Combining Washers and Dryers

Abstract

This whitepaper introduces some of the history and physics around water removal from fabrics, and studies the poor performance of ventless drying technology. The conclusion is straightforward: vented dryers work much better than ventless dryers, due to the relative humidity of the air and its saturation point. Water evaporation simply slows down when the air is hovering right around the dew point, as it does in a condenser.

A Little History

The washing machine became commercially available around 1904. The electric dryer was not practical at that time because, unlike the manual washing machine, the drying process required electricity. Most homes were not wired for power for many years after that, so dryers only started to become a mainstream staple in the America home around 1938, when electricity was more widely available. This 30-year gap between the widespread introduction of the washer and that of the dryer resulted in an odd situation: you have two machines, each of which does half the job. No other home appliance does only half of its job.

The basic idea of all-in-one laundry machine, however, is not new. In fact, such machines have previously been built and sold in Europe and Australia. As an example, consider the circa 1957 machine that is pictured to the left. Once the washing cycle was complete, the wet piles of clothes remained stationary throughout the drying cycle. There was no spinning to remove excess water. A heating coil in the top of the unit radiated heat downward onto the pile of wet clothes. The top layer of clothes slowly baked dry; the bottom of the pile stayed soggy for a long, long while. Reports of five to eight hours of drying time per load were not uncommon.

These early all-in-one laundry machines never garnered widespread adoption and ultimately were pulled from market. The reason for commercial failure rests in how they approached drying clothes.

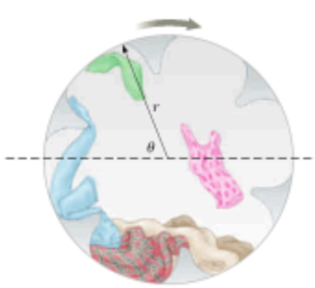
Physics of Drying Clothes

Extraction

The first action of a dryer is water extraction: spinning clothes at high velocity to forcefully remove the water, like a centrifuge. The rate of rotation is a function of the radius of the dryer drum.[1] The water is extracted in its liquid state and no evaporation occurs. This action significantly contributes to the efficiency of a dryer. This extraction step is significant, yet laundry still emerges an extra 55% heavier, even after the spin and extraction cycle.[2] Clearly, clothes cannot get fully dried simply by extraction. Internal air stays humid and clothes stay damp without a heat source and/or air exchange through venting.

Evaporation

The next drying action involves turning the remaining wetness into a gas and getting rid of the gas through the process of evaporation. Simply put, this conversion involves three components: heat, airflow, and relative humidity. The hotter the temperature, the faster the drying time.



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The more air flow (i.e., tumble space), the faster the drying time. And the lower the humidity inside the appliance, the faster the drying time. These three avenues for making drying time quick and energy-efficient were three strikes against the previously marketed all-in-one laundry machines. None of these parameters were optimized to make drying time efficient; thus, drying took many hours, making it possible to perhaps only do two loads of laundry in a day, and customer perception became that this type of machine just does not work. And that design really didn't. **An all-in-one is set up to fail when the drying process is ventless (condensing).** To explain a bit further, let's look at the different type of clothes dryers.

Types of Dryers

Drying wet clothes is an energy-intensive job that involves two processes.[3] First, energy has to be provided to change the water from liquid to vapor. Second, the vapor has to be moved away from the wet clothes, either by venting humid air out of the dryer or cooling the air to the point of condensation and drain out the liquid water.

