SANITATION GUIDE: VACUUM TECHNOLOGY IN VACUFLUSH TOILETS

El sistema de gestión de calidad de DAHLBERG S.A. obtuvo su aprobación original ISO 9001 el 18 de octubre 2003, el cual se ha mantenido en vigor hasta la fecha, aprobado por **LLoyd´s Register Quality Assurance España S.L.U.**, de acuerdo con la Norma de Sistema de Gestión de Calidad **ISO 9001:2015**. Esta certificación está avalada por **UKAS Management**

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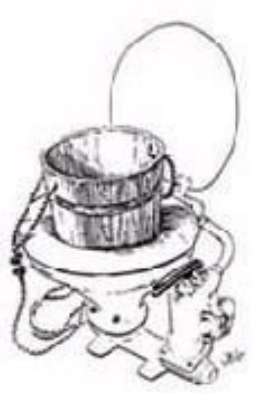
1. INTRODUCTION

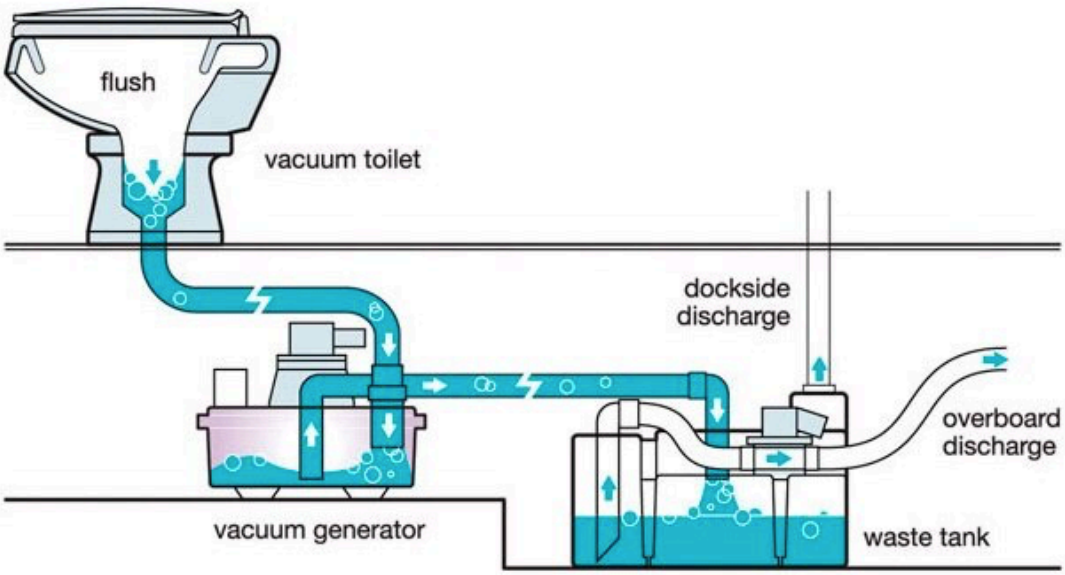


A traditional marine toilet consists of a toilet bowl with one or more pumps destined to suck seawater in and to evacuate the wastewater. There are different models of marine toilets from simple manual units with double acting pistons to more complicated systems that use high pressure water flow in the toilet to push the contents to the sewage tank.

The use of seawater for flushing in any marine toilet is not advisable due to microscopic organisms being sucked into the inlet hoses.

When the boat is not being used for some weeks, or even for days in hotter climates, the microorganisms die and decompose, causing strong sulphurous smells when the toilet is being used again. Seawater is also highly corrosive and frequently causes formation of calcium carbonate inside the hoses.

However, it is inconvenient to carry large quantities of water for flushing, in the cases when the toilet system is connected to the fresh water tank. Also the sewage tank fills up principally with flushing water and only relatively small amount of residue, leading to a problem where to find space for a big enough sewage tank, specially on small boats.



On the other hand, the **Vacuflush vacuum toilet** operates in a different way compared to the traditional marine toilets. **Vacuum technology** is used to artificially create a difference between the normal, ambient pressure and an internal vacuum, which will push the residue along a distance horizontally or upwards.

