Lining Tank (Application)

1. Introduction

Following on from the previous article on "Lining Tank" (Basic version), this article will overview the "Application".

In the basic version, we have described the types and characteristics of fluoropolymers, the fluoropolymer sheet lining process, and the basic points to note in the design of fluoropolymer lining tanks, etc. This time, we will introduce the characteristics of our sheet lining process and the sheets for lining that we handle.

2. Characteristics of our lining processing method

This article describes the manufacturing process of our high-purity fluoropolymer lining tanks, characteristics of our processing technology.

2-1) Reformation and attachment of fluoropolymer lining sheet to the head part

Fluoropolymer lining tanks generally have a fluoropolymer sheet attached to the metal can of the outer shell. The sheets are rolled up and cut into strips for use. Strips of the sheet can be attached as is to the body part of the can, but the head part has a curved surface and it is difficult to attach strips of sheet, so the sheet is attached in several equal parts.

In our attachment method, the lining sheet of the head shape is heated and molded before use.

By processing the lining sheet for the head in advance, it is possible to:

- The combination of the vacuum attachment method described below and the reforming attachment of the sheet to the head reduces the amount of scraping to the sheet surface when attaching the sheet, and drastically reduces scratches on the surface and contamination of the sheet.
- The sheet before reformation is processed into a square, and there are few welding lines. This reduces the risk of problems such as broken welds.
- The reformation temperature is higher than the vulcanization temperature of the adhesive, so there is less residual stress in the sheet.

This reduces the risk of adhesive peeling problems.

The above three effects could be expected.

Figure1 Tanks made by other manufacturers

Figure2 Our liner

Figure1 shows a lining tank constructed by another company. There are many weld lines on the head at the bottom.

Figure2 shows the liner of the head part with our heating reformation and there are no weld lines.

The liner of a tank with an internal diameter of more than 1200 mm will have one or two welding lines as shown in Figure3.

Figure3　The liner in the head part of a large tank

The maximum internal diameter for head part reformation is ϕ2800. Three sheets are connected by 2 automatic welding lines and reformed. The connection between the head liner and the body liner is also welded automatically because the head liner reaches the body.

2-2) Vacuum attachment method with fewer scratches on the sheet surface

The vacuum attachment method is a method in which a flat sheet or a head molded sheet is placed along the body of a can, and the air between the back of the sheet and the body of the can is removed to create a vacuum, so that the lining sheet is pressed against the body of the can at atmospheric pressure and could be bonded without scraping.

In this attachment method：

- Reduces the scratches on the surface of the sheet and contamination of the sheet.
- Makes it possible to bond evenly and the bonding strength is stable.

The above two effects could be expected.

2-2-1) Appearance of head part attached by vacuum attachment method

Figure4 shows an image of the scraping attachment method used by other companies.

Figure5 shows an image of the vacuum bonding method which our company developed.

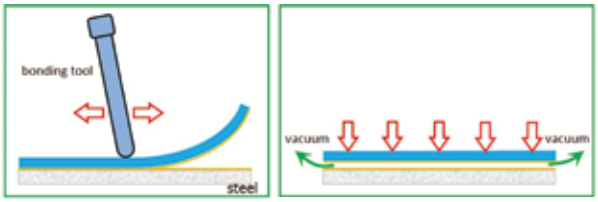

Figure4　Rubbing Attachment　Figure5 Vacuum Attachment

In the conventional method of attaching the sheet, a scraping jig press the liner against the tank. This causes abrasion scratches on the entire surface of the liner.

In vacuum bonding, it was realized that the sheet is pressed against the tank at atmospheric pressure, so only a small portion of the sheet, such as the edge of the sheet, is scraped, and the scraped area is greatly reduced.

Figure6 shows a photograph of the head part attached by the vacuum attachment method, and Figure7 is a magnified photograph.

Figure6　Head of a tank with liner attached by vacuum bonding

Figure7　Enlargement of the surface of our liner

2-2-2) Surface roughness after lining

The following are the results of comparing the liner surface of a tank head when “attachment by scraping” is used and “head reforming + vacuum bonding” is used to attach using M－PTFE sheets.

