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Modular desalting for specialized applications

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Abstract

In this paper, we consider the uses of modular containerized desalination facilities in both emergency and temporary applications in remote and populated areas. These types of systems, while not new to the marketplace, are rapidly gaining prominence for numerous system designs by those wishing rapid deployment of complete units. With the considerations of the military and emergency management organizations forming some paramount reasons for this section of the industry, these sea or land transportable system designs are also highly useful for the temporary needs of the construction industry. The need for purified water for construction personnel as well as building material support may seem unrealistic, but the rise in projects in remote areas or areas without existing water supplies has given credence to these designs. These all-inclusive self-contained units can be quickly and economically erected on various types of sites, with only a water source and available power necessary for their function. Various designs and their implementation will be discussed, with modular pre-treatment and post-treatment options examined. Also, the modular approach to larger scale facilities will be addressed. Storage and transfer modules to contain and distribute the product of these systems will be featured as well. The usage of sophisticated control systems with modem capability, both cellular and land based, will be referred to in systems designed for use in remote areas. These systems might include a modular power generation unit as well as the water treatment modules to allow for a complete, stand alone system. Also, a design proposal for systems capable of handling many different qualities of feed water will be presented as a "universal" modular system. This type of system could be installed in any location, regardless of the feed water quality, and function to provide potable water for a short-term situation.

Keywords: Desalination; Modular design

1. Modular definition

The very nature of the desalting field makes most systems, especially with membrane desalting applications, quite modular in nature. However, what we are using as a definition for this dissertation are systems that can be presented as containerized "modules" that may be easily transported and installed.

The most unusual of these systems is the highly specialized military application of this technology. The ROWPU (reverse osmosis

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water purification unit), built to the specifications of the US and Canadian Armed Forces, is a self-contained unit utilizing membrane technology. This unit has the following specifications [1]:

Description and use: The reverse osmosis water purification unit (ROWPU) is an advanced water treatment system capable of purifying any water source found in the world including contamination in fresh or salt water.

Dimensions:
- length 5.85 m
- width 2.28 m
- height 2.15 m
- weight – 8.6 t (including tools and spares).

Characteristics:
- Pure water extraction employing reverse osmosis in either a single-pass (using one membrane bank) or double-pass mode (using two membrane banks) depending on the type of water being purified.
- Two-stage pre-treatment provided by a 50-micron self-cleaning filter and a 5-micron cartridge filter
- Post-treatment by chlorination. The ROWPU has its own generator (The unit can also be hooked up to an external power source.)

Production rates:
- 5,000 l/h (at 8°C water temperature) in single-pass mode and 2,400 l/h in double-pass mode.
- Raw water intake is approximately 10,000 l/h.
- Daily production: 20 h operation/d and 4 h for maintenance.
- Water Supply Detachment composed of three field engineers trained in advanced water supply or technicians specialized in water or fuel/environment.

Water distribution:
- In bulk to units on military operations
- In bags (if a water bagger is available)

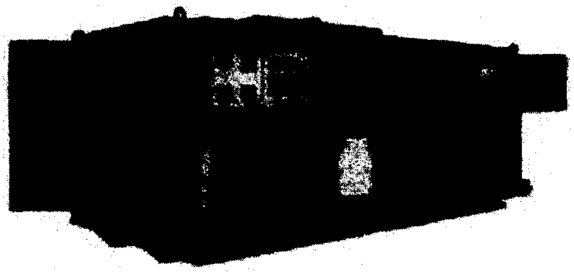

Fig. 1. Reverse osmosis water purification unit.

Operating temperature ranges:
- Air temperature –40°C to 49°C
- Water temperature 3°C to 40°C

Transport: Transportable by road, air, sea or rail. The ROWPU will fit into a 20-ft ISO (International Standards Organization) container for worldwide handling, a prerequisite for peacekeeping operations. The ROWPU is carried by a truck equipped with a palletized load system (see Fig. 1).

Cost: $10.8 million for 22 units and spares

There are also containerized SWRO units available commercially that are not as specialized. These are normally available in several sizes ranging from 250 to 1000 m^3/d permeate production. They only include the reverse osmosis equipment and minimal pre-treatment (5 micron filter), but have the advantage of being easily transported and rapidly installed. From arrival of the equipment on site to full operation can often be less than two (2) days. Shown here is a 500 m^3/d unit available form a manufacturer in Denmark (see Fig. 2).

This particular unit has the advantage of using a very advanced pump and energy recovery technology. This allows for the more compact design to fit into a standard 40’ sea container. For some water sources, though, this may require more extensive pre-treatment equipment.

Fig. 2. 500 m^3/d SWRO unit.

2. The needs of the few....

What types of applications would mandate the use of these systems? The most popular applications at present are connected to the tourist industry. The rapid growth of seaside resorts in numerous areas is presenting challenges to the constructors of hotels and auxiliary facilities. Issues regarding capital costs, space allocations, fast track projects, and temporary water necessities are in the forefront of the architect's and engineer's minds.

