White Paper

Robust Water Treatment for Disaster Situations

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Background

The Congressional Budget Office estimates that the typical annual damage from storms, floods, and hurricanes is $54 billion, or 0.3% of gross domestic product. [1] Recent notable examples include the following:

2005 – Hurricane Katrina ($125 billion)

2012 – Hurricane Sandy ($70 billion)

2017 – Hurricane Harvey ($125 billion)

2017 – Hurricane Maria ($92 billion)

2019 – Great Midwestern Flood ($6.2 billion)

In some cases, the damage is repaired quickly; however, in other cases, it may take years. For example, Puerto Rico still has not recovered from the devastating effects of Hurricane Maria.

The immediate impact of these disasters is to disrupt essential supplies, such as food and water. Table 1 shows the approximate daily mass of essential supplies required per person during an emergency. The mass of water is about 6 to 12 times greater than the mass of food. Often, during disasters water is supplied in bottles transported from distant regions that were not affected by the disaster, an expensive and cumbersome logistical problem.

During storms, floods, and hurricanes, the problem is not a lack of water; in fact, there is too much water. The problem is a lack of **<u>potable</u>** water.

During these emergencies, domestic water supply and sewage systems are flooded. The surrounding water can be contaminated with the following:

- Dirt – from land and rivers
- Sewage – from overflowing treatment plants
- Manure – from confined animal feeding operations
- Salt – from ocean storm surge

Of particular concern is the spread of water-borne diseases, such as cholera and dysentery.

Table 1. Daily supplies to support one adult during emergencies

Item	Approximate Mass (kg)
Food, two MRE*	**1.25**
Water [3]	**7.5 to 15.0**
Drinking	2.5 to 3.0
Hygiene	2.0 to 6.0
Cooking	3.0 to 6.0

* MRE = Meal, Ready-to-Eat, 1200 kcal each, average mass = 0.625 kg [2]

Conventional Water Treatment Options

In a disaster situation, the following conventional options are available to treat water for human consumption:

Filtration – Removes dirt
Ozone Treatment – Kills pathogens
Reverse Osmosis – Removes salt

A complete solution requires the integration of all three technologies. Reverse osmosis has a reputation for being "finicky." The membranes are fragile (1/500 the thickness of a human hair) and easily foul with dirt or microbes. Consequently, sophisticated pretreatments are required to preserve the membranes. In normal circumstances, this special treatment can be accommodated; however, in a disaster situation, a more robust solution is required.

Robust Technologies

Cascade Water Solutions, LLC, offers two water treatment technologies that process raw water into potable water. Both technologies have the following features:

- **Robust** – Raw water can be processed without the need for pretreatment or adaptation to local water chemistry.
- **Single step** – Desalination and sterilization occur in a single step.
- **Containerized** – They are mobile and can be readily deployed to the disaster site.
- **Compact** – Only a small footprint is required.
- **Efficient** – Energy consumption is low and can approach the theoretical limit.

Figure 1 shows the **StarDesal™** system. Raw water containing dirt, microorganisms, and salt enters the unit directly without requiring pretreatment. Using a sensible heat exchanger, the temperature increases to 180°C, which kills all microorganisms. The hot water enters a latent heat exchanger, which evaporates water leaving dirt and salt behind. The water vapors are compressed, which increases the pressure and temperature. These hot vapors condense in the latent heat exchanger and exit as potable liquid water. The compressor is very efficient, so only a small amount of work is required.

Figure 2 shows the **Advanced Vapor-Compression Desalination (AVCD)** system. It functions similar to StarDesal™, except that 10 stages of latent heat exchangers are employed.

Table 2 summarizes the properties of each system.

Table 2. Summary of Cascade Water Solutions water treatment technologies

	StarDesal™ (1/8th-scale) prototype)	**StarDesal™ (full scale)**	**Advanced Vapor-Compression Desalination (AVCD)**
Water production (L/day)	40,000	300,000	40,000,000
People served	2600 to 5200	20,000 to 40,000	2.7 to 5.3 million
Power (kW)[1]	21 to 42	163 to 326	3,818 to 7,636
Diesel fuel consumption (L/day)	119 to 238	912 to 1824	21,365 to 42,730
Multiplier	164 to 329	164 to 329	936 to 1872