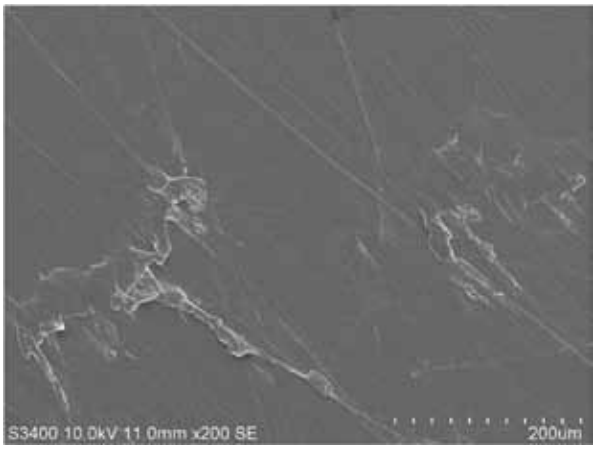

Figure8　Electron micrograph of the scraped area

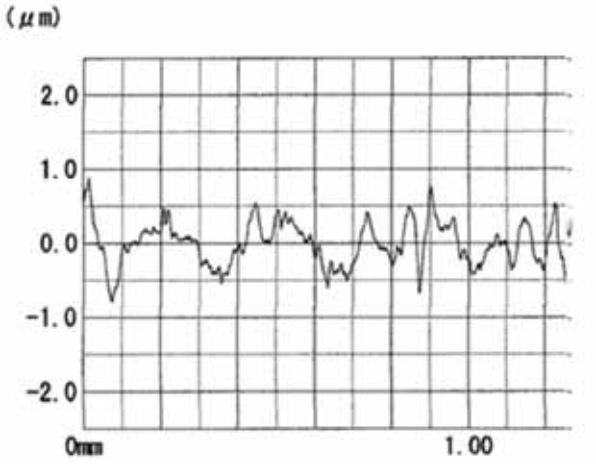

Figure9　Liner surface of our company (Ra 0.25μm)

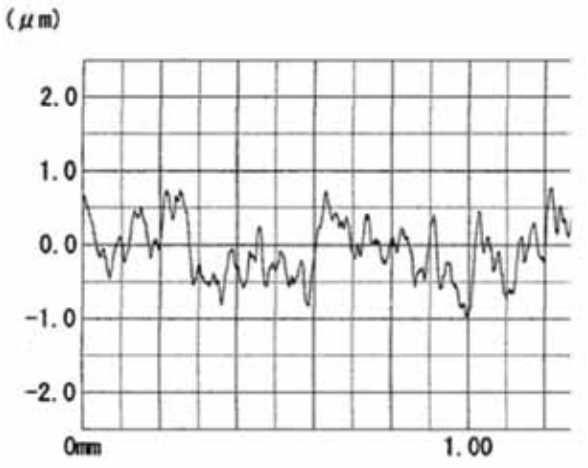

Figure10　Liner surface of another company (Ra 0.34μm)

Figure9 shows the surface roughness of the lining tank processed by the vacuum bonding method, and it was Ra 0.25μm.

Figure10 shows a graph of measurements of the surface of a sheet with conventional attachment, and it was Ra 0.34μm.

2-3) Stable quality by mechanized welding

Figure11 shows the cross-section of the welded part of the liner.

The liner of the lining tank is joined by PFA welding. There are two stages of welding: beveling at the end of the liner, followed by priming welding with PFA rods, and then band welding (reinforcement welding) using PFA strips.

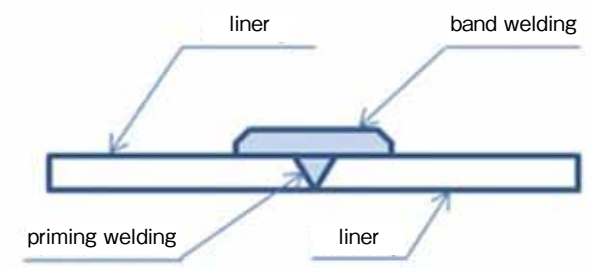

Figure11　Cross-sectional shape of band weld

We use self-propelled welders (automatic welders) for welding strips to stabilize "temperature", "speed" and "pressure", which are important conditions for welding. As a result, compared to manual welding by operators, the welding conditions were more stable and the strength variation significantly reduced.

In addition, it is now possible to weld strips with less undulation, meandering, and deformation of the welding line.

