Degassing Effect in Water
- Sterilizing Effect -

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Abstract

Present ultrapure water making system requires a very high maintenance cost. One reason is its design philosophy with bacteria propagation in the system: kill bacteria in the system and filter the dead bodies. Filters in the system block frequently by the dead bodies and have to be exchanged so often. Deoxidization of water eliminates the condition for bacteria to be alive. Using this method, the maintenance should become very simple and cheap. In this paper we investigated quantitatively the effect of deoxidization of water on sterilizing and TOC level.

1. Introduction

Ultrapure water has a very important role in the superconducting rf cavity technology. For sc cavities to have an excellent performance, the surface must be clean without particle contamination. Ultrapure water is very useful to make such a surface. This technology is well established in the semiconductor technology. This field has a very big market in the world. The maintenance cost of ultrapure water making system (UWMS) is very expensive, but it is not a so big problem in the semiconductor technology due to the big market. When use ultrapure water in SRF cavity technology, its used frequency is quite less: the using efficiency is less than 5 %, so that the maintenance cost becomes extremely expensive. We want to change this situation. What is a key to do so ? It is in the present cure against bacteria propagation in UWMS. At the present, bacteria in UWMS is killed by UV lamp set in the system, and filtered by a membrane filter or flashed out with water. Following this method, the filter is blocked by bacteria dead bodies so that one has to exchange it so often. In addition the system has to be kept operation for the flashing. This is a stupid philosophy like "beating moles". Namely bacteria is killed by UV lamp but the other propagates somewhere. This design philosophy is a cause of the expensive maintenance cost. When one deoxidizes water by degassing method and eliminate dissolved oxygen in water, there is no way for bacteria to be alive in the system. This method could make the maintenance very simple. The degassing of water is very easy and very cheap in maintenance cost. So, we propose a new idea of deoxidization of water with degassing method against bacteria propagation. To identify its sterilizing effect, a degassing equipment is installed in our ultrapure water system, and the number of bacteria and TOC level were observed. The number of bacteria in water of 1 ml was reduced to several from initial 80 pieces. TOC was also decreased to 20-80 ppb from 1500 ppb initial. A big sterilizing effect was observed in this method.

2. Experimental setup

At the first, we present the principle of degassing of water, and then the experimental equipment which was used in this experiment.

2-1. Principle of degassing of water

Degassing of water is a very simple method as shown in Fig.1. Evacuating water through a porous film with a proper mesh size, gasses dissolved into water are exhausted. A kind of gas degassed depends on the film, so one has to choose a proper one depending on the gas which he wants to degassed. We have designed and fabricated a degassing system by in-house (Nikkyo Technos Co. Ltd.) using a film with an excellent transitivity (70-90%) for oxygen gas. The degassing capacity is presented in Table 1. It can treat an amount of water of 100 l in one hour. Increasing the capacity is easy. Presently the other system which can treat 1000 - 5000 l /hr is also ready.

2-2. Experimental setup

The degassing system was installed in an ultrapure water making system (UWMS) at KEK. The flow diagram of the UWMS is described in Fig. 2. This UWMS consists of two parts : 1) pure water making system (60 l/hr) as pre-system for ultrapure water, which is the Milli-RO 60 system with a reversible osmotic film (Millipore Japan Co. Ltd.), 2) ultrapure water making system (8 l/min), which is the Super-Q system by the same company. We use civil water as raw water to the Milli-RO 60 system. Pure water is once stored in a tank with a volume of 90 l, then pressurized by a pump, and passes through an active carbon filter (AC), an ion-exchange filter (DI) where ionized contamination is removed, and finally a membrane filter (MF) where the particulate contamination or bacteria with the size bigger than 0.1 μm is filtered. Here, ultrapure water with the resistivity of 18 MΩcm is obtained. Then it is brought to the use point in the class 10 clean room, and returns back to the storage tank, if it is not used. In this circulating system, there is no UV lamp. This system is

