Text to Accompany the "Von Braun Space Station Water System Architecture" Slideset
Thomas R. Spilker, 2019 June 20

This description and drawings are intended to convey the general, high-level architecture of the water handling system to be implemented on the von Braun Space Station. Details such as precise tank and pump pressures, pipe diameters, and subassembly types (e.g., the solid-liquid waste separator) are as yet undetermined and would result from a detailed engineering trade study.

SLIDE 1, "Von Braun Space Station Water System Architecture"

Water is delivered to the von Braun Station by spacecraft docked at the Docking Hub. Some is in the form of potable liquid water, or "first-pass water", pumped directly into tanks on the station. Other water comes aboard in the form of water contained in foods delivered by the spacecraft. The water content of foods varies widely, but a reasonable estimate based on USDA research is that ~25% of the mass of the food brought aboard is water. Current estimates of per-person averages for drinking water and food consumption suggest the station will need ~1000 kg of fresh water per day for drinking, and ~250 kg of water in ~1000 kg of food, most of it fresh but some dehydrated. Preparing the food, including rehydrating the dehydrated food, will require another 400 kg/day of potable water. Clean-up after the food preparation is done with second-pass water, so that isn't included in the potable water delivery requirement. The net daily delivery to the station is 1400 kg of first-pass water and 250 kg of water contained in food, for a total of 1650 kg of water. The mass of water and food delivered per spacecraft arrival depends on the frequency of arrivals but would be 11,550 kg for weekly deliveries.

Of the total water delivered per day, 1000 kg of drinking water and the 250 kg of water contained in foods is consumed by humans. Another ~250 kg is lost to evaporation during the food preparation processes, and yet another ~150 kg is "preparation waste", potable water used in preparing the food (e.g., washing produce, water in marinades, etc.) that is not subsequently delivered to the tables. That preparation waste contains solids so it is sent to a separator, yielding ~120 kg of relatively clean (low particulate content) water sent to a water purification apparatus and ~30 kg/day of water accompanying solid wastes that are exported from the system.

Of the 1250 kg/day consumed by humans, on average 560 kg/day returns as liquid waste (urine), 530 kg/day is evaporated via exhalation and sweat, and 160 kg/day is contained in solid wastes (feces). The liquid waste is sent to a separator that concentrates the non-water components of the urine—notably, nitrogen in the urea, and sodium, potassium, and chlorine. Roughly 60 kg of that water continues with the non-water components and is exported, either to other processes on von Braun or to other orbital facilities. 500 kg/day of relatively clean water is sent to the water purification system.

The 160 kg/day of solid waste is sent to another separator that produces ~120 kg/day of relatively clean water and ~40 kg/day accompanies dehydrated solid waste, That waste contains useful elements such as sulfur and especially carbon. The relatively clean water is sent to the water purification system. The dehydrated waste is exported, again either to other processes on von Braun or to other orbital facilities.

The 530 kg/day evaporated from human bodies joins the 250 kg/day evaporated during food preparation to yield 780 kg/day of water added to the station's air. That water must be removed to maintain the air's humidity at the desired level. The humidified, "used" air is sent via the return air system to the AWP modules where the dehumidifier removes the excess water and sends it in liquid form to the water purification apparatus. [Since the dehumidification process is done via condensation, we might be able to send that water directly to the second-pass water holding tanks]

During these processes ~130 kg/day is lost to the water system, exported with the concentrated liquid and solid wastes. The remaining 1520 kg/day is processed by the AWPs' purifiers and is sent to the second-pass water system's holding tanks.

The water use rate for the second-pass system is much higher than the potable system's rate. Statistics on average indoor, non-food water use suggest that for 400 people the daily use in modules (showering, hygiene, etc.) would be ~40,000 kg. In addition to that use, second-pass water is used in the KRB Modules for cleaning purposes and in the Laboratory and Industrial Modules. Finally, using the abundant electric power available on the station, some water is electrolyzed to oxygen and hydrogen that is exported to other station processes or to other orbital facilities. About 400 kg/day of the oxygen is sent to the AWP modules' air systems for maintaining the oxygen content of the station's air, so a minimum of 450 kg of water will need to be electrolyzed for the fresh air supply. If more than 450 kg per day of water is electrolyzed, the oxygen produced above the 400kg needed for fresh air could be used in the Laboratory Modules or for rocket propellant. The hydrogen has multiple uses, including use in the Laboratory or Industrial Modules, or use directly as a rocket propellant or indirectly in the production of less storage-challenging rocket propellants such as methane or propylene.

It is possible that some of the waste water produced in the Laboratory or Industrial Modules will contain contaminants that cannot be extracted via the processes available on the station. This becomes "unreclaimable water" that is lost to the system. It is possible that other nearby orbital facilities might make use of that, and in that case that water could be exported. If not, it could be vented to space, possibly in a way that aids the station's precession engines. The system design will minimize the need for such venting.

Reclaimable water will return to the AWPs' purification systems and from there will return to the second-pass water holding tanks. If the rate of water loss to electrolysis or as unreclaimable water exceeds the rate of water input from the first-pass water system additional water will need to be delivered to the station and to the second-pass holding tanks. A goal of the system design is to have the loss rate of second-pass water be significantly less than the supply rate from the first-pass system so there is plenty of water available for electrolysis.

SLIDE 2, "Von Braun Space Station Water System Block Diagram"

Note that this high-level diagram does not show every component of the water system. A fully detailed diagram is far too complex to illustrate usefully on a sheet of this size. Many, many valves are not shown, some components (such as smaller holding or pressure tanks) are not shown, and in some cases multiple components have been combined into a single box. One lodging module is shown, along with the second-pass water system of one KRB module, but the diagram shows only the purification section of one AWP module and no laboratory or industrial modules.