Many desirable sites for these facilities are well away from nominal "civilization", and these locales are often without power, usable construction water, and potable water for the labor force. And, as with most projects designed to present a profit, time is always of the essence.

Even the heavy construction and mining industries can benefit from such systems. When constructing a mining facility, say, in the mountains of Chile, the need for temporary potable water facilities was paramount for a work force at a remote location 10,000+ ft above sea level. The only water source was highly brackish with high turbidity from the ambient (desert) conditions. Such a temporary system was used during the 18-month construction of the main facility, which included a membrane process demineralizer system with a potable side stream.

Many systems of this design are using "state of the art" control and communications protocols, allowing remote access to the systems while running to monitor process changes and anticipate systems problems. With the advances in cellular and satellite technology, it may well be possible to uplink to a system no matter what the location.

3. Design advantages

These modular systems show definite design advantages as well. The most significant of these is the minimal civil work necessary to install these modules. While a concrete slab would be a nice enhancement, these systems can be placed on any level and stable surface. There are really no buildings necessary to construct, as the "building" already comes with the system. And when you figure in building costs at near \$100/ft^2 [2] even a modest size building, if not constructed, results in tremendous savings (see Fig. 3).

Labor costs are also minimized. The fabrication of the system can be completed in the factory, with less expensive labor rates than field installation. And installation in the field is so simple that in some cases the systems are set in place, connected to water lines in and out, connected to an electrical supply, and commissioned in the same day.

Another advantage is the "point of use" theory. In some Mediterranean locations, the cost of installing distribution lines through the often-rocky underground structure can be very high. Some water suppliers have opted for the installation of modular systems directly where they are needed, tapping into existing smaller distribution locations without the necessity of lengthy connection lines.

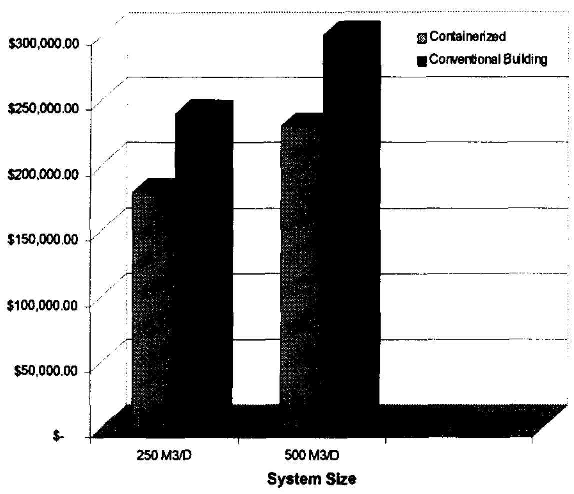

Fig. 3. Comparison costs.

The long-term value of a desalination system [3] has become an issue over the last several years. Once a large system is installed in a civil structure, the potential for removal and resale of the system, should it become necessary, is limited. Some brackish systems, for example, have lost 50% or more of their value by being decommissioned and resold in this fashion. However, the "mobile" nature of the modular system makes the inherent value of the system greater for resale, should circumstances warrant.

A company in Spain, which specializes in these systems, actually makes a large percentage of their profits from doing exactly that. In an area of expanded growth due to the tourist industry, they will remove an undersized module, replace it with a larger system, and then resell the first module to another consumer with lesser production needs. Some of the modules have been in three to four different locations, over a three-year period. The end-users get what they want at reasonable prices, the equipment gets full utilization over its lifetime, and there is profitability for all involved.

Several manufacturers of these containerized SWRO systems have added a further advantage: significant power savings. Using the most recent innovations in concentrate energy recovery, energy required for potable production has dropped to under 3 kWh/m^3. These ER devices [4], compact in nature, are coupled with multistage centrifugal pumping units to reduce the physical size of the components and increase the potential for their use in a containerized system.

4. A complete package

Taking the best design elements of both the ROWPU and commercial modular plants, it is possible to synthesize a multiple container-based system which addresses nearly all the needs of a small hotel based system. Such a systems could be transported to the site via sea, rail, and/or truck and be in place and functioning within a week.

This SWRO system, sized for 250 m^3/d production at 35% recovery, utilizes four standard 20' sea containers to house power generation, pre-treatment, seawater reverse osmosis, post treatment and storage. There is even a bit of room left for spare parts storage (see Fig. 4).

What makes this design special is the use of an integrated UF/SWRO (patent pending) that utilizes hollow fiber UF membrane technology for pre-treatment of the RO process. This particular membrane design of European manufacture is a dead-end flow design, with backwash from the filtrate side to the feed. This design, with a relatively low head loss across the membrane, uses the pressure from the feed source pump to drive through the membrane to the filtrate side and directly feed the SWRO high-pressure pump. No break tanks are necessary for the system. Primary filtration is through the use of self cleaning disc filtration rated for 100 micron.