The main benefits of the Vacuflush system stem from:

- Very low water and electricity consumption
- The average flush of a Vacuflush toilet consumes about 0,5 l of water
- The use of fresh water is a practical alternative to the use of seawater, as the daily consumption per person is no more than 4 litres, based on 5 visits to the toilet
- No more bad sulphurous smells or corrosion and scales deriving from the use of seawater
- Consequently, the true capacity of the sewage tank can increase up to 400%

2. THE VACUUM AND ITS UNITS OF MEASUREMENT

To understand the vacuum technology, it is necessary to understand the definitions of vacuum, atmospheric pressure, its units of measurement and how they are measured.

a) Vacuum

Vacuum is a space without any matter. Strictly speaking, an absolute vacuum does not exist, as any given space contains some matter. In every day use we mean with vacuum a space where most of air or gas is eliminated, even if it is only a partial vacuum.

What makes vacuum interesting is its capacity to create a very useful vacuity. For example, if a partial vacuum is created in any space, water or any other fluid can penetrate into it. This principle is applied when drinking a soft drink with a straw - when sucking at one end of the straw, the air in the straw is partially eliminated. The ambient pressure exercises a pressure on the liquid and causes it to rise along the partial vacuum in the straw.

b) How to measure vacuum and which units of measurement are used?

To measure any physical quantity a system of units of measurement is required. In Spain the legal measurement system is the ***International System of Units (SI)***, as regulated in the Second Article of the Law of Metrology 3/1985 of 18th of March and adopted by the General Conference of Weights and Measures (CGPM), also in force in the European Union as per Official State Bulletin (BOE) number 18, of 21st of January 2010, pages 5607 to 5619 (13 pages). The basic units of SI are:

Quantity	Unit name	Unit symbol
Length	Meter	m
Mass	Kilogram	kg
Time, duration	Second	s
Electric current	Ampere	A
Thermodynamic temperature	Kelvin	K
Amount of substance	Mole	mol
Luminous intensity	Candela	cd

To measure the level of vacuum in a vessel, a vertical tube of minimum length of 10,30 metres (33,8 feet) is used. One end of the tube is connected to a vessel containing water, and the other end to the vessel (tank) containing the vacuum. Measuring the height of the water sucked into the tube, it is possible to determine the level of vacuum stored in the vacuum tank. As an example, if the column of water rises up to 5,2 metres (17 feet), it means the level of vacuum in the tank is 7,4 psi, or

approximately half an atmosphere of vacuum pressure. It would be more practical to use a liquid of more density for the measurement, to avoid handling such long sections of tubes. Mercury is the densest liquid available, and therefore most commonly used for measurement purposes. The chemical symbol of mercury is Hg. Generally measurements of vacuum are expressed in inches or millimetres of mercury (inHg or mmHg).

The above described methodology for measuring vacuum identifies psi or its equivalent atmosphere as units of measurement for pressure. These do not belong to the basic units of the SI, which means that to measure vacuum a **derived unit** is needed. Derived units are obtained by multiplying, dividing or powering the base units in various combinations. According to the previously mentioned Law 3/1985, **coherent derived units** are powers, products or quotients of the base units where no other numerical factor is used except 1. For example, 1 N = 1 kg × 1 m/s^2 says that *one* newton is the force required to accelerate a mass of *one* kilogram at *one* metre per second squared. Thus the unit used to measure the quantity of pressure in Spain is:

Derived Quantity	Coherent derived unit (SI)		
	Name	Symbol	Formula in basic SI units
Pressure, tension	Pascal	Pa	m^{-1} kg s^{-2}

On the other hand it should be pointed out that units psi, atmosphere and mmHg are commonly used in the American and English metric systems, whereas millibar is used more in the nautical context. The following chart shows the the equivalencies between the above mentioned units:

Derived Quantity	UNIDADES				
	Atmosphere	Spanish metric system	American and English metric systems	Nautical Sector	Mercury
Pressure	1 atm	101.325 Pa	14,7 psi	1.013 milibar	760 mmHg

c) Atmospheric pressure

In the air that we breathe there are about 25.000 billion gas molecules per cubic centimetre. The force exerted on a surface by weight of the air above the surface is called atmospheric pressure. The atmospheric pressure diminishes with height. The standard value of the atmospheric pressure at sea level is 1 atmosphere (1 atm), the equivalent of 14,7 psi or 101.325 Pa.