Furthermore, while other companies use a 14 mm width for manual strip welding, we have increased the strip width to 17 mm through mechanization to improve the welding strength and increase the welding part's reliability.

Figure12 Welding with an automatic welding machine

Figure13 Our product - Automatic welding (M－PTFE－ET)

Figure13 shows a strip weld done by automatic welding, which is wider and has less meandering.

2-4) Safety design of the component structure

2-4-1) Nozzle structure

The tube part of the nozzle is a part that has many problems with welding because it is difficult to adhere it tightly to the body of the can.

Other companies use a structure where the expansion and contraction stresses of the liner due to temperature changes are directly applied to the weld, as shown in Figure14. As shown in Figure15, the inside of the tank is also flare processed, and this flared part receives the stress, so the welding part is not subjected to expansion and contraction stress.

Figure14 Nozzle activity and loss examples due to temperature change

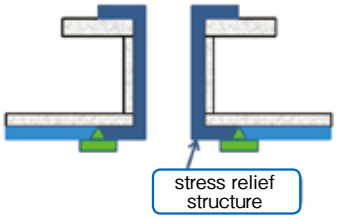

Figure15 Our nozzle construction method

2-4-2) Liquid collection cup structure

The structure of the liquid collection cup at the bottom of the tank is the same as that of the nozzle.

Figure16 Lining around the liquid collection cup is detached

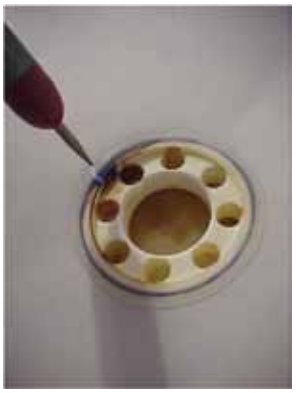

Figure17 The cause is damage to the weld between the collecting cup and sheet

Figure18 Examples of construction by other companies

Figure19 Our construction method

3. Selection of lining material

We use three types of materials of fluoropolymer lining sheets, PTFE, PFA, and M－PTFE. Two types of sheets are used for the adhesion method: chemical-etched sheets with fluoropolymer surface that is chemically processed and glass-backed sheets laminated with glass cloth sheet.

3-1) Functionality evaluation of our lining sheets

The following table shows an in-house evaluation of the five functionalities of our lining sheets on a 5-point scale.

Evaluated sheets

PTFE-ET : PTFE chemical-etched sheet

M-PTFE-ET : Modified PTFE chemical-etched sheet (PLP Sheet)

M-PTFE-GB : Modified PTFE glass-backed sheet

PTFE-GB : PTFE glass-backed sheet

PFA (NEW) -GB : PFA glass-backed seat

PFA (HP-PLUS) -GB : PFA glass-backed sheet

Evaluation details

Surface smoothness : Indicates the quality of dirt removal during washing.

Adhesion performance : Indicates the quality of the adhesive strength between the sheet and the adhesive.

Welding performance : Indicates the welding reliability of the sheet's connecting parts.

Permeation resistance : Permeation resistance to chemical solutions. Affects the life expectancy of chemical solution permeation.

Price : Indicates the quality of the cost of the sheet.

Table1 Functional evaluation of sheets for lining

evaluation: (excellent) 5・4・3・2・1 (poor)

lining sheet	surface smoothness	adhesion performance	welding performance	permeation resistance	price
PTFE-ET	3	3	3	4	5
M-PTFE-ET	4	3	4	5	4
PTFE-GB	3	3	3	2	3
M-PTFE-GB	4	3	4	4	2
PTFE-GB	5	3	5	3	2
PFA (HP-Plus) -GB	5	3	5	4	1

Note 1 ET: Etched sheet, GB: Glass Backing, M: Modified.
Note 2 Values are rated on a 5-point scale to indicate the quality.