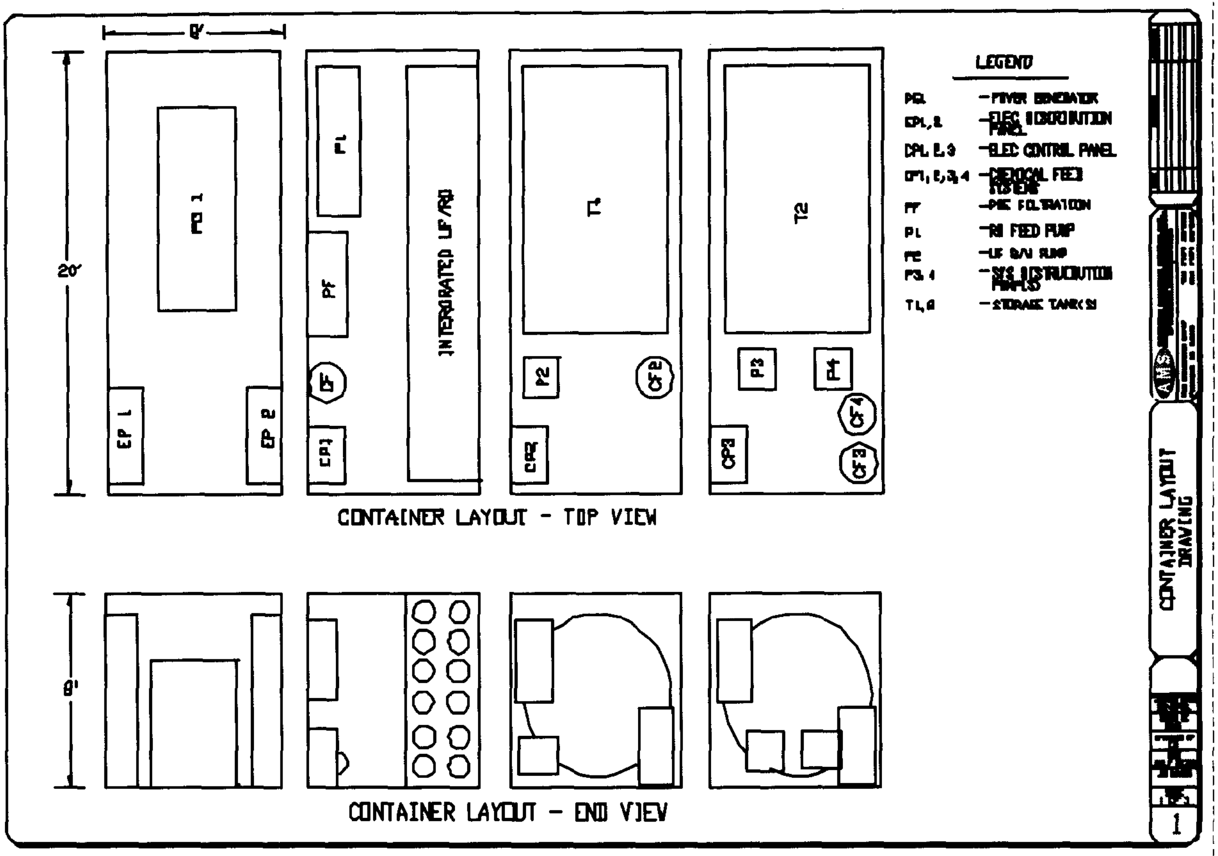

Fig. 4. Container layuot.

This design makes the systems capable of handling nearly any potential seawater feed waters. Also, with some modifications to the basic design, the system could be run to treat nearly any water source, from contaminated low TDS groundwater to the waters in the Arabic Gulf.

The capital costs for the system as shown are in the neighborhood of US $0.55M. This may seem an unrealistic expenditure to some, but the key here is potential life cycle costs. With the relatively low energy consumption at 3.2 kWh/m^3, and the UF protection for the SWRO membrane, this system would be cost effective to operate and maintain while retaining a relatively high resale value. And when compared to the standard ROWPU design and costs, the dollars per cubic meter of production capital costs are significantly reduced, by a margin of nearly 5 to 1.

5. Conclusions

Will this modular system concept ever replace the idea of large-scale facility construction? This is doubtful, due to the rising water needs of larger population centers. However, this type of system has a useful contribution to make in lower population density areas, tourism development in new areas, and new approaches for desalination with renewable energy resources. In particular, the lower energy consumption, streamlined self-contained design, and reduced capital costs makes these systems more available to a greater segment of the world's population, thus promoting membrane desalination technology even further.

Other than population growth and water reuse issues, the growth of tourism within today's economic structure is probably one of the greater driving forces in the desalination industry. The resort developers have the largest pocketbooks and profit potential, and therefore the justification for potable water from unconventional sources. But making membrane desalination more affordable and easier to obtain just increases the opportunity for the industry to grow, exponentially.

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