Performance Testing HydroGel Against Osmotic Blistering Risk Criteria

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Abstract

The HydroGel composite waterproofing system was evaluated for resistance to osmotic blistering by two methods. Inverted wet cup permeance testing was performed by a modified version of ASTM E-96, resulting in a measured rate of 0.023 perm. The tendency for the system to absorb water was measured by a long-term water immersion study based on ASTM D570. After greater than 1 year, the system was found to have gained about 3.3% of its original weight by water absorption. Taken together, the permeance testing and water absorption results meet waterproofing industry expert criteria for systems that are expected to be resistant to failure by osmotic blistering (permeance of < 0.1 perm, and long-term water absorption of < 5%).

Introduction

Waterproofing membranes are important components of the building envelope, as they protect building materials and structures from intrusion of moisture by external contact with liquid water including rain, irrigation, or groundwater. There is a vast range of products available for building waterproofing, including sheets, liquid-applied membranes, and composite systems combining both sheets and liquids. They can incorporate a wide range of materials including thermoplastics (e.g. HDPE sheets), modified bitumen, polyurethanes, and various polymer asphalt emulsions. Each type of material and approach has advantages and disadvantages in terms of cost, installation, compatibility with other building materials, and long-term waterproofing performance.

Waterproofing systems are intended to last the life of a structure. It is extremely important that the types of materials and the installation details are matched with the expected site conditions and the expected longevity of the system. Common failure modes for sub-optimal waterproofing systems include punctures, delamination, tears, or seam failure. Over the past 30 years, some liquid-applied waterproofing membranes have been observed to fail by a process known as osmotic blistering.[1-4] This occurs when a waterproofing membrane is separated from its concrete substrate as water passes through the membrane due to osmosis, driven by the partial permeability of the membrane to water and a high concentration of salt ions at the membrane/substrate interface (Figure 1).

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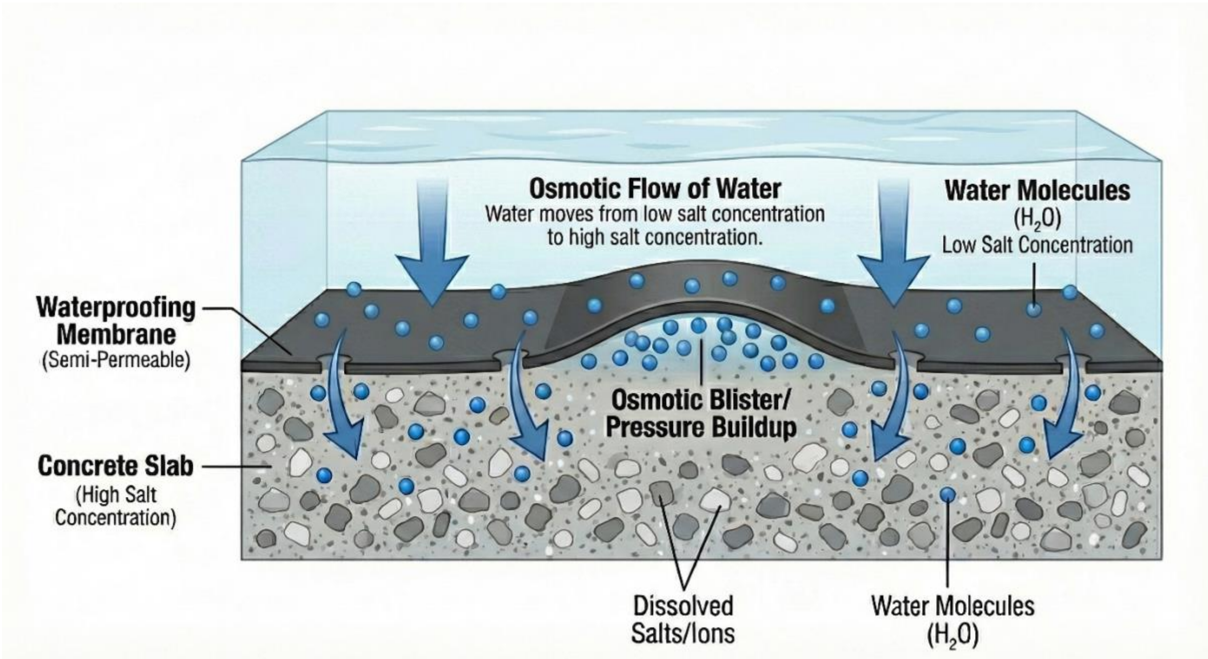