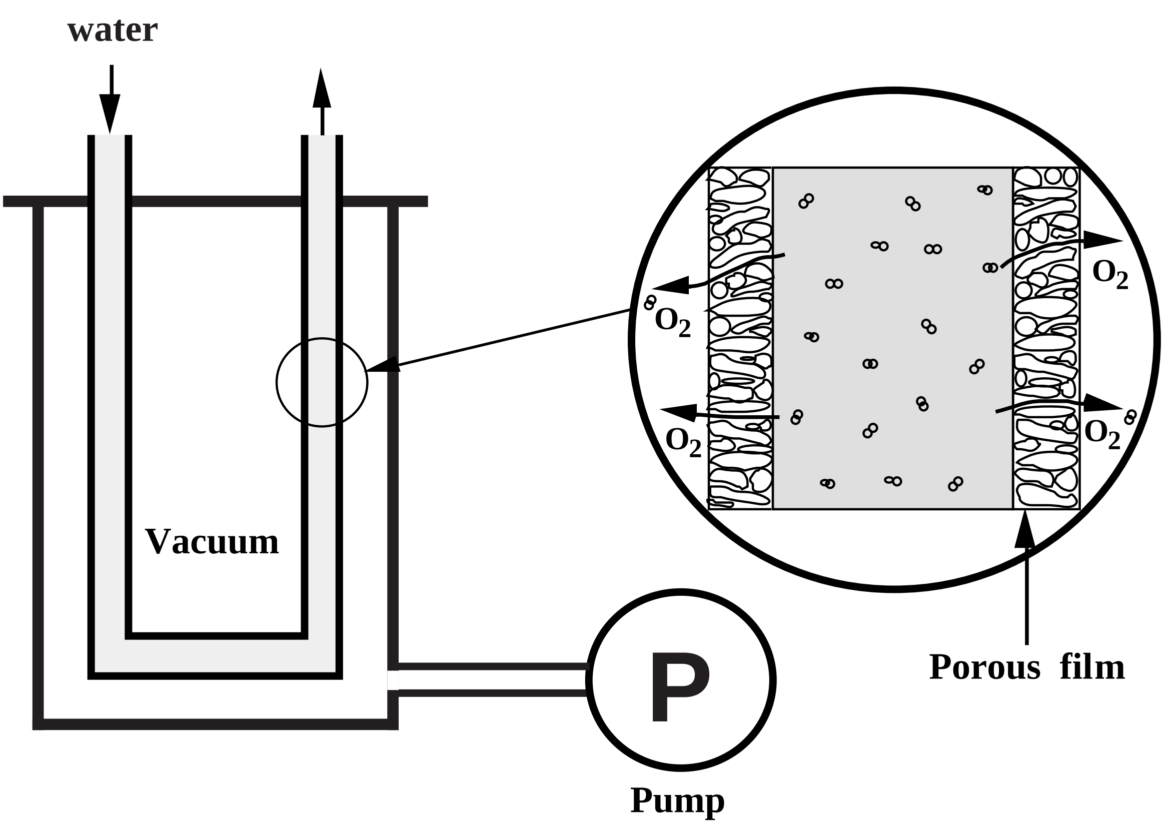

Fig. 1. Principle of degassing of water.

Table 1. Capacity of degassing with used the system.

Flow rate [l/min]	Vacuum control at 40 Torr	Degassing capacity [ppm]	Degassing efficiency [%]
1.6	normal drive	2.25	72
	continuous drive	1.60	80
1.0	normal drive	1.80	80
	continuous drive	1.00	78
0.5	normal drive	1.35	88
	continuous drive	0.75	91

Flow resistance : Approximately 0.8 kg/cm^2 (1.6 l/min at water).
Degassing capacity : Using water at 25 ^{o}C.
Initial dissolved oxygen value is 8.11 ppm.