3-1-1) Surface smoothness

The following is a photograph of the surface of three types of lining sheets made of different materials and surface roughness

Figure20 PTFE－ET×100

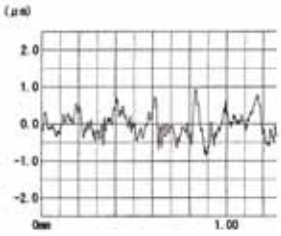

Figure21 Ra 0.29μm

Figure22 M－PTFE－ET×100

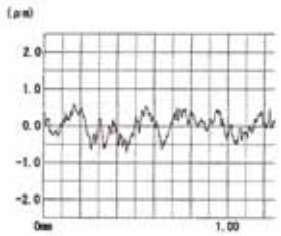

Figure23 Ra 0.24μm

Figure24 NEW PFA×100

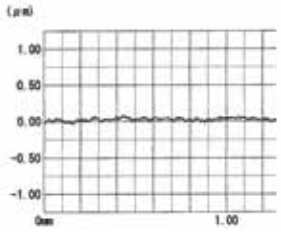

Figure25 Ra 0.03μm

PTFE : Highest surface roughness.

M-PTFE : Surface roughness is slightly lower than PTFE.

NEW PFA : The surface is the smoothest.

This measurement is at the stage of the sheets, and the surface roughness Ra after lining varies greatly due to the difference in lining construction methods described above.

3-1-2) Adhesion performance

Fluoropolymers are non-adhesive, so even if an adhesive is applied to a fluoropolymer sheet, it will not stick and peel off.

To add adhesiveness to fluoropolymer sheets in our etching processed sheets, chemical etching is conducted to add adhesiveness after the sheets are

manufactured.
On the other hand, glass-backed sheets are made by anchoring fluoropolymer sheets and glass cloth sheets by melting PFA between them to make them adhesive.

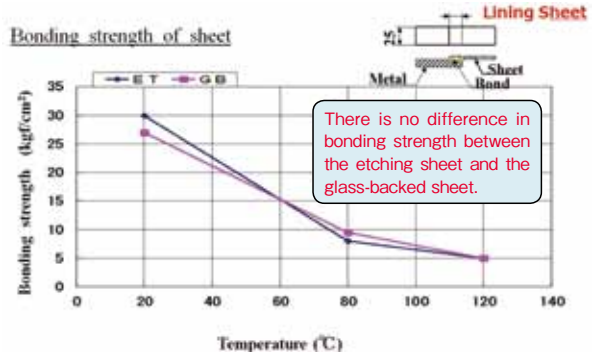

Figure26 Bonding strength (shear) of ET sheets and GB sheets

Figure26 shows the shear strength test results of ET sheet and GB sheet bonded to metal using rubber adhesive.
The peeled areas are all metal surfaces and have the same adhesive strength.

3-1-3) Welding performance

Figure27 shows a comparison of the weld strength of the lining sheets.

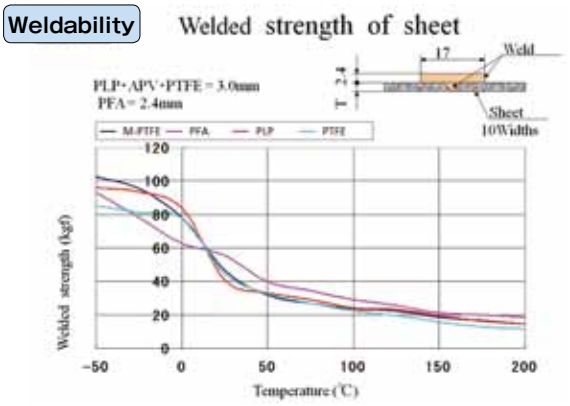

Figure27 Results of weld strength measurement

(PLP : this is a sheet of M－PTFE, but a sheet manufactured by our company with improved permeation resistance.)
There is no significant difference in the weld strength of all sheets in the temperature range where they are generally used. However, the PFA sheet, which is the same as the welding rod and strip material, could theoretically be said to have better fusion during welding and higher welding stability.
Guessing from the fluoropolymer material (molecular structure), the welding stability would be PFA> M－PTFE>PTFE.

3-1-4) Permeation resistance

It is known that the permeation of chemicals occurs mainly in the amorphous part inside the polymer.
Figure28 schematically depicts the crystal structure of a fluoropolymer sheet in the cross section.

