Development of Water Purification System Type2 Reverse Osmosis (WPS RO2) for Japan Ground Self-Defense Force

Japan Ground Self-Defense Force (JGSDF) owns a vehicle-mounted Reverse Osmosis Water Purification System that purifies natural water drawn from rivers and lakes and converts it into safe drinking water that can be provided to JGSDF members in emergencies where access to safe drinking water is not possible.

Over the past few years, this mobile water purification system has seen use in international peacekeeping operations, as well as in disaster relief following the Great East Japan Earthquake. It provides safe water for JGSDF members and disaster victims, and is expected to play an active role in any future emergencies.

Background of the development of Water Purification System Type 2 Reverse Osmosis (WPS RO2)

Conventional reverse osmosis Water Purification Systems can only purify fresh water such as river water and lake water. This can cause problems in situations where fresh water is unavailable such as when strengthening defensive capabilities on islands and or when river water is unusable due to inflow of earth and sand after a disaster. As a result, there has been an urgent need to develop a new purification system that can also purify seawater.

According to this background, bidding for the prototype development of the successor of the conventional reverse osmosis water purification unit was held in 2010, and NEC Facilities made a successful bid for the prototype. After about nine months trial period, the new prototype was successfully delivered. After the delivery of the prototype, JGSDF put it to the test, subjecting it to the most extreme conditions. Once approved by JGSDF, mass production was authorized. Bidding for the Type 2 Reverse Osmosis Water Purification System - the mass production version was held in 2013. NEC Facilities again made a successful bid and the first mass production model was delivered in 2014.

Mechanism of the WPS RO2

As shown in **Fig. 1**, “WPS RO2” is composed of a generator that supplies the electricity required to operate the system and a water purification system that purifies raw water such as river water and seawater, converting it into potable water. The two main components are secured to the chassis of a 3.5-ton truck belonging to JGSDF.

The water purification system is comprised of a pre-filtration unit that eliminates suspended solids in raw water and a reverse osmosis units that makes desalination.

NEC Facilities applied the water purifying technologies developed in NEC’s semiconductor manufacturing

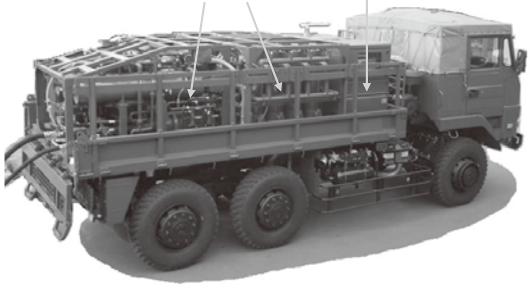

Fig. 1 “WPS RO2”.

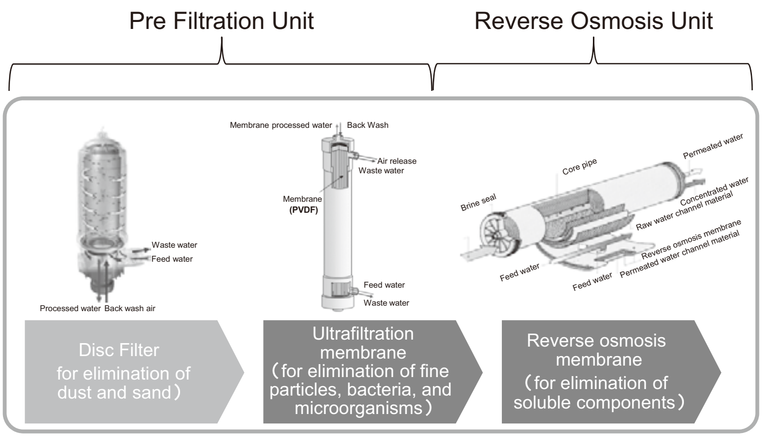

Fig. 2 Water purification flow.

field to the principal technologies of this system. The flow of the system is shown in **Fig. 2**.

Technologies to meet the rigorous requirements of JGSDF

As "WPS RO2" is intended for use in times of emergency, JGSDF insisted that it be able to withstand the most severe conditions and specified their requirements accordingly.

(1) Water purification performance and weight

Because of the virtually unlimited range of locations where JGSDF might have to operate, the unit was required to have the ability to obtain potable water not only from rivers and oceans, but also from marshes with sludge deposition and even from polluted water. Moreover, the weight of the water purification system mounted on a truck had to be 3.5 tons including the generator, so it was necessary for the design of the system to aim at compactness, light weight, and high performance.

To eliminate soluble material, a reverse osmosis membrane filter was employed. Since the system was going to be mounted on a truck, the design had to be compact and lightweight, while still offering high elimination performance.

When selecting the reverse osmosis membrane filter technology, we examined offerings from a wide range of manufacturers, including Japanese membrane manufacturers Nitto Denko Corporation and Toray Industries, Inc., which have a high level of technological expertise and strong market shares in the world. In addition to these Japanese manufacturers, various products offered by overseas manufactures of reverse osmosis filters were also looked at. Factors such as desalinating performance, water permeate flow rates, and prices were compared in order to select the optimum membrane.

