

**HOT WAXING**  
**Reality vs. The Lab**  
(Some Issues On Hot Waxing P-Tex)  
Ray Yusi, Ski Sharp Products

When choosing to wax skis/boards, most people believe that hot waxing is the best choice. This view is based on a belief that hot waxing achieves the greatest depth of penetration into the P-Tex and therefore the greatest benefit. After applying my engineering background to this subject, I have come to the conclusion that the results suggested by the ski wax companies' laboratory experiments as represented in their literature are not achievable in the real world.

Wax serves two purposes as applied to P-Tex in snow sport usage.

Wax provides optimal glide performance - this is a function of the coefficient of friction, hydrophobic characteristics and the hardness of the wax as designed for specific snow conditions.

Wax also protects the P-Tex from abrasion and the resultant wear. This is primarily a surface and migration issue that involves your choice of wax and application method. This is probably the most important issue for the recreational skier who would like to enjoy his/her skiing and protect his/her investment as opposed to racers who get there skis for free and are looking for that extra hundredth of a second.

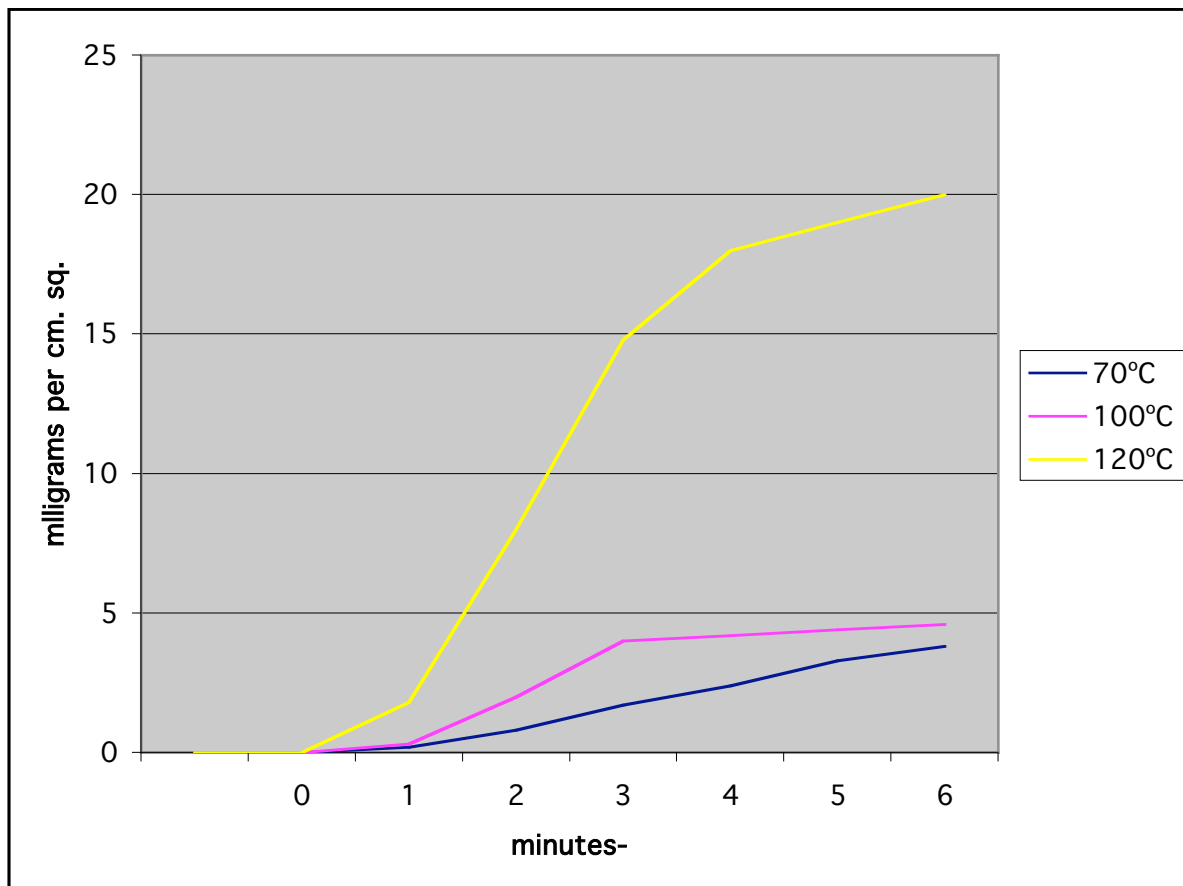
Polyethylene, the material for making P-Tex, has a structure that is both crystalline and amorphous. The crystalline portion does not absorb wax. The amorphous portion can absorb wax only a few molecules deep and that is functionally meaningless. P-Tex is now manufactured in two forms-extruded and sintered. Prior to the advent of sintered P-Tex several years ago, all P-Tex base material was extruded and therefore offered little in the way of wax absorption. With extruded bases, hot waxing was merely a convenient way to apply wax in a thin, consistent, coating, but with negligible absorption into the base. This provided little benefit after one run. But this is where the history and habit of hot waxing began even though the performance benefit was very limited.