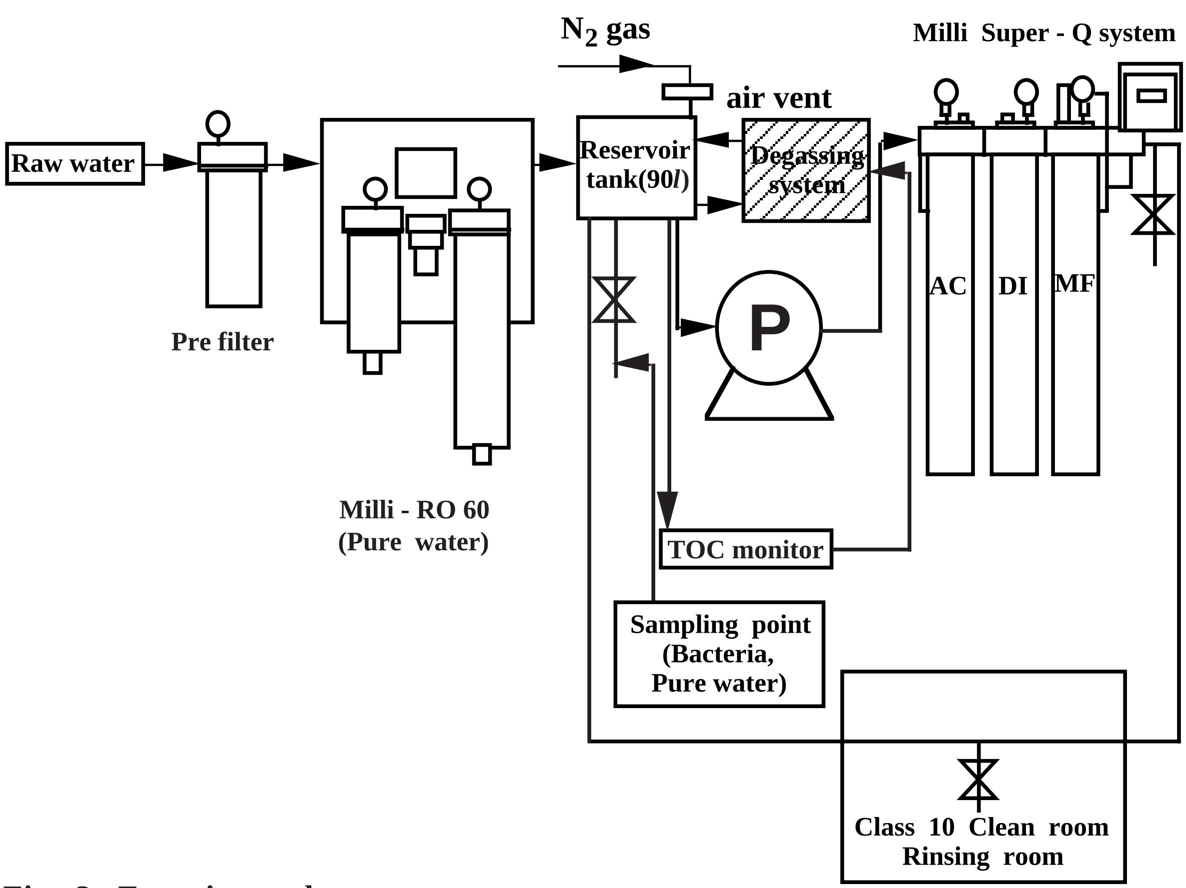

Fig. 2. Experimental set up.

Table 2. Water quality at a half year passed after completing the system.

Inspected items	Unit	Sampling point outlet Super-Q	Sampling point Clean room
TOC	ppb	1516	1750
Bacteria	pieces/ml	84	23
Particle >0.1 μm	pieces/ml	240	12 (0.1 μm filter at the use point)

running foe one and a half years. The water quality at a half year passed after completing is shown in Table 2. Water was sampled at the outlet of the Super-Q and the use point in the clean room. Since this system has no UV lamp, TOC level was very high, and also a number of bacteria was detected.

We installed the degassing system in this UWMS to investigate sterilizing effect by oxygen degassing in water. The installed place is presented in Fig. 2. Water in the storage tank is circulated continuously through it so that degassing process is kept operation. TOC level was monitored in real time at the tank. This monitor was the model A-1000 from Anatel Co. Ltd., and has an excellent sensitivity to several ppb. Water sampling is also done at the tank to count the number of bacteria.

3. Effect of oxygen degassing in ultrapure water system

Deoxidizing water by the degassing equipment, most of aerobic bacteria would suffer from oxygen starvation and die. Death or a reduction of propagation of bacteria would make TOC level low in the water. The purpose of this experiment is to see quantitatively degassing effect on sterilizing and TOC reduction.

3-1. Sterilization effect of deoxidization by degassing method

The number of bacteria in pure water is measured with a culture kit : MHPC 100 - 25 (Millipore Co. Ltd.). A fixed amount of water was sampled in a cup of the kit which a culture material was put, and kept for 30 seconds, then dumped the water. In this procedure one milliliter of water is absorbed in the culture material. The cup was sealed for 48 hours at a constant temperature of 25-35 ^{o}C. After then, the number of colony appeared on the culture material is counted by the naked eye.