1. Depends on salinity. 2. Assume 40% efficiency.

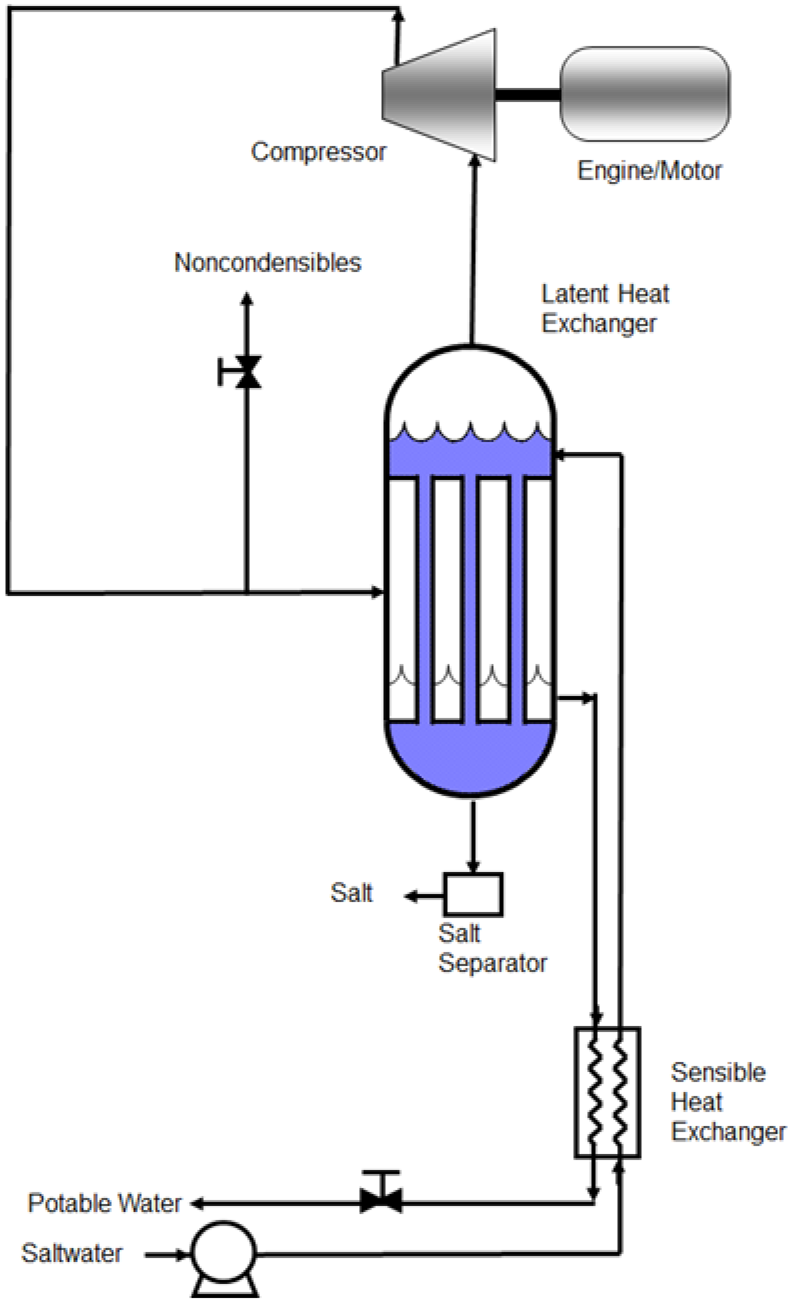

Figure 1. StarDesal™ water treatment system.