Getting back to the example of a soft drink and a straw: what is the maximum vertical distance that a straw can elevate the soft drink, regardless of the suction exercised at the top end? It is the equivalent of the weight of the air pressurizing on the surface of the soft drink. Thus, if a pressure

of one pound per square inch (psi) elevates a water (or soft drink) column by 0,7 m (2,3 feet), the maximum height that the water can be sucked through the straw is 10,3 m (33,8 feet), the result obtained as follows: 2,3 feet x 14,7 psi = 33,8 feet.

d) Units of measurement for atmospheric pressure, PSIA and PSIG

As previously mentioned, in Spain a unit Pascal (Pa) is used to measure pressure. However, as some toilet manufacturers are of American or English origin, it is important to familiarize with the units referred to in their instruction manuals and use the conversion table introduced in the chapter b) of this section.

PSIA is an abreviation for pounds per square inch absolute, and PSIG for pounds per square inch gauge. Some pressure meters have the zero level adjusted to 1 atmosphere, or 14,7 psi of pressure. In other words, these meters measure the vacuum at zero in one atmosphere of pressure. This way to measure the pressure is expressed in psig. Other meters have a different adjustment, having the zero level equivalent to absolute vacuum. This reading is expressed in psia. As a comparison, 10 inHg of vacuum is the equivalent of -5 psig or +9,7 psia.

3. VACUUM TECHNOLOGY

In the following sections you can learn the main principles of the vacuum technology in the Vacuflush toilets:

a) Level of vacuum used in Vacuflush toilets

The Sealand system is designed to work at sea level in terms of exterior atmospheric pressure, and with 254 mm (10 inHg) vacuum pressure. Other systems need to work at very high altitudes (Boeing 757) or with higher vacuum levels (cruise liners and passenger vessels). The toilet bowl funnels to an orifice of 25 mm in the base, which forces the discharged material to fragment due to the high speed of the suction in the orifice. The small size of the orifice also prevents any items larger 25 mm from penetrating the system.

b) Loss or drop of vacuum level

➢ Levels of Turned on and Turned off

The vacuflush pump is activated by a differential pressure switch installed in the vacuum tank or a generator that stores the volume of vacuum in the same way as a storage tank in a positive displacement air compressor stores compressed air. The pressure switch is preadjusted in the factory to activate the pump when the level of vacuum falls under 203 mm, and to stop the pump when the vacuum level reaches 254 mm.

➢ Leak-down time

The possibility of a leak is inherent in any system using vacuum. One of the benefits of vacuum is that a leak will cause air to enter the system, instead of liquid running out of the system. The leak-down time of the Vacuflush system is the time needed for the vacuum level to drop from 254 mm to 203 mm.

A leak-down time of three hours is an acceptable level of trustworthiness of the system. It is fundamental to always determine the leak-down time first, before carrying out any problem solving methods. Pump noise can be annoying if the pump starts automatically several times during the night..

➢ Audible vacuum loss

A leak that causes the pump to start once an hour is usually perceivable to the ear, at least when background noise is reduced. Turning off other equipment onboard and listening carefully close to each of the principal components of the system could be the best way to detect a leak.

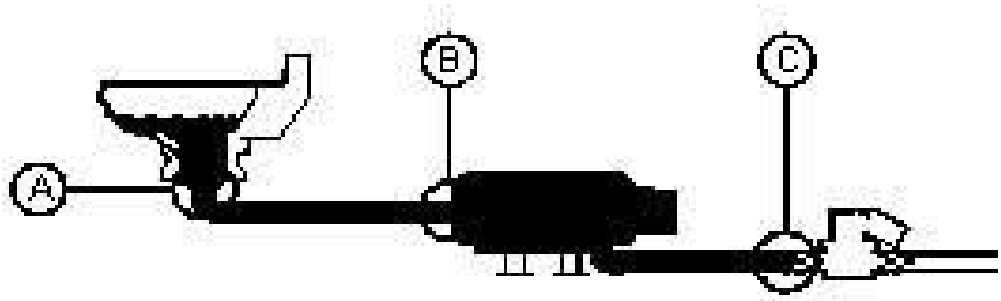
4. DETECTION OF VACUUM LEAKS

a) Vacuum tester

SeaLand has developed a simple tool to locate a vacuum leak. A vacuum tester consists of a vacuum gauge and a cone shaped rubber plug reader. Insert the reader in the vacuum tank inlet or in the generator in order to isolate the toilet from the system. This way it will be easy to localize a leak in the toilet, in the vacuum generator, in the vacuum tank or in the vacuum pump. See the user instructions for the vacuum tester in the next section.