Figure 1. Diagram of osmotic blistering, which can lead to waterproofing membrane failure

Waterproofing systems that incorporate a liquid-applied component can have distinct benefits for ease of installation and cost. However, depending on their composition and how the system is constructed, some liquid-applied membranes may be susceptible to failure by osmotic blistering when in contact with liquid water for extended periods of time. An example of a liquid membrane exhibiting osmotic blistering is shown in Figure 2.[3]

In recent years, thorough studies have been published on the osmotic blistering phenomenon, and a variety of waterproofing products have been tested. Through this detailed work it has been determined that the tendency of a waterproofing membrane to blister through osmosis can be determined by either custom laboratory osmosis testing, or by proxy through testing water absorption and wet permeance of the membrane or system.[1]

Figure 2. Membrane exhibiting osmotic blistering (Finch 2014)

Water absorption is tested by measuring weight gain of a membrane sample immersed in water over a long period of time (months to years). This approach employs a modified method based on the ASTM method D570,[5] for testing the water absorption of plastics. Through immersion testing, previous work has concluded that samples which absorb less than 5% of their mass after long term immersion should have a low risk of osmotic blistering.[1]

Inverted wet cup permeance testing, a modification of ASTM method E96,[6] involves sealing a chamber containing water, then inverting it such that the water is in direct contact with the waterproofing system. Monitoring the change in water mass over time allows calculation of a permeance rate for the waterproofing system. A diagram of the inverted wet cup method is shown in Figure 3. Research has shown that under these conditions, a permeance of <0.1 Perm indicates the waterproofing system has a low risk of osmotic blistering.[1]

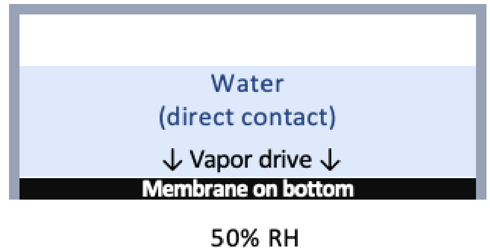

Figure 3. Diagram of inverted wet cup permeance method derived from ASTM E-96

HydroGel is a single component, elastomeric, polymer rubber gel. The HydroGel Composite Waterproofing System combines a liquid-applied polymer rubber gel membrane (HydroGel) with a durable HDPE protection sheet (GFG16). The combination of the monolithic liquid-applied polymer rubber gel with HDPE sheet creates a dynamically responsive and durable composite waterproofing system.

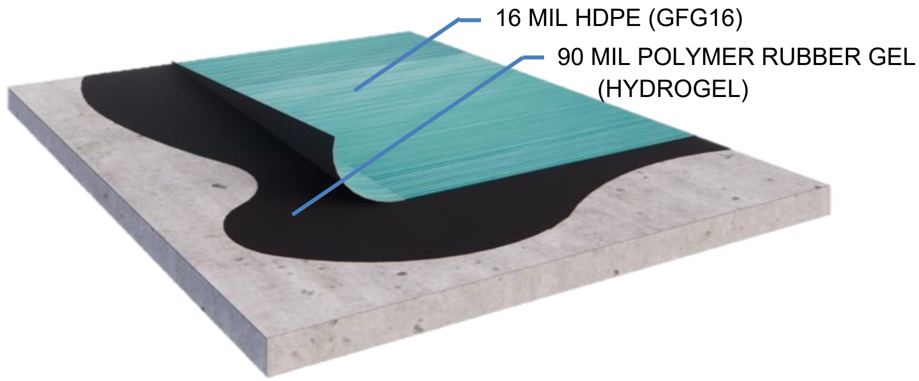

Figure 4. HydroGel composite waterproofing system assembly

There is interest in understanding the potential susceptibility of the liquid-applied HydroGel component of the system to osmotic blistering failure mechanisms. To estimate the performance of the system with respect to osmotic blistering, samples of the HydroGel composite system were tested by modified ASTM D570 and ASTM E96 methods. The work below describes quantitation of the long-term water absorption and wet cup permeance rate of the Hydrogel composite system.