Another factor that had to be taken into consideration was that while a reverse osmosis membrane filter effectively desalinating, it can get stained easily and clogging is likely to occur with even a small amount of turbidity. For this reason, selection of an appropriate prefiltration system was critical in order to extend the service life of the reverse osmosis membrane filter and enable it to perform at optimum levels. Thus, an ultrafiltration membrane filter with extremely fine pores measuring 0.01 µm was adopted, making it possible to eliminate not only turbidity but also bacteria. Passing the water through the ultrafiltration membrane filter assures that the water is suitable for washing and shower (when using only fresh water as a source).

The most difficult part of this project was the pretreatment system for the ultrafiltration membrane filter. The requirement from JGSDF specified the concentration of the turbidity of raw water (the index for the amount of turbidity) at 200 mg per litter. When water with this concentration was passed through the ultrafiltration filter as it was, the load would be too high and clogging would occur in the ultrafiltration filter. Therefore, coarse elimination of high turbidity needed to be performed prior to the filtering. Conventional turbidity elimination systems, however, were too large and made of steel and stainless steel, making them too heavy, so it was not suitable to use them as a part of this water purification unit. Consequently, we looked at other devices that could be used for the pretreatment of the ultrafiltration membrane filter, finally selecting a disc filter - a compact, high-performance filter made of resin - and adopting it as the pretreatment device for the ultrafiltration membrane filter after confirming the effectiveness of its performance through validation tests.

Despite the fact that this filter was much more compact and lightweight than comparable steel units, it was still difficult to design a system that would meet the tight restriction of 3.5 tons or less. Repeated simulations were conducted and the weight of every component, down to individual nuts and bolts, was calculated. After repeated refinement, the requirements were finally achieved.

(2) Environmental resistance requirements

As we have already discussed, the "WPS RO2" must be capable of being used in any location under any environmental conditions; accordingly, very high environmental resistance specifications are required. The most rigorous of these is the operating temperature requirement, which specifies that the unit be operable at ambient temperatures ranging from –30°C to 60°C.

Generally, the ambient temperature range recommended by manufacturers includes both storage temperature and operating temperature. Although the manufacturers of the components of "WPS

RO2" guarantee a storage temperature as low as the –30°C level, most only guarantee an operating temperature of 0°C or higher. This means that in order for "WPS RO2" to operate under the conditions demanded, the temperature around the unit must be raised to 0°C or higher. Since the truck on which "WPS RO2" is mounted has a hood, an enclosed space is created when the hood is closed. Thus, the temperature around the system can be raised by incorporating a heater in the system.

The biggest problem our engineers faced was finding a way to prevent water from remaining in the pipes and freezing. As a lot of time and fuel are required to thaw the frozen water, the optimal solution was to minimize the water remaining in the pipes. A water purification system is by its very nature a complex device with intricate pipes of various sizes, including many thin pipes with diameters of 10 mm and 20 mm in which water can freeze easily. To deal with this, we applied a number of different measures, including placing drainage valves at various strategic locations and incorporating a function to blow away residual water using pressurized air. Moreover, because residual water would adversely affect the weight of the system, we carried out residual water checking tests and altered the locations of the drainage valves as necessary.

(3) Durability requirements

The water purifiers of the "WPS RO2" can be divided into three sections. This makes it possible for the system to be carried by a helicopter, enabling it to be transported to mountainous regions inaccessible to ground transportation. It was also required to withstand a g-force up to 3G, which is the maximum acceleration at the moment a helicopter lifts off. In order to maximize durability while minimizing amount of structural reinforcement required due to the weight restrictions discussed above, the required reinforcement positions in the system's frame design were determined using structural calculations with 3D analysis. An example of the strength analysis is shown in **Fig. 3**.

Transportation tests using an actual helicopter were conducted by JGSDF to confirm that the system functioned as required. An example of the transportation tests is shown in **Photo**.

Plans to improve the WPS RO2

The work described above is only a fraction of what was involved in developing this system. Getting to final delivery of the mass production model was a long haul, but the company wide cooperated activity brought this project to fruition. Hard work and continuous consultation as well as collaboration with JGSDF enabled us to achieve our goal, and we are proud of our success in developing a system that satisfied the client. Once this system has been deployed, we will continue our efforts to further improve "WPS RO2" refining the design to better meet performance requirements during actual operation with the goal of developing the world's number one water purification system.

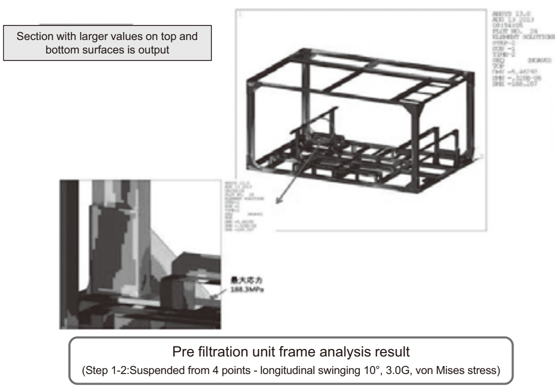

Fig. 3 Frame strength analysis.

Photo Helicopter transportation test by JGSDF.

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