At first, the degassing equipment was operated for a while, but the resistivity of the ultrapure water became very low. We stopped the UWMS for one and a half months to exchange the AC and DI filters. This degradation of water quality is not sure whether it was owing to the operation of degassing equipment or filter lift limit itself. The first bacteria counting was done for the water remained in the degassing equipment during this stop. The number was 167 pieces / ml. After that, UWMS only was started to operate. Degassing system was still stopped. The second bacteria counting was done at the storage tank after 72 hours operation of UWMS. The number was 201 and not so much different from the first one. After the measurement, we started to degas. After this, intermittent bacteria counting was done in every proper time at the same sampling point as the second one. The result is shown in Fig.3. At the first stage, the number of 201 / ml pieces was detected but it reduced to 16 pieces / ml by one hour degassing, and finally it saturated to around 10 pieces / ml. An additional experiment was repeated to see the reproducibility of the result. After the first experiment, we switched off the degassing system for two days and the UWMS was operated for that time. Then, we started again to degas. The number of bacteria just after the operation was 47 pieces / ml but it reduced to 14 pieces / ml in two hours. After 7.5 hours operation, it was 3 pieces / ml. Thus, we observed a clear correlation between the reduction of bacteria and the oxygen degassing time. Later we installed an oxygen density monitor in this UWMS to see the ability of deoxidization with this degassing equipment. The oxygen level less than 0.1 ppm was reached by this degassing equipment.

We have not an enough data yet about the correlation between the oxygen density and bacteria reduction, however, roughly saying the oxygen density which bacteria dies would be about 0.5 ppm.

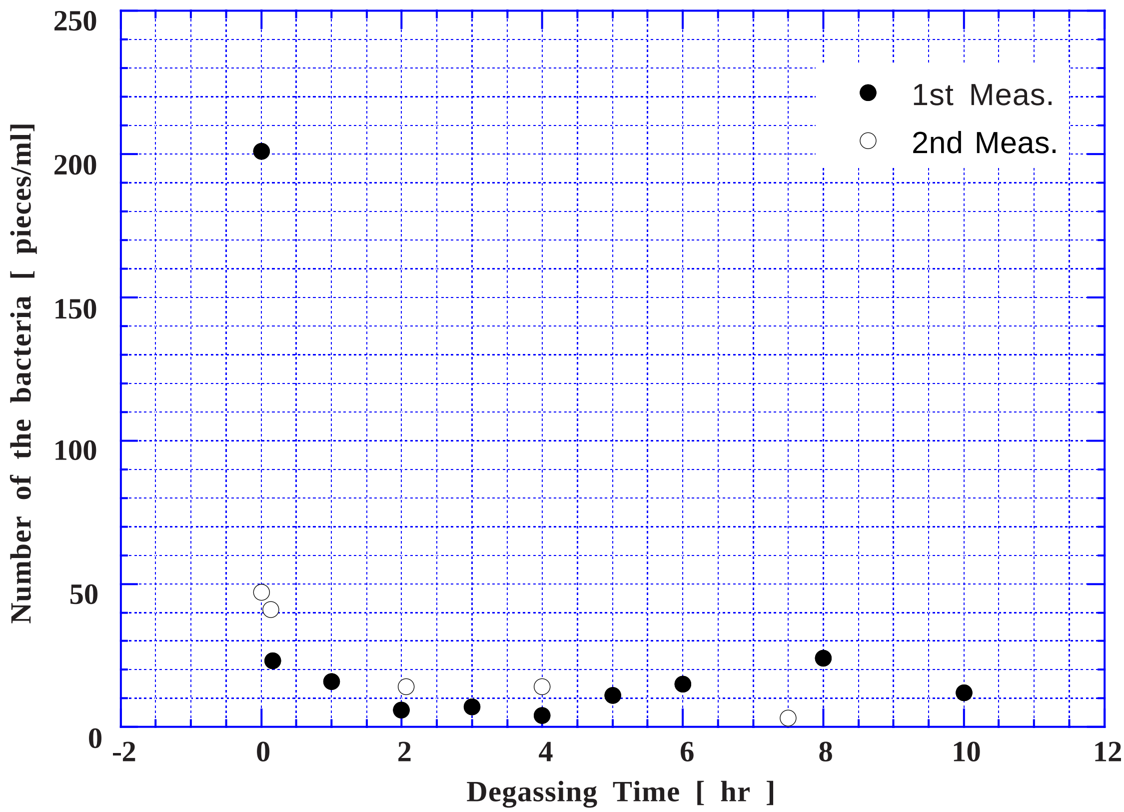

Fig.3. Relationship between degassing time and number of bacteria in water.

