Joseph W. Lstiburek

Balancing Act

Exhaust-Only Ventilation Does Not Work

BY JOSEPH W. LSTIBUREK, PH.D., P.ENG., FELLOW ASHRAE

There. I said it. It just does not work. OK, it works sometimes.* But it does not work in tight building enclosures and certainly not in new houses, apartments, town houses and row houses. Basically in nothing new that we are building. Because it sucks—literally. I know we were here before ("Unintended Consequences Suck," *ASHRAE Journal,* June 2013), but we have to come back and deal with it again. Why? As amazing as it seems, things have gotten worse and are going to get worse. But the good news is as they become intolerably bad, we will end up finally dealing with them. Not quite there yet, but almost.

This next part should be obvious—but is apparently not to some people and is quite acceptable to others. Exhaust-only ventilation leads to depressurization in houses, town houses and row houses constructed to meet the 2015 International Residential Code and significant depressurization in apartment construction that is constructed to meet the 2015 International Building Code. In single-family detached houses, this leads to contaminants being pulled from attached garages, especially in houses with bedrooms over garages. Contaminants are also pulled from under slabs—if radon was valuable we would mine it this way—and what better way to bring soil gas, herbicides and pesticides into a home?

In row houses and town houses, exhaust-only ventilation leads to air being pulled from neighboring units as well as from attached garages and from under slabs. In apartments exhaust-only ventilation leads to air being pulled from neighboring units and corridors.

In apartment construction, the corridor issue is a smoke and fire issue. You would think this might be something we ought to care about? Well, we do. In a serious way. But from a "tightness" perspective, not from a pressure perspective. We are getting good at the compartmentalization part, especially because we now test for it. But the compartmentalization makes the pressure issue way worse when we use exhaust-only ventilation.

Why not supply ventilation? Supply-only ventilation works in detached single-family houses, but not in apartments and town houses and row houses, as it drives air into neighboring units, and we have the associated odor and contaminant transfer issue. You can't

* Leaky single-family detached houses with small exhaust flows with undersized air conditioners and poor solar control with black shingles and poorly insulated ducts located in vented attics—the types of houses we encourage people to build. Exhaust-only ventilation no longer works in new single-family detached because we now codify "tight" and test for it.

