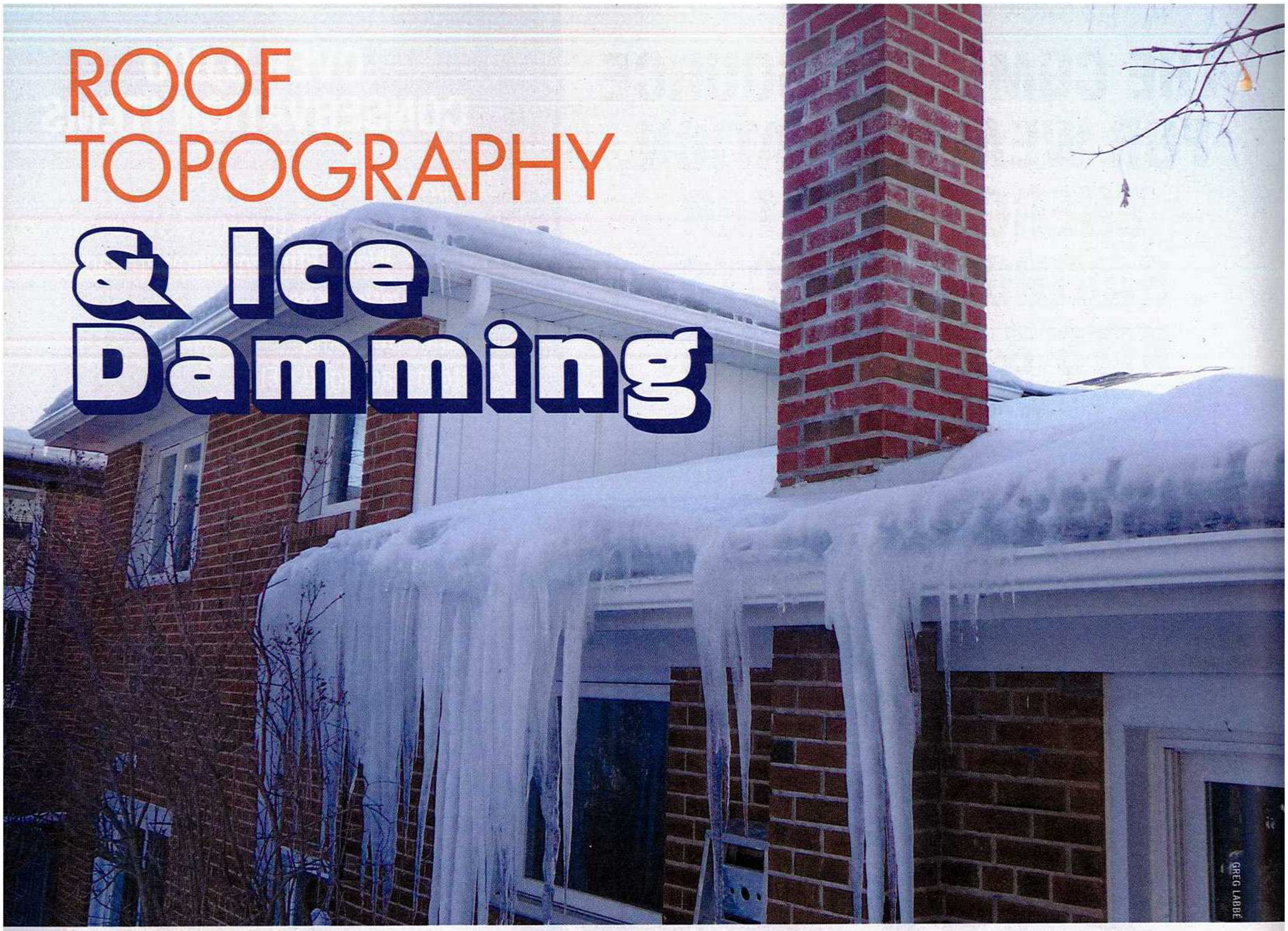
ROOF TOPOGRAPHY & Ice Damming


GREG LABBÉ

BY GREG LABBÉ

We know that ice dams form when there is lots of snow, and winter temperatures are mild; and that heat escaping from the top floor of a house into the attic causes snow to melt, move down the roof, and refreeze at the eave. But walk through neighborhoods in the wintertime and you will notice distinct patterns in the ice dams, depending on when the house was built. There is no doubt that poor construction techniques—a disregard for good air sealing and thorough insulation—are largely responsible for the formation of ice dams. But what about poor design?