Experimental

Materials: Epro Services, Inc. provided samples of HydroGel (in block form) and sheets of the 16 mil HDPE film product GFG16. Together, these two components form the HydroGel waterproofing system. Two measurement chambers for ASTM E96 were purchased from Thwing Albert (EZ-Cup Vapometer ¾" depth, 2.9375" Diameter, part # 00068-3002). The testing cups are shown in Figure 5.

Figure 5. ASTM E96 testing cups

Inverted Wet Cup Permeance Testing

Sample Preparation: The HydroGel material is highly viscous and sticky at room temperature. The following procedure was performed to prepare each 2.9” diameter circular sample of HydroGel (90 mil) attached to the 16 mil HDPE: Small pieces of HydroGel were hand-separated from the block and rolled into a ball using hands protected with nitrile gloves, until the mass of the HydroGel ball was sufficient to create a 2.9” diameter circle of material with a thickness of 90 mil. A circular piece of HDPE film with a diameter of 2.9” was cut from the GFG16 stock. A flat silicone mat was placed on a laboratory hot plate and heated gently to about 40 °C. The ball of Hydrogel was then placed on the silicone mat. When the ball had softened and spread to approximately 2.75” diameter, the circular HDPE sample was gently laid upon the hydrogel. When the hydrogel was spread evenly underneath the HDPE disk, the mat and sample were placed in a refrigerator at 4 °C. After 24 hours, the cold assembly was removed from the refrigerator. While the sample was still cold, it could be easily peeled away from the silicone mat. The samples were stored on the silicone mat in the refrigerator until use. The samples are shown in Figure 6.

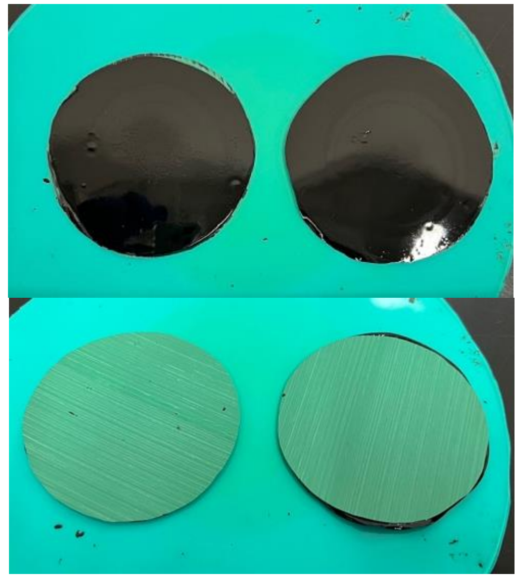

Figure 6. Test specimens as prepared for chamber assemblies (both sides)

Test Procedure: Each chamber was assembled by the following procedure: The cold sample was mounted into the chamber between two rubber gaskets with the HDPE side facing out. The threaded ring was tightened firmly by hand to ensure a sufficient seal. Chamber A (test chamber) was filled with 15 mL of water prior to assembly. Chamber B (blank specimen chamber) was assembled empty, and was monitored to account for any small mass changes inherent to the chamber, environmental conditions, and barrier materials. The assembled chambers are shown before and after inversion in Figure 7.

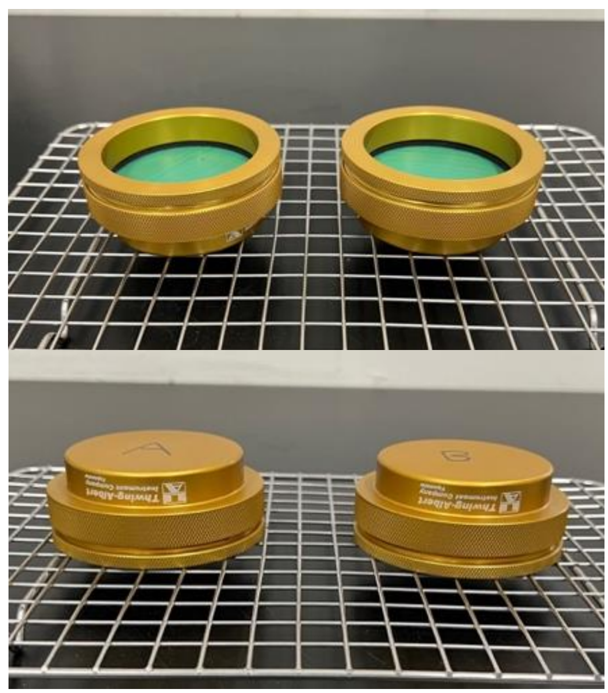

Figure 7. Test and Blank chambers before inversion (top) and during test (bottom)

