bonds that hold the molecules of the substance together. For example, each molecule of table salt (NaCl) is composed of one atom of sodium bonded to one atom of chlorine. When table salt is dissolved in water, the sodium and chlorine atoms are separated from one another. Of particular importance to our discussion, the sodium and chlorine atoms have equal—but opposite—electrical charges on them. The sodium atom has a positive charge and the chlorine atom is negatively charged. These oppositely charged atoms in the salt solution are called "ions".

By way of contrast, sugar molecules remain intact as complete sugar molecules when they dissolve. They do not break down into their constituent atoms or ions. When sugar molecules are dissolved in water, they have no overall electrical charge on them; i.e., they are electrically neutral.

Now we have enough background chemical theory to understand how a TDS meter works. If you examine the end of the TDS meter that is inserted into the water, you will see two metal probes with a small gap between them. When the meter switch is turned on, a small voltage from the battery inside the meter is applied across the two probes. The water completes the electric circuit and a small amount of current flows through the water between the probes. The digital display at the other end of the TDS meter provides a numeric readout, which is nothing more than a measure of the "conductivity" of the water; i.e., how much current is flowing through the water.

Pure water is a very poor conductor of electricity and will produce a very low reading on the meter. Ions, on the other hand, are electrically charged particles and excellent conductors of electric current. The amount of current that will flow through the water sample is directly proportional to the number of ions dissolved in the water.

At this point, it should be clear that the TDS meter provides a measurement of the level of ions present in the water sample. Since dissolved salt consists of ions, a TDS meter does an excellent job of indicating how much dissolved salt is present in a water sample. That's all it does!

Limitations of a TDS Meter: We've learned that a TDS meter provides an accurate measurement of the quantity of ions in a water sample. In general, this is quite useful for testing the product water from an RO watermaker with "clean, open ocean seawater" as an input source. There is, however, a widespread misconception that a TDS meter provides a measurement of the level of *total contaminants* in the sample water. This is absolutely wrong and, in certain circumstances, could lead to a false sense of security. There are two edges to this sword.

First, a TDS meter will record *any* substances that separate into ions in solution. This includes acids (muriatic acid, battery acid, vinegar, oxalic acid), bases (lye, potash, cigarette ashes), and other soluble salts (baking soda, nitrates, sodium metabisulfite).

The second conclusion is the more alarming: a TDS meter will give *no indication whatsoever of any substances that do not disassociate into ions when dissolved*. This includes a vast array of interesting materials and chemicals; e.g., sugar, starches, alcohols, chlorinated hydrocarbons, petroleum products and byproducts. In particular, *it will not indicate the presence of bacteria and viruses*.

A Useful Experiment: You needn't take my word about this. In fact, I encourage readers to perform their own "Dr. Science" experiment. Obtain a glassful of product water from a watermaker. Use a TDS meter to get a baseline reading for the sample. Then add a pinch of sugar to the water and stir it up with an uncontaminated chopstick until it is dissolved. Take a second reading. You should see no change in the readout. Next, simulate the presence of a lethal dose of toxic bacteria by adding a pinch of bread yeast. Again, stir the sample water and take a reading. Again, there should be no change. Finally, just to convince yourself that the TDS meter is still working, add a slight pinch of table salt. The reading should double, more or less, depending on the size of the pinch.

Guideline Readings for Potable Water: Now that we have an understanding of how a TDS meter works, and what it can and can not do, it would be useful to know what kind of readings to expect when testing the product water from a watermaker processing "uncontaminated" seawater. A little simple arithmetic is all we need:

A typical sample of "open-ocean seawater" contains approximately 3% salt. This is equivalent to 3 parts per 100, or 30,000 ppm (parts per million). PŪR specifications for their watermakers claim a 98% rejection rate. This means that the product water will still contain about 2% of the salt that was originally present; i.e., 2% of 30,000 ppm. Multiplying 0.02 (2%) times 30,000 ppm gives us 600 ppm. Therefore, any TDS meter reading of 600 or less for product water will mean that the water sample falls within the claims of the PŪR specifications.

In fact, the TDS meter readings I've obtained from numerous tests of several different ***PowerSurvivor*** watermakers have ranged from 150 to about 400. Slightly higher readings should be expected if the intake water is higher than average salinity.