It is possible to order just the vacuum tester (Art. No. 530002), it also comes as a part of Complete System Maintenance Kit (Art. No. 310228).

b) Uso How to use the vacuum tester?



A vacuum tester can be used for detection of leaks in vacuum toilets, in vacuum tanks or in vacuum generators, as well as for finding worn out seals in vacuum pumps. Follow the instructions below:

1. Vacuum toilet (A)
2. Close the water supply. Insert the cone shaped plug into the orifice in the base. Wait till the pump stops and compare the time between pump cycles with the previous measurement (note: if it takes more than 5 minutes for the pump to stop, the leak is probably located further down).
3. Vacuum tank (B)
4. Inserting the plug in the inlet of the vacuum tank or generator isolates the toilet from the system. In this way a troublesome leak can easily be located in either system. Wait till the pump stops and compare the pump cycles as before.
5. Vacuum pump (C)

6. Due to the small size of the inlet, the vacuum gauge will fluctuate with every revolution of the pump. Insert the the plug in the pump.
7. Leave the pump on for two or three minutes. Cut the power to the pump.
8. Check the position of the vacuum indicator (it will probably not show more than 178 or 203 mm). If there is no variation in the indicator within 10 minutes, the seals probably close well enough and there is no need to change them.

c) How does a vacuometer work?

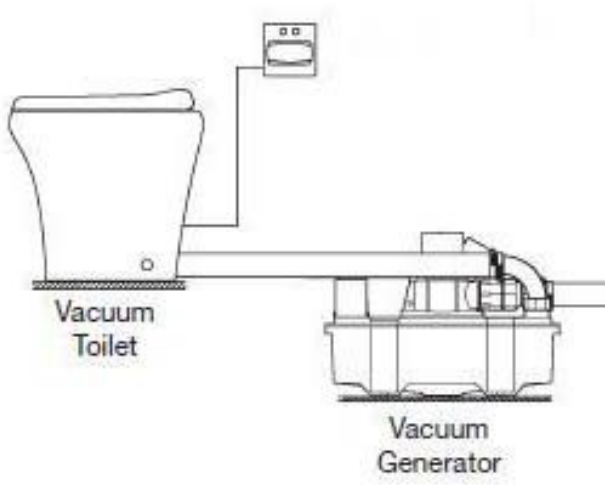
A digital vacuum tester or vacuometer is used to determine the leak rate of the system and the pump cycle interval:

1. Close the water supply to the toilet.

2. Open the flush ball and insert the rubber plug in the 2,5 cm orifice in the base of the toilet bowl. The vacuum pump will start.

3. Once the vacuum pump stops, wait about a minute till the digital gauge has stabilized.

4. Press the button on the vacuometer and take the reading of the vacuum in hundredths of inches (0.01”).



5. Leaving the rubber plug in the orifice, wait 15 minutes and take another vacuum reading.

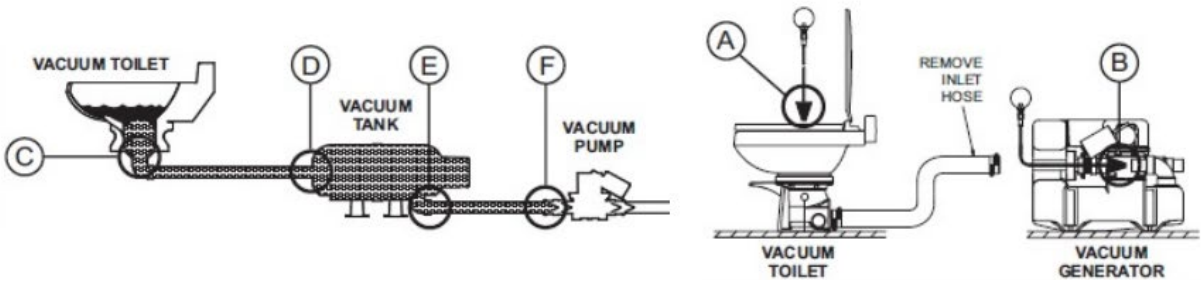
6. The difference between the two readings show the drop in the level of vacuum

d) Maximum acceptable level of vacuum leak

See below the different levels of vacuum and their classification for the operation of the system:

Drop in vacuum	Extrapolated time between pump cycles
0,2" Hg (not acceptable)	2,5 hours
0.15" Hg (acceptable)	3,0 hours
0,10" Hg (god)	5,0 hours
0,05" Hg (very good)	10,0 hours

e) How to localize leaks in a vacuum generator?