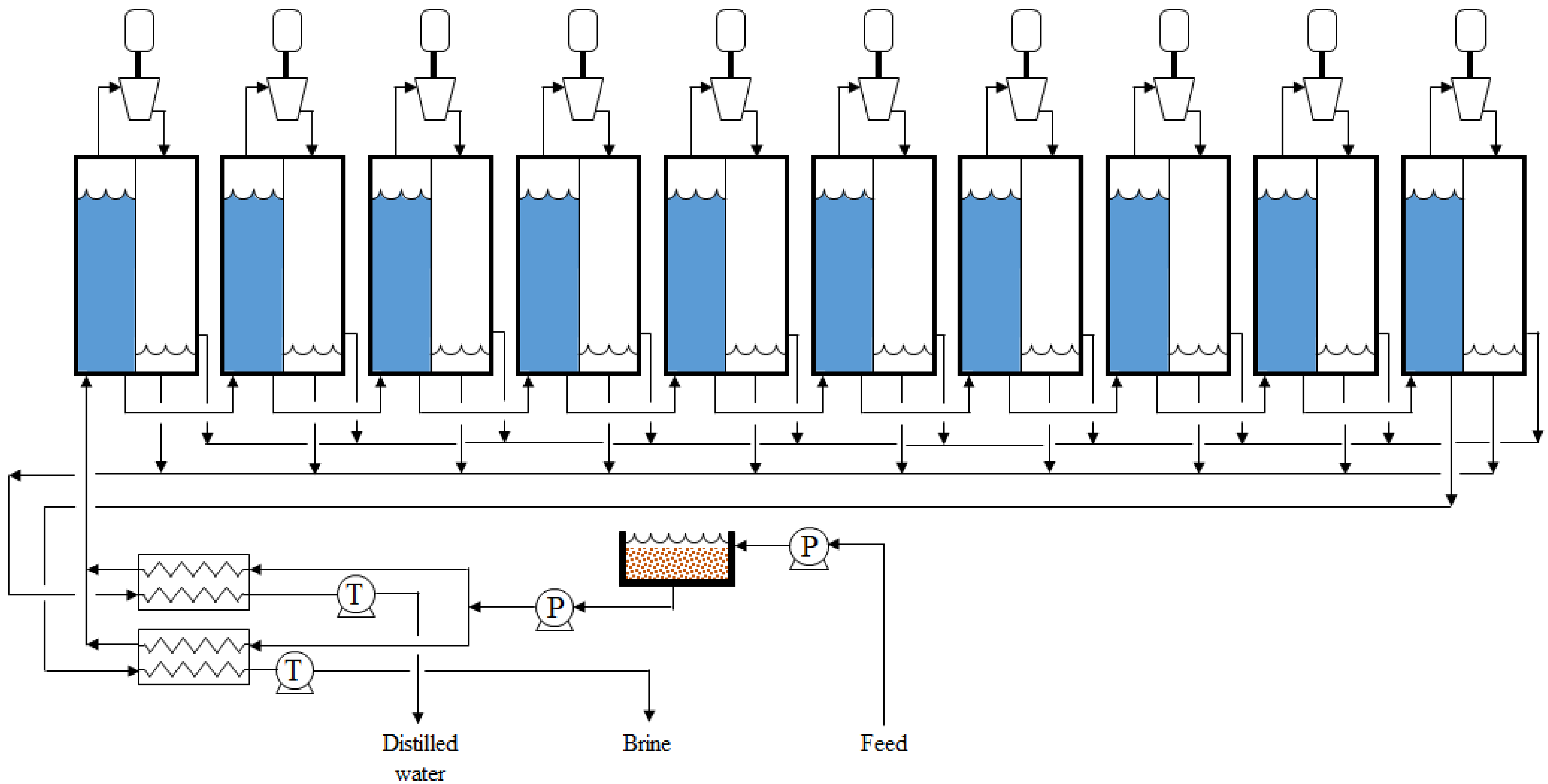

Figure 2. Advanced Vapor-Compression Desalination (AVCD) water treatment system.

Conclusion

For both systems, Table 2 reports the *multiplier*, which is defined as the ratio of water production to fuel consumption. Because it is difficult to remove water from salts, highly saline water requires more energy. In Table 2, the lower multiplier corresponds to seawater and the higher multiplier corresponds to brackish water. StarDesal™ has a multiplier of 164 to 329, and AVCD has a multiplier of 936 to 1872. Higher multipliers are possible if the feed water has a low salt content.

A typical fuel tanker has a capacity of 20,800 to 43,900 L, which is sufficient to power AVCD for an entire day; thus, the water needs of 2.7 to 5.3 million people can be supplied by transporting one fuel tanker to the disaster site each day. Alternatively, the fuel can be prepositioned so no external fuel supply is required.

References

[1] https://www.cbo.gov/system/files/2019-04/55019-ExpectedCostsFromWindStorm.pdf

[2] https://en.wikipedia.org/wiki/Meal,_Ready-to-Eat

[3] https://www.who.int/water_sanitation_health/publications/2011/tn9_how_much_water_en.pdf

For more information, visit…

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