The fact that many pre-WWI homes have steeply pitched roofs, or that their occupants kept the inside temperature of their homes lower than they do today, may offer a clue as to why these homes seem less prone to severe damage in the living space from ice dams. There is no denying that homes built after WWII—sprawling bungalows with can lights and ductwork in the attic—are much more susceptible to ice damming.

What about attic ventilation? Is this another factor in the development of ice dams? Attic ventilation is, in effect, an acknowledgment on the part of both builders and code officials that poor insulation, and poor air sealing of the attic floor, are facts of life in new construction. The purpose of attic ventilation is—ideally—to ensure that the warm, moist air that leaks up through the top of the house and into the attic convects out the ridge vent, causing cool, dry air to come in through the eave vents, thereby compensating for the sin of sloppy construction. Even though studies from Sweden and more recently from Canada Mortgage and Housing Corporation have shown that "identical attics, one unvented and the other vented to code, have much the same humidity and temperature," ventilation codes have not changed and building codes still require extensive ventilation. When concerns about unvented roofs arise, shingle manufacturers warn us that shingles will fail prematurely. Yet studies have shown that shingle life may be degraded by at most 10% reduction in lifespan when comparing a vented versus unvented roof; that ventilating a roof reduced temperature by 0.5°C; and that shingle color, direction, and geography has more effect on attic temperature than adding ventilation, even with wind assistance.

A typical ice dam on a Mansard roof. Note the dormer effect.

Snow cover on a roof affects the inside temperature of an attic in three ways; snow is a great insulator; snow may block vent air flow; and snow reflects the sun's heat. Because snow is a good insulator, the greater the snow load on a roof, the easier it is for a warm roof deck to melt the snow in contact with the shingles. Normally, hot air in an attic could dissipate out through the vents, but if the vents are covered with snow, the heat will be trapped in the attic. The trapped heat will raise the temperature of the sheathing, causing the snow on the roof to melt. The melt water refreezes at the eaves to create ice dams. Once a section of roof is bare, the sun can beat down on its usually dark asphalt surface, raising the temperature of the air in the attic. At this point even north-facing slopes are not immune to ice damming, thanks in part to the sun and shingle color.

Roof Slope and Ice Damming

The slope of a roof helps to determine how much snow is likely to accumulate, where on the eave the dam will form, and how high the melt water must reach before it comes through the sheathing and the ceiling. Thermodynamically, the attic loses heat no differently than any other room in the house. The greater the heated volume of air in an attic, the greater its ability to buffer escaping heat from the living space. Further, the surface area through which heat is dissipated increases as the height of the roof increases. A typical 32 foot x 40 foot pre-WWI home with a

Table 1. Roof Pitch and Wall Area

House (40 ft deep x 32 ft wide)	Roof	Pitch
Floor area 1,280 ft^2	4/12	12/12
Rafter length (ft)	23	28
Gable height (ft)	5	16
Gable end area (ft^2)	171	512
Roof deck area (ft^2)	1,850	2,210
Total attic sheathing (ft^2)	2,020	2,720
Total volume of attic air (ft^3)	3,410	10,240

Low-Slope Roof (cross section)