The chambers were allowed to stand on the laboratory bench in an inverted position for 9 weeks. During this time, the temperature and humidity was measured hourly with a monitoring device. The average humidity during the study was 54% and the average temperature was 20.4 °C (69 °F). The mass of each chamber was measured after assembly, then again at each time point including 1d, 2d, 3d, 7d, and weekly thereafter up to a total time of 63 d (9 weeks).

Water Absorption Immersion Testing

Sample Preparation: The HydroGel material is highly viscous and sticky at room temperature. The following procedure was performed to prepare each 2.9” diameter circular sample of HydroGel (90 mil) attached to the 16 mil HDPE GFG16: Small pieces of HydroGel were hand-separated from the bulk and rolled into a ball by hand (wearing nitrle gloves), until the mass of the HydroGel ball was sufficient to create a 2.9” diameter circle of material with a thickness of approximately 90 mil. A circular piece of HDPE film with a larger diameter of 3.5” was cut from the GFG16 stock. A flat silicone mat was placed on a laboratory hot plate and heated gently to about 40 °C. The ball of HydroGel was then placed on the silicone mat. When the ball had softened, the circular HDPE sample was laid upon the HydroGel and light pressure was applied. When the HydroGel was spread evenly underneath the HDPE disk to approximately 2.9” diameter, the mat and sample were placed in a refrigerator at 4 °C. After 2 hours, the cold assembly was removed from the refrigerator. While the sample was still cold, it could be easily peeled away from the silicone mat. Samples were stored on the silicone mat in the refrigerator until use. Test samples are shown in Figure 8.

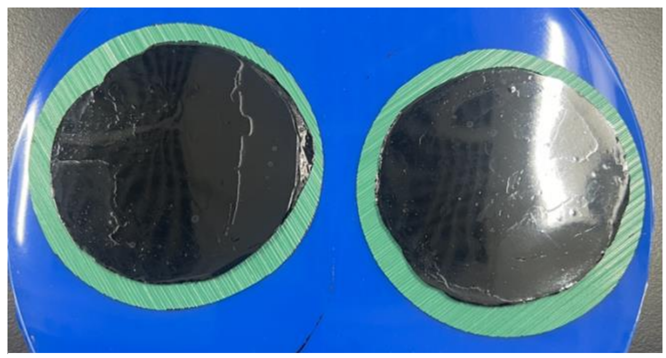
Figure 8. HydroGel test specimens as prepared for immersion testing

Test Procedure: A HydroGel system sample was carefully immersed in a sealable, 1 quart plastic container containing 200 g of tap water. The sample is less dense than water, therefore a cross-shaped piece of HDPE was placed above the sample to keep it fully immersed without touching the bottom of the chamber. A top view of the submerged sample is shown in Figure 9.


Figure 9. Immersion test setup for HydroGel sample

The test chamber was sealed with a plastic lid, and the sample was stored on the laboratory bench at room temperature. The average temperature during the study was approximately 20 °C. The mass of the absorption test sample was measured before assembly. Over the course of about 15 months, the sample was weighed periodically to evaluate mass gain by water absorption. For each measurement, the sample was dried quickly with gentle compressed air and a paper towel, taking care not to disturb the tacky HydroGel material.

Results and Discussion

Inverted Wet Cup Permeance Testing

The largest decrease in mass was observed in the first week, which may be attributed to moisture loss and equilibration around the sealed edges of the sample. After one week, a relatively stable rate of mass loss was observed for the remainder of the study. The mass readings of the sample chambers are listed in Table 1, and the net change in mass for each chamber is plotted in Figure 10.