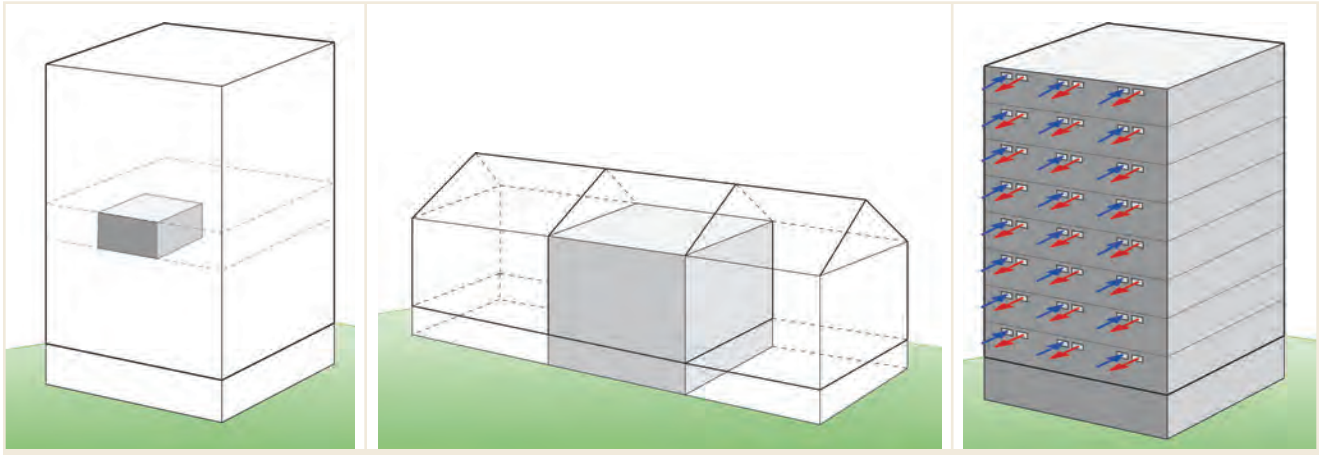

FIGURE 1 (LEFT) Compartmentalization. This is what it means. No air from the top of the "cube" or the bottom of the "cube" or the sides of the "cube." And we go out of our way to make the front of the cube "tight" as well. When you "suck" where does the air come from? FIGURE 2 (CENTER) Row House or Town House. This is what the model codes ask for and are getting. No air from neighboring units and "tight" construction. When you "suck" where does the air come from? FIGURE 3 (RIGHT) Balanced Ventilation in an Apartment Building. Out with the bad and in with the good in a balanced, controlled powered manner. Individual distributed balanced ventilation systems.

ever make them "tight-enough" to prevent this; there are practical limits to compartmentalization.

Kinda leaves us with only one option that works in everything everywhere—balanced ventilation. Notice the words "everything" and "everywhere." But the model codes don't encourage it and ASHRAE Standard 62.2-2016 and RESNET actively discriminate against it.[†] That is insane. We are penalizing better systems when we incentivize poor systems and don't encourage good systems. This is what I mean by things getting worse. We are incentivizing worse. We are discriminating against good. Note the word "insane."

Are we done yet? Nope. How do you deal with exhaust vented kitchen range hoods? How about vented clothes dryers? The only viable options are interlocked powered makeup air[‡] for both or not using a vented clothes drier and going to condensing dryers. Or venting the apartment unit or house through the kitchen range hood and providing ducted supply air directly to the apartment unit or house. Good idea in compartmentalized buildings and low-rise, but not in tall buildings using central systems.

Not in tall apartment buildings? Huh? Yes, we have done this for years in tall apartment buildings. But there are two fundamental problems with large rooftop exhaust systems pulling from every unit interlocked with large rooftop supply systems ducted to every unit.

First, the approach tends to overventilate the entire building because the systems run all the time and units get ventilated regardless of whether they are occupied or not. Second, fighting the stack effect is not a trivial matter. Most units with central rooftop exhaust and supply end up being over-ventilated or under-ventilated—by large margins.

And all this is exacerbated by failure to compartmentalize units, corridors, elevators, utility shafts and stairwells. Yes, yes, we were there before ("How Buildings Stack Up," *ASHRAE Journal,* February 2014).

We need to compartmentalize (*Figures 1* and *2*), and we need to have individual distributed balanced ventilation systems in apartment buildings and row houses and town houses (*Figure 3*). And, as I mentioned, we are getting the compartmentalization figured out. And we are certainly getting new houses, town houses and row houses tight. Why? Again, I mention for emphasis, we are testing them. These things are code requirements and we are testing for them and meeting them.

So, distributed balanced ventilation systems work in everything everywhere. But—and this

[†] Following ASHRAE Standard 62.2-2016 results in higher air change when a balanced ventilation system is compared to an exhaust-only ventilation system. It gets worse. RESNET procedures result in rating points hits when balanced systems are used compared to exhaust-only systems because RESNET references ASHRAE Standard 62.2-2016. Builders and raters are not stupid. Both are "gaming the ratings system" and exhaust ventilation becomes the obvious choice. RESNET stands for "Residential Energy Services Network" and is responsible for the Home Energy Rating System (HERS) index.

[‡] Don't talk to me about recirculating range hoods—those are like toilet bowls that never flush, swirling stuff round and round.

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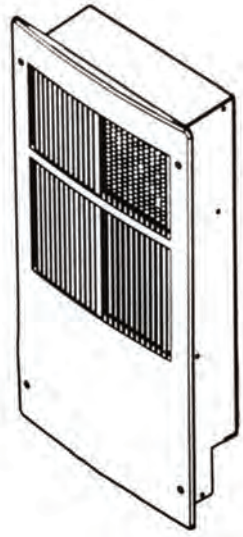