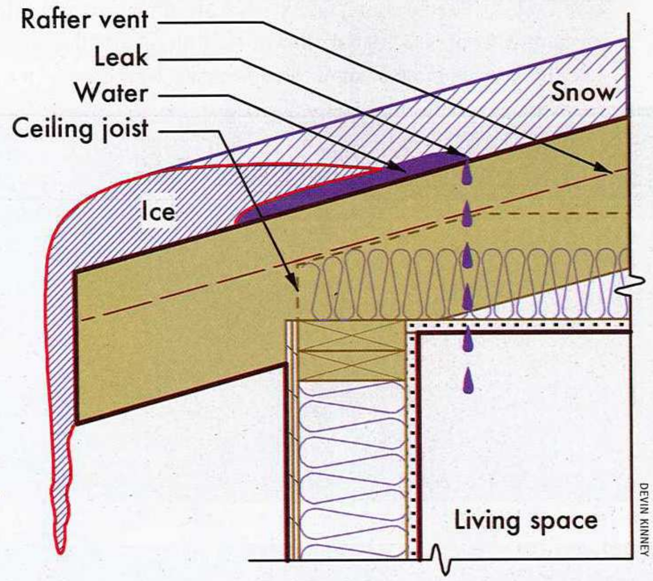


Figure 1. The low-pitched roof makes it difficult to insulate the attic well at the eave. A small rise in water level moves the leak into the house.

High-Slope Roof (cross section)

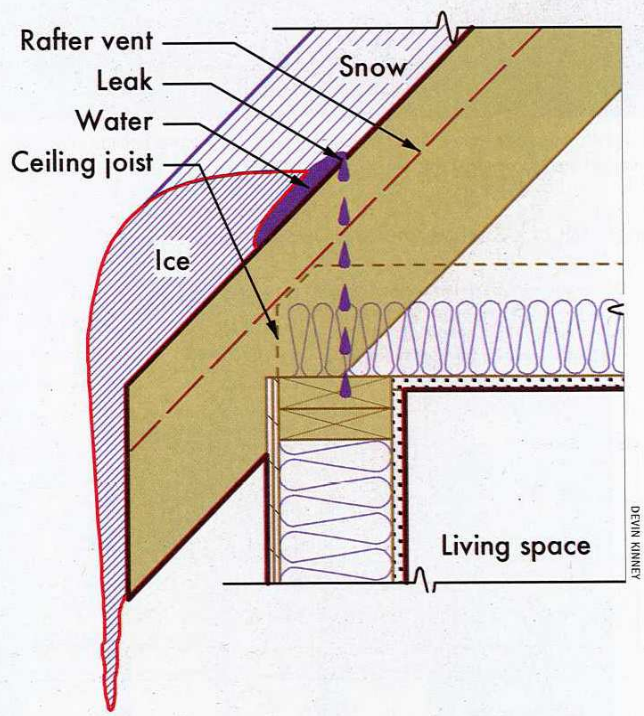


Figure 2. The steep slope allows for proper insulation. For water to leak into the house, the water level must go higher than in a low-pitched roof.

12/12 pitched roof has over 30% more surface area and almost 3 times more attic air volume than a home with a 4/12 pitched roof (see Table 1). Furthermore, take two identical houses one with a steep roof the other with a shallow roof. Both roofs will accumulate the same volume of snow, the difference is in how deep the snow accumulation is. The steeply pitched roof will always have less of an insulative layer even if the snow doesn't fall off.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Clear, thick ice has built up on sheathing due to an open drain.


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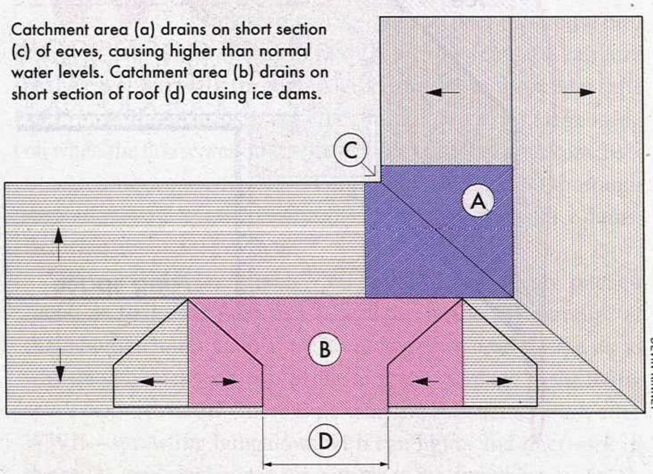
This photo was taken from a ladder looking in from the soffit area into the floor cavity. Note that the vapor barrier was not sealed,

Roof Plan of L-Shaped Roof with Two Dormers

Catchment area (a) drains on short section (c) of eaves, causing higher than normal water levels. Catchment area (b) drains on short section of roof (d) causing ice dams.