1. Close the water supply to the toilet

2. Open the flush ball and insert the rubber cone into the 2,5 cm orifice in the bottom of the toilet bowl (A). If there is no vacuum leak at this point, the leak is above the orifice in the base.
    - Check for a crack in the base, funnel, or flush ball.
    - If there is a vacuum leak, go to the next step.

3. Remove inlet hose to vacuum generator and insert the rubber plug in the inlet fitting (B).
    - Check the hose and clamps between the toilet and the vacuum generator. If there is a vacuum leak:
    - Check duckbill valves for foreign objects or cuts and that they are not open
    - Check spin nut and fitting between pump and vacuum tank

4. Identify vacuum leak location in vacuum tank / vacuum tank system.
5. Before starting vacuum tests, determine the amount of time between pump cycles or the amount of vacuum drop within a specific time span.

➢ Part 1: How to identify a leak in vacuum tank

1) Remove vacuum hose from inlet on vacuum tank (D).
2) Insert rubber plug in tank inlet.
3) Note the vacuum reading, then determine time between pump cycles.
    - If time between pump cycles increases or no vacuum drop is recorded on test gauge, the leak is before the vacuum tank. Go to Part 2.
    - If time between pump cycles remains the same or a vacuum drop is recorded on the test gauge, go to Part 4.

➢ Part 2: How to identify a leak in the toilet outlet

1) Reinstall vacuum hose on vacuum tank inlet
2) Remove hose from the toilet outlet (C).
3) Insert rubber plug into open end of the hose.
    - If time between pump cycles increases or no vacuum drop is recorded on test gauge, go to Part 3.
    - If time between pump cycles remains the same or a vacuum drop is recorded on test gauge, the leak is in the hose between the toilet and vacuum tank. Retighten the connections or replace hose as necessary.

➢ Part 3: How to identify a leak in the orifice in the bottom of the base

1) Reinstall vacuum hose on the toilet outlet.
2) Turn off incoming water and prop open flush valve in toilet.
3) Insert rubber plug into the orifice in the bottom of the base (A).
    - If time between pump cycles increases or no vacuum drop is recorded in test gauge, the vacuum leak is in the toilet seals or rotor shaft.
    - If time between pump cycles remains the same or a vacuum drop is recorded on test gauge, the leak is in toilet outlet fittings or funnel. Replace funnel, or repair/replace fittings as necessary.

➢ Part 4: How to identify a leak in the vacuum tank outlet

1) Reinstall vacuum hose to vacuum tank inlet.
2) Shut off power to vacuum pump
3) Remove hose from vacuum tank outlet (E).
4) Insert rubber plug into vacuum hose.

5) Turn on power to vacuum pump.
6) Shut off vacuum pump at about 10 inHg on test gauge.
    - If no vacuum drop is recorded, the leak is in the vacuum tank. Tighten or reinstall fittings as necessary.
    - If a vacuum drop is registered, go to Part 5.

➢ Part 5: How to identify a leak in vacuum pump

1) Reinstall vacuum hose to vacuum tank outlet.
2) Remove hose from inlet on vacuum pump (F).
3) Insert rubber plug into inlet of pump.
4) Turn on power to vacuum pump.
5) Shut off vacuum pump at about 10 inHg on test gauge.
    - If a vacuum drop is recorded, inspect the valves and fittings in the pump. Tighten or replace as necessary.
    - If no vacuum drop is recorded, inspect the hose between vacuum tank and pump. Tighten or replace as necessary

f) Maintenance of the vacuum tester

With age the rubber cone of the vacuum tester can deteriorate.


We have received a lot of enquiries from technicians and engineers asking whether there is a kit to replace the rubber of the cone.

The cone is not available as a spare part, but DAHLBERG S.A can supply a combination of the rubber cone and a flexible tube, as shown in the picture below:

Fuentes:

- DAHLBERG S.A.
- Dometic
- Adinet

DAHLBERG S.A.

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