Recommended Spare Parts

The standard seal kit provided by PŪR contains all the components necessary for regular seal maintenance of the ***PowerSurvivor*** watermakers. In addition, replacing the seals is often all that is needed to repair many of the most common problems that can arise. Nevertheless, the owner who expects to be spending much time in remote locations, far from access to the factory or a warranty repair station, needs to consider a wider range of potential problems and plan ahead for some of the less common failures that can occur.

To address this need, I suggest purchasing and carrying on board the following additional spare parts. You may never need them but, if and when you do, you'll be glad you included them in the ship's stores.

Several of the following parts are not listed in PŪR's standard parts/price list. Therefore, I cannot at this time provide either part numbers or retail prices. It is also unlikely that most warranty repair stations would stock some of these parts as discrete items.

If you decide to purchase these parts, I suggest you call the factory direct. Ask for the MROD (Marine Reverse Osmosis Device) Product Manager. Tell him you're interested in "*ISHI's Super-Extended Cruising Kit*," and he'll take care of you.

Membrane
Membrane brine seal
Piston
Cylinder (PS 35)
Pressure relief valve o-ring (PS 35)
Prefilter housing o-ring
Spare set of electric motor brushes
Intake/reject hose barb assembly (PS 35)

In the meantime, I wish you fair winds and pleasant sailing (I don't particularly like "following seas"). I hope to see you somewhere down the line.

I've included in this *Appendix* an assortment of tables and information of possible use to owners of watermakers and those interested in the general subject of reverse osmosis desalinators.

Drinking Water Contaminants: The *Safe Drinking Water Act of 1974* contains some important information on known harmful contaminants of water. Of special concern is information about those substances which reverse osmosis is *ineffective* at removing. **Table A-1** is a list of some relatively common contaminants and **Table A-2** lists some common organic chemicals. **Table A-3** lists some typical inorganic contaminants. This information was obtained from various Internet sites after a search on the term "reverse osmosis." Much more is available on the net. The author has no way to assure the accuracy of the information in these tables. Use them only as a general guide to indicate when further information should be obtained.

Table A-1: Partial List of Pesticides, PCBs and Semivolatile Synthetic Organic Contaminants

Maximum Contaminant Levels (**MCL**), MCL Goals (**MCLG**) and Best Available Technology (**BAT**) Treatment Techniques.

Contaminant	MCL mg/l	MCLG mg/l	BAT*
Acrylamide	TT	0	
Alachlor	0.002	0	GAC
Aldicarb sulfoxide	0.004	0.001	GAC
Aldicarb sulfone	0.002	0.001	GAC
Aldicarb	0.003	0.001	GAC
Atrazine	0.003	0.003	GAC
Benzo[a]pyrene (PAHs)	0.0002	0	GAC
Carbofuran	0.04	0.04	GAC
Chlordane	0.002	0	GAC
2,4-D	0.07	0.07	GAC
Dalapon	0.2	0.2	GAC
Di(2-ethylhexyl) phthalate	0.006	0	GAC
Di(2-ethylhexyl) adipate	0.4	0.4	GAC,PTA
Dibromochloropropane	0.0002	0	GAC,PTA
Dinoseb	0.007	0.007	GAC
Diquat	0.02	0.02	GAC
Endothall	0.1	0.1	GAC
Endrin	0.002	0.002	GAC
Epichlorohydrin	TT	0	
Ethylene dibromide	0.00005	0	GAC,PTA
Glyphosate	0.7	0.7	OX
Heptachlor	0.0004	0	GAC
Heptachlor epoxide	0.0002	0	GAC
Hexachlorocyclopentadiene	0.05	0.05	GAC,PTA
Hexachlorobenzene	0.001	0	GAC
Lindane	0.0002	0.0002	GAC
Methoxychlor	0.04	0.04	GAC
Oxamyl (Vydate)	0.2	0.2	GAC
Pentachlorophenol	0.001	0	GAC
Picloram	0.5	0.5	GAC
Polychlorinated biphenyls	0.0005	0	GAC
Simazine	0.004	0.004	GAC
2,3,7,8-TCDD (Dioxin)	3x10-8	0	GAC
Toxaphene	0.003	0	GAC
2,4,5-TP (Silvex)	0.05	0.05	GAC

Notes:* Granular activated carbon (GAC), packed tower aeration (PTA), or oxidation (OX). TT = Treatment Technique required

Table A-2: Some Organic Contaminants

Maximum Contaminant Levels (MCL), MCL Goals (MCLG) and Best Available Technology (BAT) Treatment Techniques.