DEVIN KINNEY

Figure 3. Drain patterns on a roof tend to overburden short sections of eave, allowing ice dams to form more quickly there than on other parts of the roof that receive less melt water.

Therefore a low-pitched roof will be prone to ice damming problems for five reasons (see Figure 1). First, there is not enough stack effect to provide proper ventilation. Second, deeper snow builds up on the deck. Third, there is not much room above the top plate for insulation. Fourth, the attic is a small room with a very small exterior surface area through which to dissipate heat. And finally, the ice dam is more likely to cause leaks in the house than through the eave, given that the dammed water level at this angle doesn't have to rise much before it breaches the exterior wall. Taken together, these factors make low-pitched roofs more prone to damming and more vulnerable to damage.

Cover the same leaky or radiating attic floor with a steeply pitched Victorian roof (see Figure 2) with the same-sized soffit, and you create more stack effect due to the increased height of the roof; a reduced snow load due to the steep angle of the roof; more room above the top plate for insulation; and a larger enclosed attic with more exterior surface area through which to dissipate heat. Finally, if an ice dam does leak through, it will go through the soffit, perhaps drip on the wall top plate, but not come through the ceiling as often, given that the dammed water level needs to rise much higher on a steep roof before it breaches the exterior wall.

Note that occasionally the damage caused by an ice dam doesn't come from melt water produced on the roof (see photo, upper left). Sometimes the damage occurs inside the attic, when moist air keeps washing against the backside of a freezing roof deck or an ice dam, causing condensation. This is especially common when the moisture source is close to the eave inside the attic.

Other post-WWII housing trends that make homes more susceptible to ice damming are homes with roofs that are measured by the acre adorned with dormers, valleys, split levels, skylights, exhausting vents, and plumbing vents. You get the picture—more of everything. The larger the roof area, the more snow load accumulates. Make it an L-shaped footprint, and not only is there a lower-pitched valley for snow to gather in, but the increased catchment area producing melt water on both sides of the valley sends all that water down the valley to one inside corner of eave, causing ice to dam up more quickly there than on other parts of the roof (see Figure 3). As any roofer knows, the best foothold is in a valley, and it seems that ice is in on the roofer's secret.

Dormers add to ice dam misery in two ways. First they tend to have a lot of wood framing and are difficult to insulate, so they melt their snow load onto the lower main roof (see Figure 3). But the real problem with dormers is that, while they protect the eave below the dormer itself, they force melt water and snow to either side of the dormer onto shorter sections of eave. This increases the chance that an ice dam will form, because more melt water falls onto a shorter length of eave.

Conventionally Vented Mansard Roof

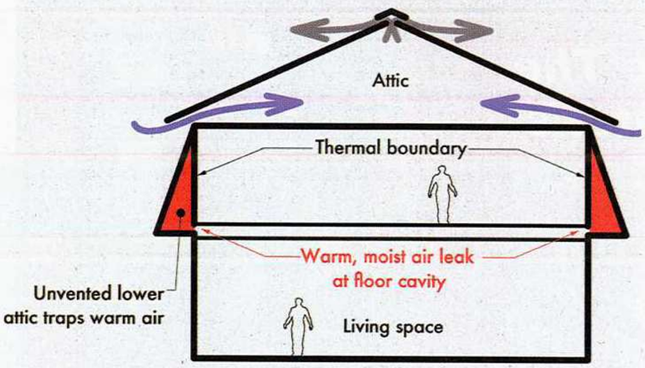


Figure 4. Conventional venting of top attic on a Mansard roof.