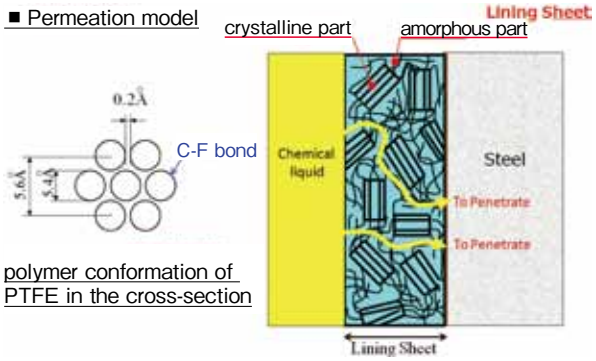

Figure28 Image of chemical permeation into fluoropolymer

The part where molecules are lined up orderly fashion is the crystalline part, and the part where molecules are intricately intertwined is the amorphous part.
The crystalline part is densely packed with molecules and has a high density.
The amorphous part has a low density due to the entanglement and random arrangement of molecules.
Therefore, the more crystalline the sheet, the greater the specific gravity.
The chemical permeates through the amorphous part and gradually diffuses through the sheet. Eventually, it reaches the body side of the can, which is the back side of the sheet with the adhesive surface.

Figure29 shows the specific gravity of fluoropolymer and the amount of hydrochloric acid permeation. The graph also shows the specific gravity of fluoropolymer sheets available on the market.

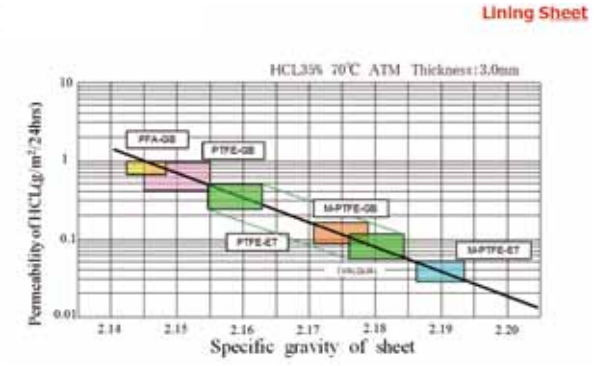

Figure29 Permeability against the specific gravity of fluoropolymers

This figure shows that the amount of chemical permeation decreases with the specific gravity.

PTFE gelate can retain its shape even if it exceeds the melting point. So it is possible to control the cooling conditions that affect crystallization. This characteristic can be used to control the degree of crystallization.

The specific gravity of PTFE generally available on the market, considering productivity is about 2.14 to 2.16. However the specific gravity of our sheets for lining is finished to about 2.18 to improve permeability. PFA is a molten polymer, and it is difficult to control the cooling conditions due to its molding method, so the specific gravity is generally in the range of 2.14 to 2.15.

Figure30 shows a cross-section of M－PTFE－GB sheet.

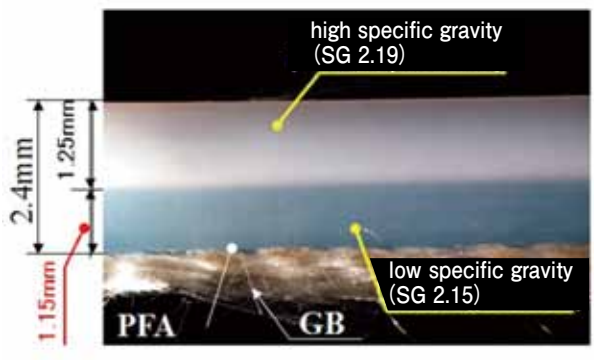

Figure30 Cross-section of M－PTFE－GB sheet.

It is necessary to gelate the sheet when laminating the glass cloth to the sheet to produce PTFE－GB and M－PTFE－GB sheets. Cooling is conducted after gelation, but the specific gravity decreases because of the difficulty of slow cooling.

The translucent part on the GB side is shown in the photo where the specific gravity has become low.

Figure31 shows a cross-section of our PLP sheet.

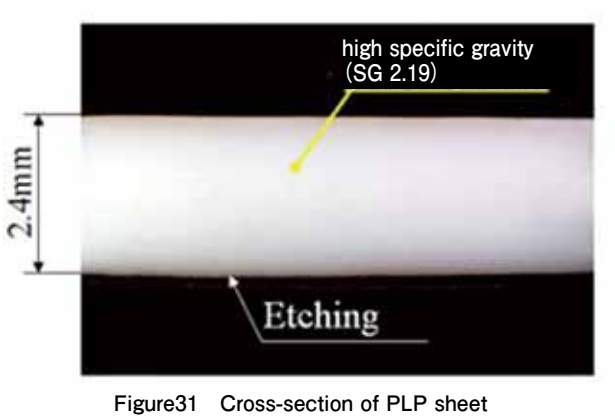

Figure31 Cross-section of PLP sheet

PLP sheet is a polymer that could be denser than PTFE, and since the etching process that does not require heat treatment that could gelate the sheet, without lowering the specific gravity.