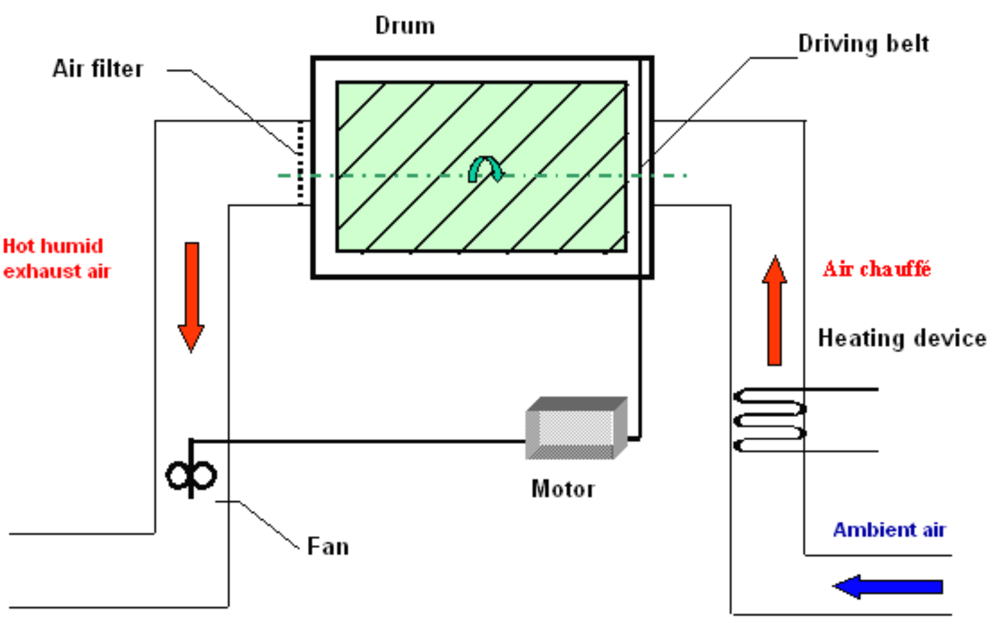
The two major categories of clothes dryers fundamentally differ on how the remove moisture out of the drying chamber, leading to substantial differences in their internal mechanics and underlying principles of physics. The essential difference is in whether or not the dryer has an external venting source to eliminate water in it gaseous state—the local humidity inside the dryer. Drying time gets reduced as the humidity internal to the machine is dissipated. Relatedly, a dryer in arid Albuquerque dries is able to dry clothes faster than its counterpart in rainy Seattle.

Relative humidity is a critical variable to the efficiency of drying laundry. Venting dryers tackle this problem directly by continuously redirecting steam out of the dryer; lower humidity means faster evaporation. In contrast, ventless dryers do not exchange air flow and condense the liquid into a drainpipe; moisture lingers for that extra latency that it takes for the water to go from liquid to gas back to liquid and, therefore, humidity drops at a much slower rate inside of a ventless dryer and timing of the drying cycle gets extended.

Venting Dryers

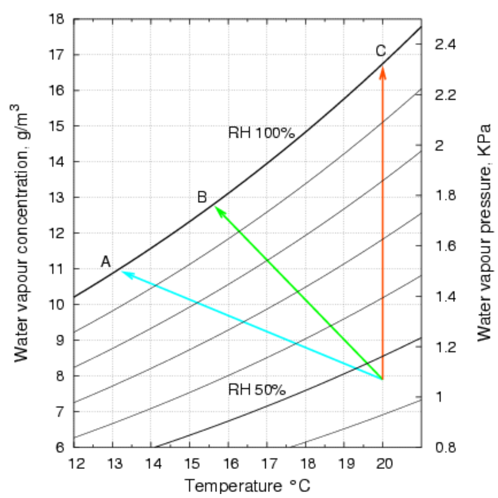
The performance of a venting dryer is superior to that of a ventless (condensing) dryer. Not surprisingly then, most of the dryers in the American market are venting machines. A venting dryer works by pulling in cooler air from the outside, heating the air, and then actively discharging it through a vent to the exterior of the home.

Converting cold water into hot steam (latent heat of vaporization) is an energy-intensive process, making the dryer an expensive appliance to run and one that is prime for energy use refinement in a new model of dryer. The feature the most effectively drives drying time and energy efficiency is the external vent on the dryer. For frame of reference, steam at a temperature of 100 degrees takes up 1500 times as much room as liquid water. Therefore, it is critical to get rid of steam as quickly as possible to reduce relative humidity and pressure inside the dryer tumbler. Without an external vent, moisture does not escape quickly and the humidity inside the dryer stays at a higher level for an extended time. In effect, it's always a rainy day in a ventless dryer.