Variation on Venting Mansard Roof

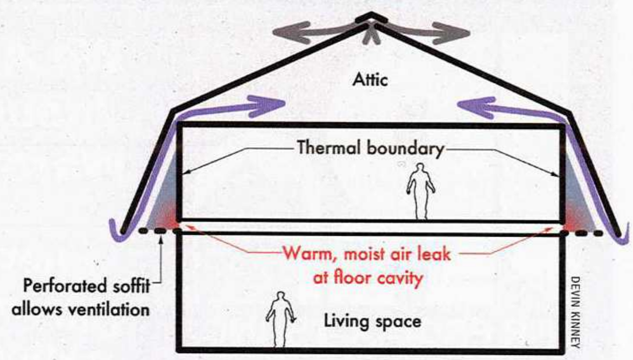


Figure 5. A flawed variation on venting connecting the lower attic to the upper attic.

The Mansard Challenge

The Mansard roof was originally designed in 17th century France for property owners who wanted to evade higher taxes by incorporating additional living space above the roofline, and not as a comfortable living space in cold climates, leading to problems today. The Mansard design consists of a steeply pitched lower roof, with a flat roof or a very low-pitched roof on top. The steeply pitched lower roof, which surrounds the top floor walls, is covered with shingles. The Mansard style has been popular in Canada for many years, especially for row houses, public housing, and condominiums (see "Mansard in Massachusetts"). Despite its popularity, it is more prone to ice damming than other styles of construction. By the forces of stack effect, the conditioned moist air from the living space moves into both the steeply pitched lower roof and the peaked attic, raising the temperature of the roof, often causing condensation damage on the inside and ice dams on the outside of the eaves. While this could be blamed on shoddy construction, such as poor insulation and inadequate air sealing, certain Mansard roof assemblies have intrinsic design flaws when it comes to cold-weather performance.

Ontario Building Code (OBC) 9.19.1.4 specifies that attic get 25% of its ventilation from the edge of the top roof, using mushroom-type vents at the point where the rooflines meet (see Figure 4). This area is usually filled with structural lumber making it prone to excessive thermal bridging, and clearance between ceiling and roof deck not high enough to adequately insulate. Further the insulation and roof vents work against each other in that the insulation prevents easy air flow if placed too low on the roof. However, the home performance company I work for, Green Saver, has found a number of Mansard roofs built in 2005 where the builder has worked around the thermal bridging issue by raising the 'heel' to allow for more insulation at the edge of the top roof, and—more crucially—has added an air chute connecting the lower Mansard attic to the upper attic (see Figure 5). We suspect that this was done to eliminate the clumsy venting required by OBC at the junction of the two roofs, and to improve air flow by drawing air in from the soffit under the Mansard and exhausting it out the ridge vents. This technique of constructing Mansards must be more thoroughly examined and possibly discontinued. Though it may improve curb appeal, it actually contributes to the formation of ice dams.

In conventional roof assemblies, the roof collects heat from the ceiling. Some Mansards go one step further and collect the heat from the ceiling, plus the heat coming off the top-floor walls and the floor cavity assemblies, simply because they are encapsulated by the lower Mansard roof. Furthermore, if the lower stories are bricked, the drainage gap between the brick and the insulated wall will vent its hot air into the Mansard roof convectively, if the wall assembly below was poorly air sealed and insulated.

Snow is likely to build up on the flat or low-pitched top roof of a Mansard, where it will reflect the most solar radiation. On the steeply pitched lower roof covering the walls, the snow rolls off, leaving the shingles bare. The bare lower roof will convert solar energy into attic heat. On a sunny winter day, the low-angled sun is tangentially reflected off the snow-covered top roof, but it beats squarely on the lower roof, effectively turning it into a Trombe wall. If the upper and lower attics are connected, the hot air in the lower attic rises up through the air chute into the upper attic, which may be covered with insulating snow. Add a few dormers to this scenario to concentrate melt water onto shorter sections of eave, and you have an ice damming disaster when sunny skies coincide with a high snow load.