3-2. TOC reduction due to deoxidization

Next, let's see the effect on TOC reduction by deoxidization. The experimental result is shown in Fig. 4. This figure shows a correlation between the operation time of the degassing equipment and TOC change in water. Before the operation, TOC level was 220 ppb. When the operation started, it increased to 400 ppb after a several hours. On the other hand, the number of bacteria was reduced as mentioned above. So, this TOC degradation would be that bacteria was killed by deoxidization and the dead bodies were counted as the TOC level.

Then, we stopped the operation for two days. TOC increased from 400 to 2000 ppb. This would be owing to propagation of bacteria, actually the number of bacteria increased from 13 to 43 pieces / ml in this pause. After this, degassing was started again. TOC was remarkably decreased to 120 ppb, then gradually degraded to 200 ppb. Here, operation was stopped again to watch TOC change without degassing. TOC was kept at 200 - 300 ppb and does not changed so much in this period. The equipment was again switched on, we observed once a tendency for the bacteria number to decrease by degassing, but again it saturated around 200 ppb. Here, we thought that it was difficult to remove dead bodies of bacteria by just circulation of water, namely we needed to exchange water in the storage tank. Introducing nitrogen gas in the tank, we exchanged water. TOC level became worse and we tried again to exchange water, the effect became getting clear. So we repeated the procedure. At the 4th exchanging, TOC level was improved to 20 ppb once, then gradually became worse and saturated around 80 ppb. After that, we exchanged water several times but the situation was same as the 4th exchanging. After 8th exchanging, we watched TOC level. The UWMS was let as alone for one week, however, TOC was kept at 80 ppb very stably. TOC level was 1500 - 1800 ppb initially in this experiment. This number of 80 ppb is remarkably low comparing to this number. So, we believe this is owing to deoxidization by the degassing equipment.