Contaminants	MCL (mg/l)	MCLG (mg/l)	BAT*
Benzene	0.005	0	GAC, PTA
Carbon tetrachloride	0.005	0	GAC
cis-1,2-Dichloroethylene	0.07	0.07	GAC, PTA
1,1-Dichloroethylene	0.007	0.007	GAC, PTA
1,2-Dichloroethane	0.005	0	GAC, PTA
Dichloromethane	0.005	0	PTA
1,2-Dichloropropane	0.005	0	GAC, PTA
Ethylbenzene	7	.7	GAC, PTA
Monochlorobenzene	0.1	0.1	GAC, PTA
o-Dichlorobenzene	0.6	0.6	GAC, PTA
para-Dichlorobenzene	0.075	0.075	GAC, PTA
Styrene	0.1	0.1	GAC, PTA
Tetrachloroethylene	0.005	0	GAC, PTA
Toluene	1	1	GAC, PTA
trans-1,2-Dichloroethylene	0.1	0.1	GAC, PTA
1,2,4-Trichlorobenzene	0.07	0.07	GAC, PTA
1,1,2-Trichloroethane	0.005	0.003	GAC, PTA
1,1,1-Trichloroethane	0.2	0.2	GAC, PTA
Trichloroethylene	0.005	0	GAC, PTA
Total Trihalomethanes (for disinfectant residuals)	0.1	0	PTA
Vinyl chloride	0.002	0	PTA
Xylenes (total)	10	10	GAC, PTA

* Granular activated carbon (GAC), packed tower aeration (PTA)

Note that reverse osmosis is considered a "Best Available Technology" for the removal of many of the *inorganic* chemicals in **Table A-3**. In contrast, RO is *not* listed as a technology for *any* of the *organic* chemicals. In most cases, activated carbon is the preferred technology. Many of the organic chemicals contain halogens (chlorine, fluorine, bromine and iodine) and other components that will quickly damage RO membranes.

Table A-3: Maximum Contaminant Levels for Some Inorganic Chemicals

Maximum Contaminant Levels (MCL), Maximum Contaminant Level Goals (MCLG) and Best Available Technology (BAT) treatment techniques.

Contaminant	MCL (mg/l)	MCLG (mg/l)	BAT
Antimony	0.0006	0.006	**RO**/CO/FT
Arsenic		0.05*	
Asbestos	7 Million Fibers/liter(>10 mm)	7 Million	CO/FT Direct and Diatomite FT/ Corrosion Control
Barium	2	2	**RO**/IE/LS/ED
Beryllium	0.004	0.004	**RO**/Activated Alumina/CO/FT/IE/LS
Cadmium	0.005	0.005	**RO**/CO/FT/IE/LS
Chromium	0.1	0.1	**RO**/CO/FT/IE/LS (BAT for Cr III Only)
Cyanide (as free Cyanide)	0.2	0.2	**RO**/IE/Chlorine
Fluoride	4	4.0	
Mercury (Hg)	0.002	0.002	**RO**/CO/FT/GAC/LS †
Nickel	0.1	0.1	
Nitrate	10 ‡	10 ‡	**RO**/IE/ED
Nitrite	1 ‡	1 ‡	**RO**/IE
Total Nitrate and Nitrite (as Nitrogen)	10	10	(see Nitrate and Nitrite)
Selenium	0.05	0.05	**RO**/Activated Alumina CO FT (BAT for Selenium IV Only/LS/ED
Sulfate**	400/500	400/500	
Thallium	0.002	0.0005	Activated Alumina/IE/Turbidity/TT

Notes: TT = Treatment Technique required; LS = Lime Softening; **RO** = Reverse Osmosis; IE = Ion Exchange; CO = Coagulation; FT = Filtration; ED = Electrodialysis; GAC = Granular Activated Carbon;

* The maximum contaminant level for arsenic applies only to community water systems. ** Proposed stan-

Data on permissible levels of exposure to various kinds of radiation and other, more exotic, types of contaminants may also be found on the World Wide Web. Use search engines on "reverse osmosis" and "desalination." Not surprisingly, much of the available research material has its sources in middle-eastern countries.