Remediation

To prevent the formation of ice dams, it is crucial to air seal the attic floor first, and then to insulate it well and yes, increasing ventilation should be part of the remediation strategy. A scrupulous wall-to-wall air sealing inspection of the attic floor must be done in order to prevent heat and moisture from escaping out of the living spaces into the attic. With careful work, ice damming can generally be reduced, and often eliminated, in other types of roof, but the Mansard roof with the air chute poses specific problems that make remediation difficult. Ice dam remediation of these roofs

MANSARD IN MASSACHUSETTS

COURTNEY MORIARTA

Mansard roofs exist in many different types of housing, but the technical challenges remain the same from single-family homes, to townhouses, to apartment buildings. In one low rise apartment building in Massachusetts, interventions completed by Steven Winter Associates and New England Insulation resulted in a dramatic reduction in heat loss through the top floor and roof. (See photos above. Middle photo is before, right photo is after intervention.) This 1960s-era building owned by the Winn Companies and managed by Mayflower Limited has a Mansard-style roof that is vented at the soffit between second and third floors with over 6,300 square feet of attic space above the third floor. Air sealing of the attic consisted of removing existing flooring to access top-plates, plumbing chases, and other penetrations to be sealed. In addition, the perimeter of the floor cavity between the second and third floors was insulated and sealed using high-density cellulose blown in through the interior at the second-floor ceiling. Open-blow cellulose was added to the existing fiberglass batts in the upper attic area after air sealing was completed.

The exterior infrared images taken on similar 40°F overcast days before and after treatment demonstrate clearly how the thermal losses at both the top and bottom of the Mansard wall have been effectively stopped. Now that the heat loss and stack effect are under control, the owners can now turn their attention to additional planned renovations to upgrade the existing heating system with properly sized, balanced, and controlled boilers and hot water distribution.

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requires a lot of time and effort. Mansard attics are often shallow, full of insulation, and trussed, making them very difficult to work in. Remediation has to start by sealing the lower attic from the upper attic if connected and adding vents around the perimeter of the top roof to satisfy conventional ventilation requirements.

Active solutions, such as installing heating cables to melt ice, could work for roofs in general. Some contractors advocate attic exhaust, but this strategy may pull more moist up into the attic making matters worse. Some people recommend installing taller vents that protrude above the built-up snow, such as the whirly gig. Others suggest solar-powered roof vents that vent while the sun shines.

>> For more information:

Attic Venting, Attic Moisture and Ice Dams. Ottawa, Ontario, Canada: Canada Mortgage and Housing Corporation, 2004. To download a copy of this report, go to www.cmhc-schl.gc.ca/en/co/maho/gemare/gemare_001.cfm.

Cash, Carl G. and Edward G. Lyon. "What's the Value of Ventilation?" *Professional Roofing Magazine*, March 2002. To download a copy of this article, go to www.professionalroofing.net/archives/past/mar02/feature2.asp.

Schumacher, Chris. *Building Science Digest 149*. "Unvented Roof Assemblies for All Climates" Building Science Press, 2007. Go to www.buildingscience.com/documents/digests/bsd-149-unvented-roof-assemblies-for-all-climates.

Samuelson, Ingemar. "Hygrothermal Performance of Attics" Swedish National Testing and Research Institute, *Journal of Thermal Envelope & Building Science*, Vol. 22, Oct 1998.

Designing Ice Dams Out of Architecture

Ultimately the best solution is always a passive solution, but the frustrating thing about the ice damming problem is that much of it could be avoided if builders would adopt best practices at the design and construction stage. The truth is that today, homes are being built that will be damaged needlessly by ice dams. Building Code officials, contractors, designers, architects and Municipal building officials need to learn more about what causes ice dams, so they can adopt best practices. Many features of a roof can predispose it to ice damming, but all of this would be moot if builders would seal and insulate those attic floors properly. If they did that, perhaps code officials might allow them to eliminate costly ventilation for attics irrespective of the slope. In the end, some winters are worse than others, but a large, complicated, low-pitched roof with many dormers will always form ice dams in bad winters, whereas a simple steeply pitched roof is much less likely to do so. This winter, as the icicles fall from the roofs of the Stata Centre in Massachusetts and the ROM Crystal building here in Toronto, making a mockery of contemporary design, perhaps we should contemplate why our ancestors built their buildings the way they did. After all, many of us live happily in those old buildings.

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