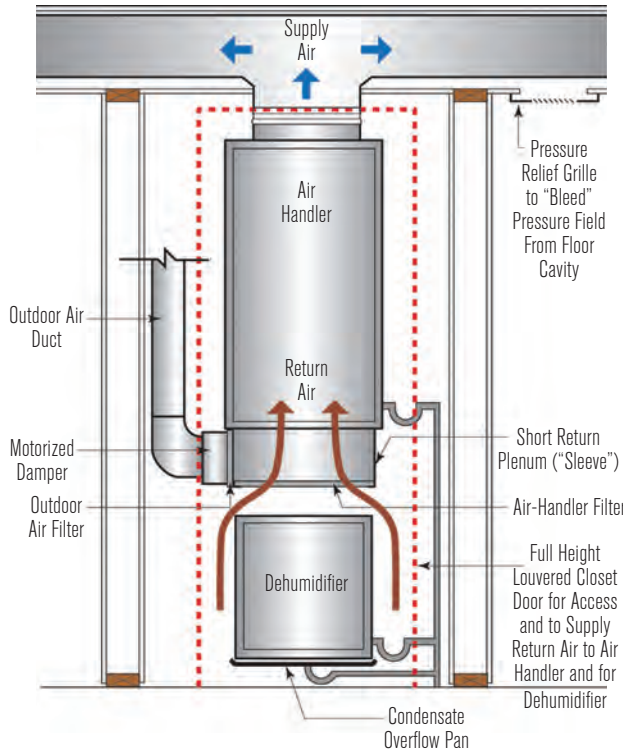

FIGURE 4 Supplemental Dehumidification. Relax. Everyone relax. This can be accomplished with stand-alone dehumidifiers. Small, wall-mounted fit-in-the-stud space dehumidifiers. A nice improvement over the older technology.

FIGURE 5 (LEFT) Old Dehumidification Technology. Cheap dehumidifier in a return closet. Works, but we can do better. PHOTO 1 (RIGHT) Dehumidifier In Return Closet. Works, but we can do better.

is a big but—in small units and small houses we are going to need supplemental dehumidification. Aw, man. Yes, pretty much everywhere south of the Mason-Dixon line and east of Interstate 35 in Texas. In hot-humid climates and mixed-humid climates, part-load humidity cannot be controlled without supplemental dehumidification. Relax. Everyone relax. This can be accomplished with stand-alone dehumidifiers. We have the technology. And yes, we were here before. What has changed is that we now have better and more options available. We have the technology (*Figure 4*). Small, wall-mounted fit-in-the-stud space dehumidifiers. A nice improvement over the older technology (*Figure 5* and *Photo 1*).

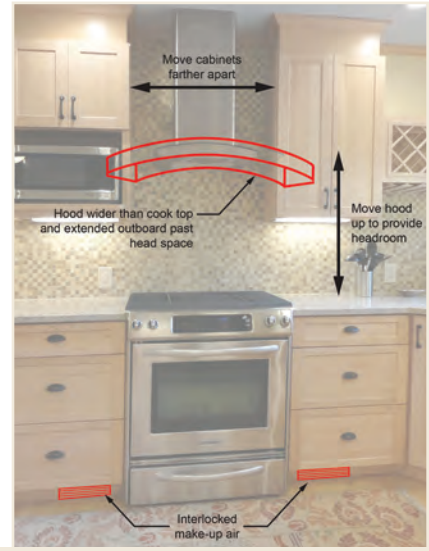

PHOTO 2 (LEFT) Kitchen Range Hoods. We are getting better capture efficiency with better hood design and that means we can get away with lower exhaust flows. PHOTO 3 (RIGHT) Need Some Space Here. Need a bigger hood, a deeper hood and interlocked makeup air.

Don't forget the vented clothes dryers. They extract 200 cfm (94 L/s) or more from units, houses, row houses and town houses. Best solution, don't use them. Use condensing clothes dryers. The big change for condensing clothes dryers in the last few years is that manufacturers have figured out there actually is a market for them. Yes, we have had condensing clothes dryers for quite a long time—but not large ones that actually dry clothes before you finish reading *War and Peace*.[§] We got large SUV-sized ones "turbo-charged," as befits us non-Europeans.

[§] Author: Leo Tolstoy, first published 1869, paperback 1,440 pages.