Table 1. Chamber assembly mass vs. time

Day	Chamber A (g)	Chamber B (g)	Net Change A (g)
0	143.721	128.944	0.000
1	143.715	128.944	-0.006
2	143.706	128.944	-0.015
3	143.702	128.944	-0.019
7	143.697	128.944	-0.024
14	143.693	128.945	-0.029
21	143.693	128.948	-0.032
28	143.691	128.950	-0.036
35	143.689	128.949	-0.037
42	143.689	128.950	-0.038
49	143.686	128.951	-0.042
54	143.687	128.957	-0.047
63	143.685	128.958	-0.050

The data were corrected for the slight mass changes observed in the blank assembly. The sample test assembly exhibited a 50 mg decrease in mass over the 63 days of the test. The net mass change data over time is listed in Table 1. In the 8 week period after the first week equilibration, the assembly decreased in mass by 26 mg. This 8 week period was used to calculate the water vapor permeance of the HydroGel system.

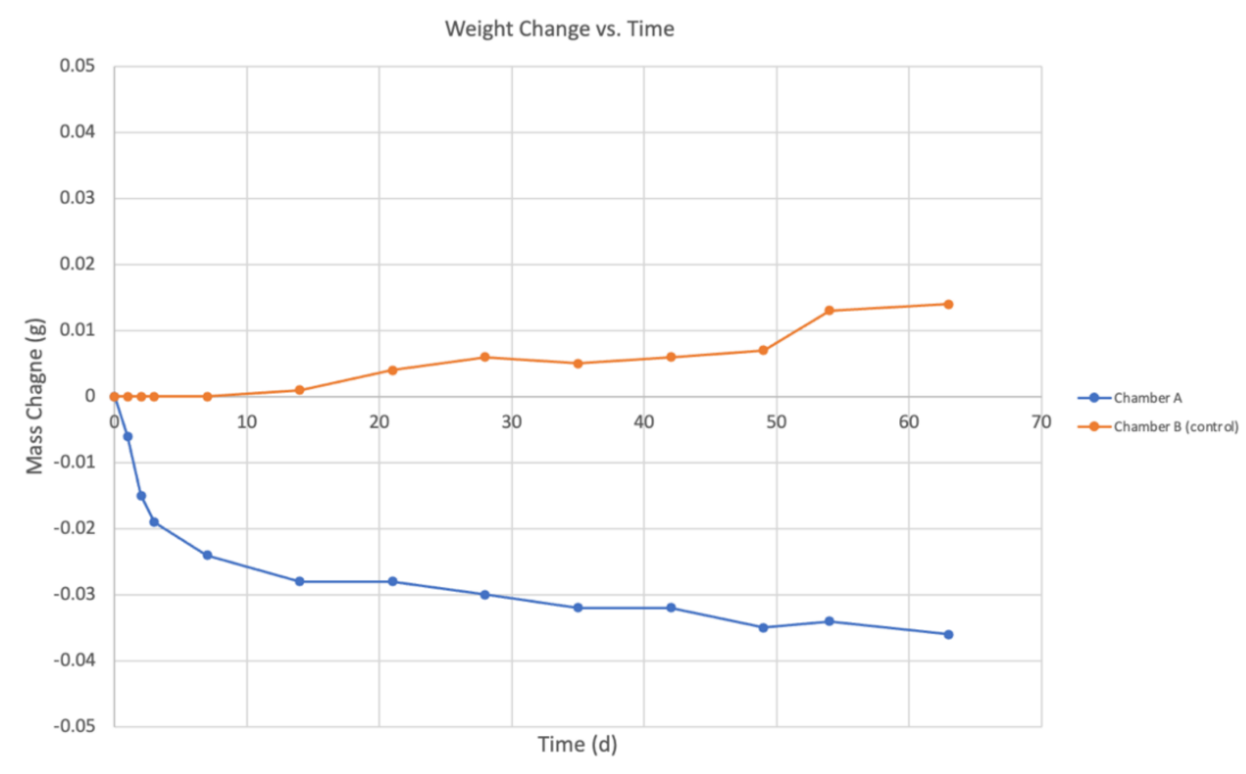

Figure 10. Sample mass change data

Permeance Calculation Results: Considering a water mass loss of 26 mg over 56 days, a humidity of 54% and an exposed barrier diameter of 2.5 inches, the following results were calculated for water vapor transmission rate (WVTR) and water vapor permeance (WVP) for the HydroGel system:

Parameter	Result
WVTR	0.0087 grains/(h*ft^2)
WVP	0.023 perm

Water Absorption Immersion Testing

The sample mass measurement data are shown in Table 1.