POTABLE WATER SYSTEM

After an arriving spacecraft has completed hard docking and spin-up with the von Braun Station, flexible pipes in the docking arms are connected to outlets in the spacecraft's port and to connectors where the docking arms meet the Docking Hub. Unloading pumps in the docking arms then pump the water from the spacecraft's tanks through pipes to one or both of the Docking Hub's two 21-m^3 potable water holding tanks, one in each of the two Operations Control Centers (OCCs), storing enough potable water for 30 days of normal operations. In an emergency, water use reduction protocols could more than double that duration, and use of liquid water produced by the air system's dehumidifiers as potable water could extend it much longer.

Outlet pipes from the holding tanks feed pump-pressure tank combinations that in turn feed the Docking Hub Potable Water Manifold (DHM). That manifold supplies water to each of the four Main Standpipes, one in each of the Main Elevator Shafts, that go radially all the way to the base of the ORT Access Tunnel, where they feed the ORT Potable Water Manifold (ORT-PWaM). Under normal station rotation, the pressure at the base of the ORT-PWaM will be ~60 kPa (~8.7 PSI) higher than the pressure at the DHM. The ORT-PWaM extends the entire circumference of the ORT, passing through all of the station's 24 couplings and Junction Blocks.

At each coupling or Junction Block, secondary standpipes go from the ORT-PWaM, through the coupling's elevator shaft to the adjacent modules, through the modules' ports and into the modules' Potable Water Holding Tanks at their bases. The pressure at the base of those tanks will be ~80 kPa (~11.6 PSI) higher than at the DHM. From the module's holding tanks water goes to a pump-pressure tank combo for delivery to the various fixtures in the module. There are limited uses for potable water in the lodging modules because the great majority of eating and drinking will be done in the KRB modules. Some drinking of locally-supplied water will be done in the lodging modules, possibly tea and coffee made in the rooms as well as pure water. There might also be in-room microwave ovens for heating light snacks, which might lead to some cleaning of dishes and utensils. But the total of these is still a limited amount of water, possibly 3-4 kg per person per day. For a module with an occupancy of 20 people that would be 60-80 kg per day, or 420-560 kg per week. One cubic meter of water at room temperature has a mass of ~998 kg, so a week's worth of water use requires a tank of only ~1/2 cubic meter volume. For the even more limited amount of potable hot water needed in the lodging modules electric demand heaters do the heating. Any water that goes into the associated drains is collected and piped to the second-pass water system's purification apparatus in the two AWP modules.

Potable water demands will be much higher for the KRB modules so they will be located near Main Standpipes. Their potable water holding tanks will be considerably larger than those in the lodging modules. Potable water use there will be limited to drinking and food preparation, including any washing needed for foods that will not be cooked.

In all modules, all potable water not used for drinking enters one of the drains (showers or sinks) and is collected and piped to the second-pass water system's purification apparatus in the two AWP modules

SECOND-PASS WATER SYSTEM

Water collected from the modules' drains and various other sources as described below will reach the Second-Pass Water System. This system supplies water that has been either passed directly from the ORT-PWaM or reclaimed, having gone through the purification process in one of the AWP modules. It features a Second-Pass Water Manifold (SPWaM) that, like the ORT-PWaM, traverses the entire circumference of the ORT. There is a direct connection from the ORT-PWaM to the SPWaM through a control valve (not shown) and a backflow valve, allowing potable water to pass to the SPWaM but not the other direction. The primary use of that direct connection is to perform the initial loading of the SPWaM and second-pass water holding tanks in the modules. Subsequent use would be necessary only if the mass of water supplied to the purifier from the potable water system's used-water collectors were consistently less than the losses from the second-pass system, as discussed below.

The second-pass water system's holding tanks in the modules are much larger than the potable water holding tanks and are oversized for dual use in the station's mass balancing system. Outlet pipes lead to pumps that can rapidly send water from the holding tanks back to the SPWaM and into holding tanks in modules on the other side of the station to balance the shifting mass as people and materials move about the station. This flow is controlled automatically (with manual overrides) from the OCCs, whose sensitive accelerometers can detect minor changes in the station's mass distribution and orchestrate the shift of water to compensate.

In the lodging modules second-pass water moves from the holding tanks to a pump-pressure tank combo and from there to the three types of bathroom fixtures that use it: showers, toilets, and a faucet for washing and shaving. The showers and toilets use the great majority of the second-pass water in lodging modules, ~89% of the nearly 40,000 kg/day for all the lodging modules in the station.

In the KRB modules the second-pass water is for cleaning (cooking surfaces, containers, utensils, etc.) and bathrooms (toilets and sinks, no showers). All this used water is sent first to separators that concentrate liquid and solid wastes. Relatively clean water is then sent to the purifiers in the AWP modules, while dehydrated liquid and solid waste, along with any water remaining in it, is exported; that residual water is lost to the system.

Aside from the uses in the lodging and KRB modules, second-pass water sees multiple uses in the AWP, Laboratory, and Industrial modules. Like the lodging and KRB modules, those modules are all involved in the station's balance system. Internal to the modules there are many potential uses. In the AWP modules electrolysis uses a minimum of 450 kg of water per day to provide 400 kg/day of oxygen to the station's air system, which is also centered in the AWP modules. Any hydrolyzed water is lost to the system. Depending on the balance of water lost to other processes and water supplied from the potable system's wastes, electrolysis could provide a supply of gaseous oxygen (that could be liquified) beyond the air system's needs, and gaseous hydrogen.

Potential uses in the Laboratory and Industrial modules are not yet well defined, but there are many such potential uses with currently undefined use rate requirements. Those modules would need bathroom facilities that except for emergency showers would closely mirror bathroom facilities in the KRB modules.