What about kitchen range hoods? Yes, I know we were here before ("Deal with Manure & Then Don't Suck," *ASHRAE Journal,* July 2013). But things are getting easier. We are getting better capture efficiency with better hood design, and that means we can get away with lower exhaust flows (*Photos 2* and *3*). And, we are on the verge of getting makeup air systems that are premanufactured and designed for residential applications. Right now, you have to be a real engineer and design your own. You have to duct the makeup air under the cooktop and decide how to precondition the or not.[#]

Can you get away with really small kitchen range hood exhaust that has high capture efficiency in a tight enclosure? Yes, maybe. I think. Not sure. Less than 100 cfm (47 L/s) of exhaust intermittently? Have not done the work. No one really has. Someone should. Note that intermittently means not all of the time.

So what should these balanced ventilation systems look like? I've been playing with a couple that follow.

Each system is balanced and has provision for powered, interlocked makeup air for vented kitchen range hoods. Each system is designed to operate in single-family detached houses, town houses, row houses or compartmentalized multifamily units, and with distributed heating and cooling systems or central systems where only hot water or chilled water or refrigerant is distributed, not air.

The first system (*Figure 6*) uses an outdoor air duct that is connected to the return side of the air handler, and the air handler operates continuously. The air handler is interlocked with a continuous bathroom exhaust fan. The rate at which outdoor air is brought in through the outdoor air duct is matched by the exhaust rate of the bathroom exhaust. For example, if 45 cfm (21 L/s) is supplied via the outdoor air duct, then the bathroom fan exhausts continuously at a rate of 45 cfm (21 L/s). In apartment units with only one bathroom, this is pretty easy. A single exhaust fan is used.

If two or three bathrooms are in the unit or if we are dealing with a single detached house or town house or row house, then the exhaust rate is split between the bathrooms. A single exhaust fan is used with an exhaust grille in each bathroom. There are controls available to make all this work. The individual fans operate at a low speed for general ventilation and intermittently at a higher rate when the bathroom is

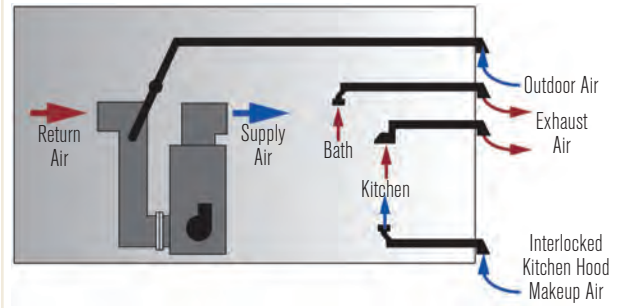

FIGURE 6 First System. Outdoor air duct is connected to the return side of the air handler, and the air handler operates continuously. The air handler is interlocked with a continuous bathroom exhaust fan. A vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate makeup air fan.

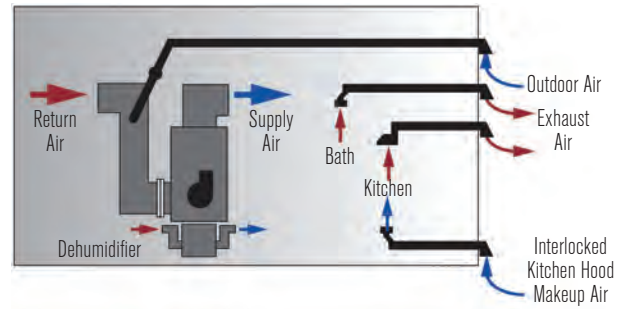

FIGURE 7 Second System. Supplemental dehumidification using a dehumidifier.

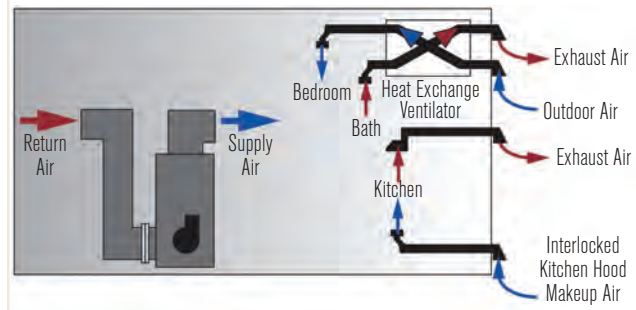

FIGURE 8 Third System. Fully ducted heat recovery ventilator (HRV) or a fully ducted energy recovery ventilator (ERV) providing balanced ventilation independent of the forced air-conditioning system. The HRV/ERV extracts air from the bathroom(s) and supplies air to the bedroom(s). The rates modulate based on switches in each bathroom, upping the rate intermittently when the bathrooms are in use. A vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate makeup air fan. It is a bad idea to vent the kitchen range hood through an HRV or ERV. Did I mention that this is a bad idea?