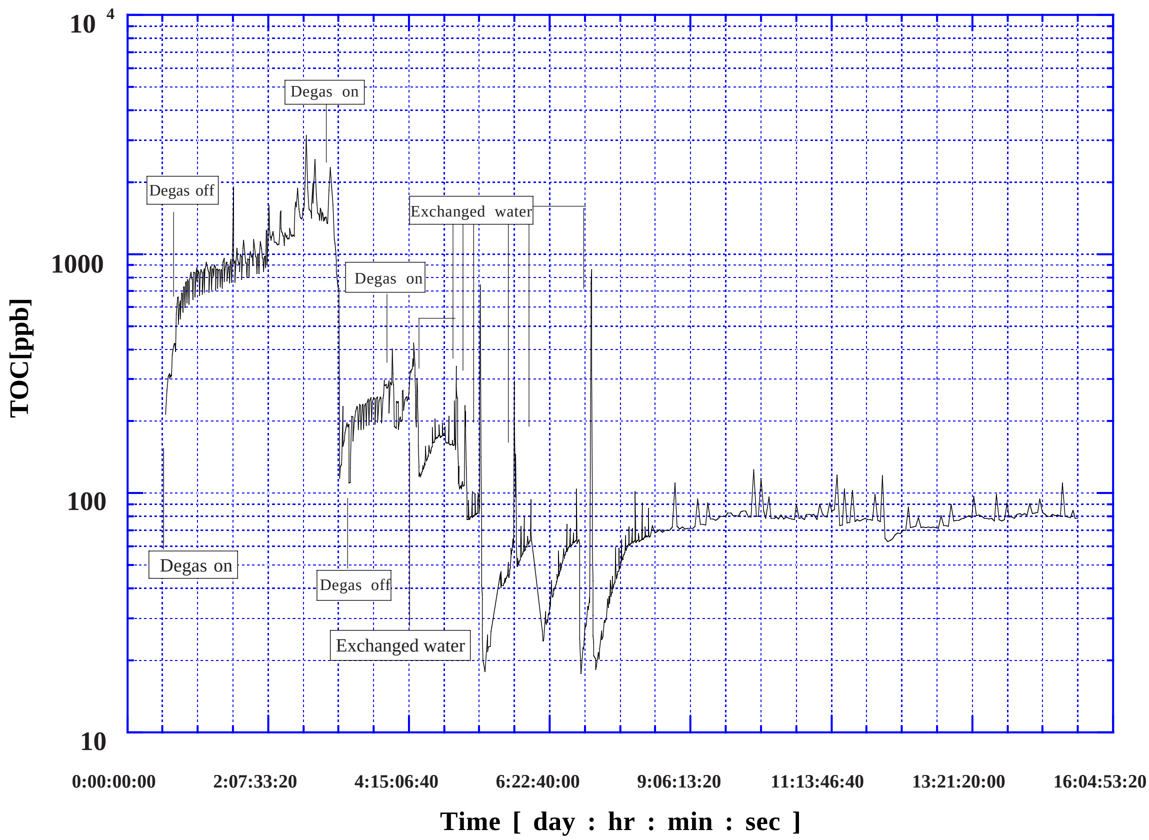

Fig.4. Relationship between degassing time and TOC level in water.

4. Spreading effects of degassing method

Degassing is already applied to a preparation for silicon wafer in order to prevent oxidation during cleaning procedure[1]. Here, we propose several applications to the accelerator technology.

4-1. Cost saving on the maintenance of ultrapure water system

Until now UWMS has been designed based on the philosophy : bacteria propagates in the system and UV lamp is used to kill it and to filter the dead body with a membrane filter for TOC level not to degrade. Blocking in the filter is inevitable by this philosophy and one need to exchange filters frequently in the maintenance. Sometimes flashing a part of the circulating water in the system is needed to take out efficiently dead bodies of bacteria. Flashing water requires to continuous operation, even if it is not used. These bring an expensive fee to the maintenance. Actually we has spent a lot of money every year to keep our large UWMS which was constructed for the TRISTAN-I superconducting RF cavity project. A large cost saving is possible, if one abandons this philosophy like "mole beating". If one stands the philosophy, in which he makes bacteria never propagate in his UWMS, he does not need to exchange filters or flashing water. Deoxidization of water can offer such a method. Namely deoxidization of water gives a condition for bacteria not to be alive, so that filter life is prolonged or water flashing is not necessary in UWMS. That will remarkably reduce the maintenance cost .

4-2. Reduction of water volume used in high pressure rinsing

Recently high pressure water rinsing (HPR) is widely used in superconducting RF cavity technology to remove particulate contamination on cavity inner surface against field emission [2]. HPR is a breakthrough technology for cavities. However, there is a problem to use a large volume of water (e.g. 1 ton for a L-band single cell cavity). Now we do not reused the dumped water in HPR. If water is reused, the volume of water becomes very little. Using filter, it will be possible because water used in HPR has no chemical contamination. A main question is propagation of bacteria, because the water has to be circulated. Using an UV lamp and membrane filters against bacteria propagation, the same problem as mentioned before will happen. However, it can be solved by using the degassing equipment. In conclution, we could say that if one uses degassing, he can reduce remarkably a volume of water in HPR. This is important for the countries poor in civil water.

4-3. Oxidation free HPR for normal conducting RF cavities

Metal surface is oxidized by usual HPR. This is no problem for niobium cavities because it has a thin naturally oxide layer (Nb_2O_5). However, for the other material like copper, surface is sometimes oxidized thicker and a color change appears. We have no answer about how it influences on the cavity performance, but usually everybody worries about it. Using degassing, such a worry could be eliminated. Normal conducting people will be happy to get oxidation free HPR.

5. Summary

Installing a degassing equipment in an ultrapure water making system, its effects on sterilizing bacteria and TOC reduction are investigated quantitatively. The number of bacteria was decreased by one or two figures by this method. TOC level also remarkably decreased. This simple and low cost method will bring a large benefit to the accelerator technology which is bothered with expensive maintenance cost in the ultrapure water making system. And also, it will open a spread application of high pressure water rinsing to normal conducting accelerators.

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