Table 1. Sample Mass vs. Immersion Time

Time (d)	Mass (g)	Time (d)	Mass (g)	Time (d)	Mass (g)	Time (d)	Mass (g)
0	9.925	42	10.074	91	10.084	192	10.348
7	10.007	50	10.074	98	10.075	447	10.252
15	10.100	63	10.070	105	10.083		
21	10.034	70	10.080	112	10.089		
28	10.061	77	10.072	140	10.087		
35	10.062	84	10.084	168	10.090		

Water absorption was also calculated as a percentage of sample mass over time, and those results are plotted in Figure 11.

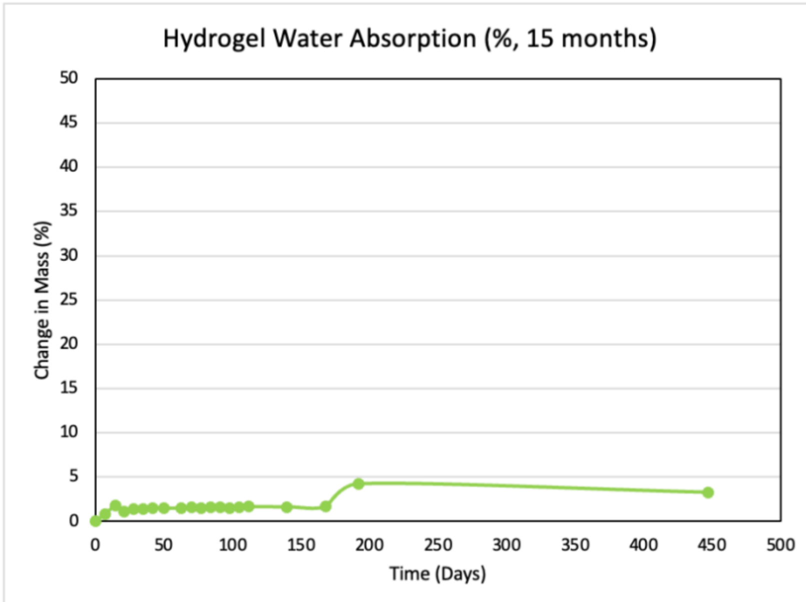

Figure 11. HydroGel water absorption as a percentage of sample mass

After 447 days, the water-immersed sample mass had increased by only 3.3% due to absorption of water. HydroGel absorbed about 1.5% of water in the first month of the study. At 192 days (approximately 6 months), an increase in mass of up to a total of 4.3% w/w was observed. The reason for this increase is uncertain, however it could be due to insufficient drying of the sample by the laboratory analyst at that data point. It can be difficult to remove all the water from the surface of the sample. A final measurement after 447 days (approximately 15 months) indicated the water absorption had stabilized at <4% of the system sample mass.

Conclusions

In these studies, the HydroGel waterproofing composite system was evaluated by 3rd party criteria for water absorption and inverted wet cup permeance. These tests, based on ASTM D570 and ASTM E96, serve to quantify the water resistance properties of a system, and they are proxies to estimate a membrane system's risk of failure by osmotic blistering.

The permeance of the tested HydroGel waterproofing barrier system was found to be 0.023 perm. This low number is very close to the range (≤0.015 perm) for materials described as "extremely low WVP materials" in the ASTM E96 standard. With a very low permeance of < 0.1 perm, and in the context of the published literature on the subject,[1] the HydroGel waterproofing system would not be expected to be susceptible to osmotic blistering problems after installation.

A HydroGel system sample was immersed in water for over one year, during which time the sample absorbed 3.3% of its weight as water. About half of the water absorption occurred in the first month of immersion, after which the absorption slowed dramatically, equilibrating at less than 4% of system sample mass after more than one year of immersion. The 3.3% water absorption is well below the 5% ceiling identified by Henderson et al. and therefore this material would not be expected to be susceptible to osmotic blistering problems after installation.

Considering these test results in comparison to published osmotic blistering risk criteria, the HydroGel composite waterproofing system's permeance of 0.023 perm and long-term water absorption of 3.3% by weight indicated that this system should have a low risk of failure by osmotic blistering.

References

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