The reader should also be aware that new chemicals are created daily and microbes are constantly evolving. Laurie Garrett's excellent book, *The Coming Plague*, documents many new types of viruses and bacteria that have emerged within recent decades, including HIV, dengue fever, and ebola. She also discusses new, resistant strains of traditional threats like TB, malaria, Hanta virus, and e-coli. Some of the new strains of microbes are resistant to traditional purification techniques, including chlorine exposure, boiling water and ultra-violet light exposure.

Recovery Engineering, Inc.: Just for the record, here is a list of information about Recovery Engineering, Inc., that might be of use to the owner of a PŪR ***PowerSurvivor*** watermaker.

PŪR *is a Division of*

Recovery Engineering, Inc.
9300 North 75th Avenue
Minneapolis, Minnesota 55428

Phone: (612) 315-5500

800: (800) PUR-LINE (787-5463)

Fax: (612) 315-5505

MROD Product Manager:

Nate Mueller (800) 845-7873 Ext. 5561

Watermaker Specifications: Here is a table comparing the relative sizes, output and requirements of the PŪR ***PowerSurvivor*** watermakers, including the discontinued **Model *35***. All specifications are for modular configurations using 12 VDC. 24 VDC and enclosed models are also available. Salt rejection is 98.4% typical, 96% minimum for all models. The dimensions for the **Models *80E*** and ***160E*** are for the pump and drive assemblies only. Dimensions of the prefilter assembly are the same for all models: 12" H x 6" dia. The **Model *80E*** membrane module measures 31" L x 2.5" dia. The **Model *160E*** membrane module measures 25" L x 3.5" dia. Take all the dimension specifications with a grain of salt. Recovery Engineering publishes slightly different numbers in various brochures and documentation. All data is from published specifications, not from actual measurements.

Table A-4: Specifications for *PowerSurvivor* Watermakers

Model	35	40E	80E	160E
Power req'd (amps)	4	4	8	16-21
Output/hr. (gals.) ±15%	1.4	1.5	3.4	6.7
Feedwater flow (gal/hr.)	15	20	34	80
Pump length (in.)	26.25	16.5	16	17.5
Pump width (in.)	14.75	15.5	14	13.5
Pump height (in.)	5.75	6.75	6	6

Pump weight (lbs.)	21	25	34	36
Construction, pump body	plastic	316 SS	316 SS	316 SS

Membrane Data: Information from PŪR on the performance characteristics of their reverse osmosis membranes is not, to my knowledge, published elsewhere. Here are the general operating specifications for all of their RO membranes:

Membrane Type	thin-film composite polyamide
Maximum operating pressure	1000 psi (6.8 MPa)
Maximum operating temperature	113ºF (45ºC)
Free chlorine tolerance	< 0.1 ppm
pH range, continuous operation	2–11
pH range, short term (30 min.), cleaning	1–12

Rejection Rates: Here is a short list of some common chemicals, their molecular weight, and their rejection rate (in %) by the reverse osmosis membranes used in ***PowerSurvivor*** watermakers.

Here's an example of using the rejection rate table. From the table, the rejection rate for sodium chloride (NaCl) is 98%. If a solution is normal seawater, it will contain about 32,000 ppm NaCl. The membrane will remove 98%, allowing only 2% (640 ppm) of the salt to pass through with the product water.

Table A-5: A Selection of Molecular Weights and Rejection Rates

Solute	***Molecular Weight***	***% Rejection***
Sodium fluoride (NaF)	42	98
Sodium cyanide (NaCN: pH 11)	49	97
Sodium chloride (NaCl)	58	98
Silica (SiO_2: 50 ppm)	60	98
Sodium bicarbonate ($NaHCO_3$)	84	98
Sodium nitrate (($NaNO_3$)	85	93
Magnesium chloride ($MgCl_2$)	95	98
Calcium chloride ($CaCl_2$)	111	99
Magnesium sulfate ($MgSO_4$)	120	99
Nickel sulfate ($NiSO_4$)	155	99
Copper sulfate ($CuSO_4$)	160	99
Formaldehyde	30	35
Methanol	32	25
Ethanol	46	70
Isopropanol	60	90
Urea	60	70
Lactic acid (pH 2)	90	94
Lactic acid (pH 5)	90	99
Glucose	180	98
Sucrose	342	99
Chlorinated pesticides (traces)	—	99

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