Schematic showing efficient air flow through a vented dryer. Cooler air is vented in
and hot, moist air gets vented out.

Textile care requires more delicate balance of variables than just blasting the wet clothes at the highest possible heat and providing substantial airflow. The science of psychrometry is the study of the interaction of water and air. Applied psychrometry related to laundry has yielded curves (see figure to the right) that dictate dryer heat settings, tumble speed, internal chamber pressure, and rate of airflow to optimally dry wet textiles.



Ventless Dryers

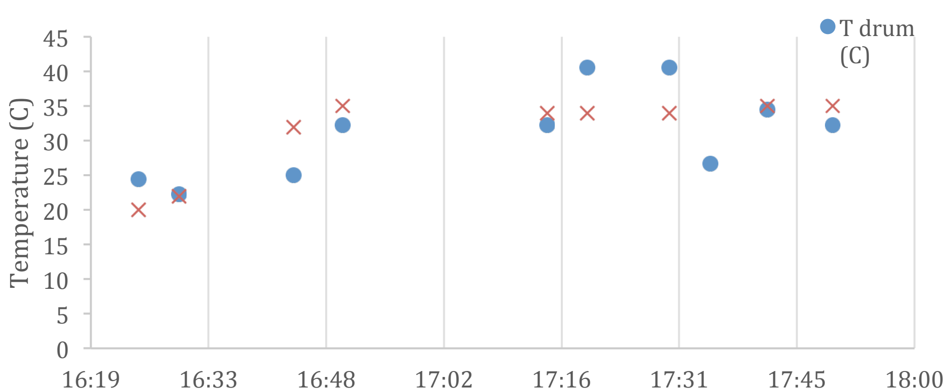
Ventless (condensing) dryers are less common but have a distinct type of application. Because they do not require an output vent, they can be used in tight or unconventional spaces such as RVs and boats where venting and strong airflow are impossible or compromised. The tradeoff for being able to have a dryer where a more standard vented dryer cannot go is in efficiency of drying time. Also called condensing dryers, ventless dryers work by drawing air from the room and passing it through a heat exchanger inside the machine to condense the moisture. The heat exchanger serves as a cooling device; by cooling the air, the trapped moisture in the air is removed by condensation. The condensed beads of liquid are stored in a containment chamber and drip their way to exit the machine through a drainpipe.

Vented Drying – Linear Water Removal

Detailed studies of the inter-relationships between vapor pressure, relative humidity, and evaporation have been conducted. See below for an example round of pilot testing. Rigorous safety testing (results not shown) is ongoing to ensure that industry safety standards are met or exceeded.[4]

Summary: Across a number of tests, Marathon's first generation all-in-one machines have been demonstrated to be of equal efficiency of drying time of a standard high-end dryer currently on the market, as measured by the drying latency and the slope of the linear reduction in water volume of the clothes sampled throughout the drying cycle.

Notes	Time	Weight (lbs)	T drum (F)	T drum (C)	T out (C)	RH out (%)
IL fan on outlet, No exhaust fan	*16:25*	6.74	76	24	20	65
	16:30	6.74	72	22	22	72
IL fan to inlet, exhaust fan	*16:44*	6.68	77	25	32	52
	16:50	6.62	90	32	35	41
Restarted with exhaust fan	*17:15*	6.54	90	32	34	
	17:20	6.46	105	41	34	
Added fan before HE	*17:30*	6.36	105	41	34	
	17:35	6.28	80	27		
	17:42	6.20	94	34	35	
	17:50	6.14	90	32	35	



[4] U.S. Consumer Product Safety Commission. (2003). Final report on electric clothes dryers and lint ignition characteristics.

Conclusion

Ventless Drying is Far Less Time Efficient

Because the relative humidity inside a ventless machine is very close to the saturation point for the air at the given temperature, evaporation slows dramatically, leading to poor drying performance. A vented dryer strategy is the basis for a new generation of all-in-one washer/dryer combos.