[#] Just putting a hole in the wall does not work—especially in the hot-humid south—every AC supply grille between the hole and the exhaust hood is going to sweat as the makeup air finds its way to the hood. And, you have to figure the control thing out. Most of the time I do not precondition—or if I do, I just mix it with air already in the space to temper it.

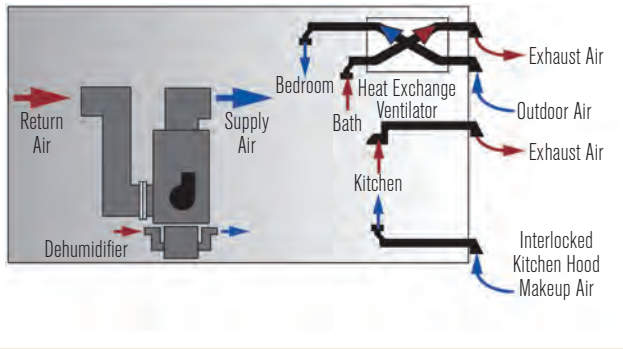

FIGURE 9 Fourth System. Supplemental dehumidification added to the third system.

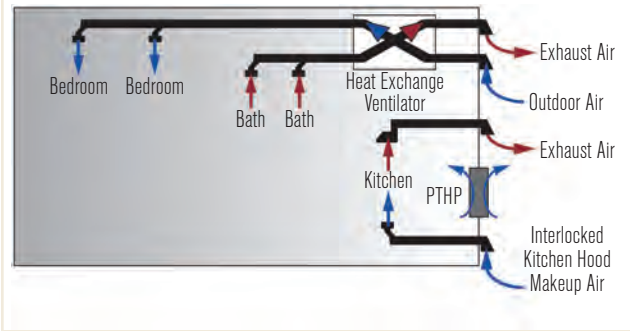

FIGURE 10 Fifth System. System for apartment units or exceptionally efficient houses. A fully ducted heat recovery ventilator (HRV) or a fully ducted energy recovery ventilator (ERV) provides balanced ventilation independent of the packaged terminal heat pump (PTHP) conditioning system or, in the case of exceptionally efficient houses, independent of the heads of multi-split systems. The HRV/ERV extracts air from the bathroom(s) and supplies air to the bedroom(s). As in the previous cases, a vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate makeup air fan. Note, that with exceptionally efficient houses, even when using more than one head, some mixing is necessary to provide thermal comfort.

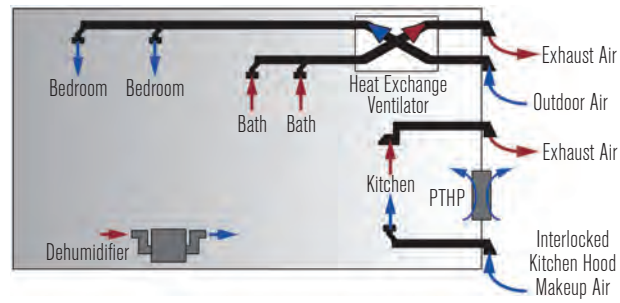

FIGURE 11 Sixth System. Adding supplemental dehumidification in the usual way.

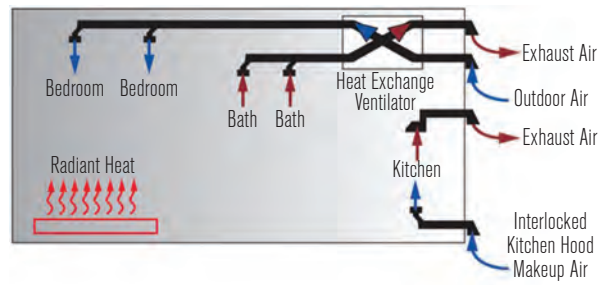

FIGURE 12 Seventh System. Used in locations where air conditioning is not used such as the Pacific Northwest. A fully ducted heat recovery ventilator (HRV) or a fully ducted energy recovery ventilator (ERV) provides balanced ventilation. Heating is provided by a radiant heating system. The HRV/ERV extracts air from the bathroom(s) and supplies air to the bedroom(s). Again, as with all the previous systems, a vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate makeup air fan.

in use. A vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate makeup air fan.