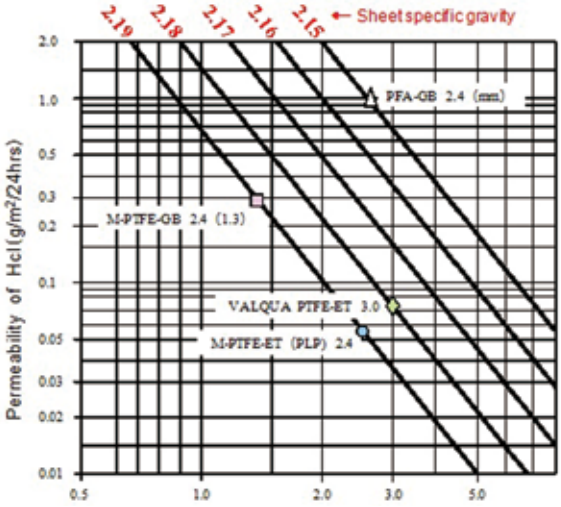

Figure32 Specific gravity, thickness and permeability of fluoropolymers

This figure shows that the thickness of the sheet is also an important factor in permeation resistance.

3-1-5) Price

Figure33 shows the relationship between the surface smoothness of the lining sheet and the market price of the lining sheet, and Figure34 shows a schema of the relationship between surface smoothness and

permeation resistance.
The right side of the horizontal axis indicates higher functionality, and the upper side of the vertical axis indicates higher cost.

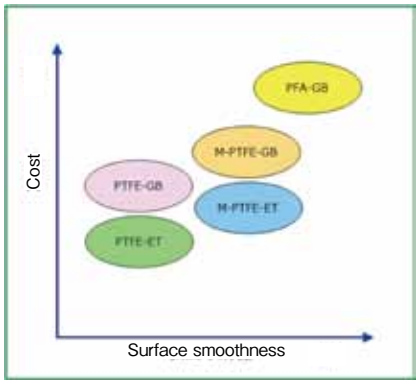

Figure33　Surface Smoothness：Cost

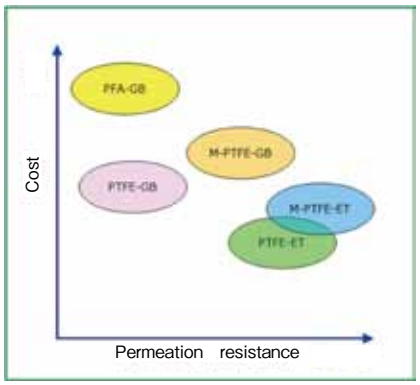

Figure34　Permeation Resistance：Cost

The cost of fluoropolymer raw materials is：
PFA＞M－PTFE＞PTFE
The cost of providing adhesion is ET＞GB.
The surface smoothness of the base sheet is PFA＞M－PTFE＞PTFE.
This is due to the different characteristics of the raw materials and the processing methods used to make the sheets. However, the method of lining attachment also needs to be considered.

4. Conclusion

Since the start of lining tank production, our company has responded with any queries from our customers regarding our product defects. We always inform our customers if there is any update regarding our production method. Although the causes of abnormalities differ, they could be roughly classified into three categories.
These are "chemical permeation," "unexpected structural defects," and "inexperienced construction techniques". We have been investigating the causes of each problem and making improvements.

For example, for chemical permeation, we have been working on selecting materials for lining sheets and increasing the density of the sheets. For structural problems, we have been working on design methods of the body of the can and improvement of the nozzle structure as described in the previous article. For construction technology, we have been working on the automation of welding strips.
With the rise of the semiconductor industry, cleanliness, which was not a requirement for chemical plants, has become more important, and the development of vacuum bonding and head liner molding technologies enabled us to reduce scratches to the liner surface as much as possible.
We will continue to strive to develop new technologies to meet the demands of the market.
Our next article will introduce an overview of the technologies we are currently working on and our future goals.

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