The second system adds supplemental dehumidification provided by a dehumidifier (*Figure 7*).

The third system (*Figure 8*) uses a fully ducted heat recovery ventilator (HRV) or a fully ducted energy recovery ventilator (ERV) providing balanced ventilation independent of the forced air-conditioning system. The HRV/ERV extracts air from the bathroom(s) and supplies air to the bedroom(s). The rates modulate based on switches in each bathroom, upping the rate intermittently when the bathrooms are in use. A vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate makeup air fan. It is a bad idea to vent the kitchen range hood through an HRV or ERV. Did I mention that this is a bad idea?

The fourth system also adds supplemental dehumidification with a dehumidifier (*Figure 9*).

The fifth system (*Figure 10*) works in apartment units or exceptionally efficient houses. A fully ducted heat recovery ventilator (HRV) or a fully ducted energy recovery ventilator (ERV) provides balanced ventilation independent of the space conditioning system. That space conditioning could be a packaged terminal heat pump (PTHP) as shown, or, in the case of exceptionally efficient houses, mini-split or multi-split heads. The HRV/ERV extracts air from the bathroom(s) and supplies air to the bedroom(s).

As in the previous cases, a vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate makeup air fan. Note, that with exceptionally efficient houses, even when using more than

one head, some mixing is necessary to provide thermal comfort.

The sixth system adds supplemental dehumidification in the usual way (*Figure 11*).

The seventh system (*Figure 12*) is used in locations where air conditioning is not used such as the Pacific Northwest. A fully ducted heat recovery ventilator (HRV) or a fully ducted energy recovery ventilator (ERV) provides balanced ventilation. Heating is provided by a radiant heating system. The HRV/ERV extracts air from the bathroom(s) and supplies air to the bedroom(s). Again, as with all the previous systems, a vented kitchen range hood is ducted separately to the exterior and is interlocked with a separate makeup air fan.

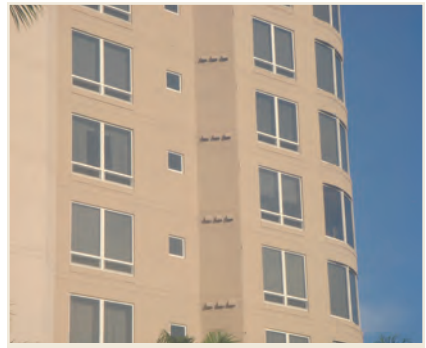

PHOTO 4 Lots of Penetrations. You want energy efficiency? You want a controlled indoor environment? You want to build tight and ventilate right? You better get used to living with the holes. Putting the stuff on the roof or at the bottom of the building does not work. Might work in houses and row houses and town houses, but not in apartments.

Yes, architects, I know, I know. Lots of penetrations in the walls (*Photo 4*). Get over it. You want energy efficiency? You want a controlled indoor environment? You want to build tight and ventilate right? You better get used to living with the holes. Putting the stuff on the roof or at the bottom of the building does not work. Might work in houses and row houses and town houses, but not in apartments.

Are we done yet? Nope. Let me talk about insane and insulting to one's intelligence. There are currently no provisions in any U.S. codes or standards that recognize the benefits of balanced systems with mixing and distribution. Balanced systems with mixing and distribution do much more with less air than exhaust systems without mixing and distribution. There should be some reward and punishment here.

Actually, there is. We reward the exhaust systems without mixing and distribution, and punish the balanced systems with mixing and distribution because we treat them the same. It is pretty clear that ASHRAE is incapabable of fixing this based on the current antics of the ASHRAE Standard 62.2 Committee. But I have hope for RESNET and both the International Residential Code (IRC) and the International Building Code (IBC). Stay tuned. It is going to get worse before it gets better. But better will happen. Just not easily and not without pain.

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