Recognizing the need for tougher P-Tex and deeper wax penetration into the P-Tex, manufacturers developed a P-Tex described as Ultra High Molecular Weight (UHMWPE) produced by a sintering process, as a replacement for the extrusion process. Simply stated, sintering is the process by which the P-Tex is made into a seemingly solid material by applying heat and high pressure to microscopic balls of UHMWPE. Visualize if you can, ping pong balls dumped into a bucket. Imagine that they are glued together where they touch each other. When the glue has hardened, you can remove the mass of ping pong balls as a solid unit, but there are huge air spaces

within the “solid” unit where the surface of the balls are not in contact. These air spaces represent theoretical potential to be filled with wax – a theoretically enormous improvement over extruded P-Tex.

In the old days of extruded P-Tex we were only concerned about getting enough heat to spread the wax since absorption was negligible. Now, as we reach for the highest absorption possible we are led to employ higher temperatures, facing two possible risks. If the temperature gets too hot (135°C, 275°F), we will melt the P-Tex and seal the pores in the P-Tex making it behave like extruded material as far as absorption is concerned. Because we now spend more time working the wax into the base, the high temperatures can be damaging to the ski structure because of the vastly differing coefficients of expansion for the materials employed. High temperatures will cause the interface between differing materials to be highly stressed putting the ski at risk for de-lamination and/or distortion.

To fully appreciate the effect of high temperature on wax absorption, we need to discuss a graph that both Swix and Toko present in their waxing manuals. I have chosen to replot their graph here using a linear spacing on the vertical axis for improved clarity.



Their graph shows milligrams of wax absorbed per square centimeter on the vertical axis and time at temperature on the horizontal axis. The curves displayed on the

graph represent three possible ironing temperatures. The accompanying descriptions in the manuals suggest that little wax is absorbed below 70°C (158°F). The horizontal time scale stops at 6 minutes because more time results in little additional absorption. Their graph has a non-linear scale on the vertical axis which distorts the impression by suggesting wax begins to be absorbed immediately and understates the effect of increased temperature on absorption.

As an engineer, I naturally thought about how the experiment was conducted to obtain the data to create the graph. In order to gather the data and have it be reliable, it seems unlikely that they used an iron because it would add a significant degree of variability to the experiment that would distort the data. It seems most likely that they used sample pieces of P-Tex sealed on all sides except one to simulate the ski. Then to simulate hot waxing, they immersed the samples in temperature controlled baths of molten wax for pre-determined times to obtain data points for their graph. After scraping, the sample would have been weighed and the net increased weight reported as absorption. (I also believe the sample was preheated to the test temperature before immersion into the wax bath. More on that below.)

It is important to understand that the time referred to on the graph is the time at temperature for every portion of the ski. Which means you will spend a lot more time than most people do in order to keep the WHOLE ski at temperature for 6 minutes. Without an oven this is virtually impossible to accomplish. For example, if the iron is 4 inches wide and the ski is 60 inches long, there are 15, 4 inch sections along the base ( $60/4=15$ ). The graph infers that each of those 4 inch sections must be at 120°C (248°F) for 6 minutes. Therefore we can reason that the total time to apply the wax will be 6 minutes times each of the 15 sections. Totaling that up, we get 15 times 6 minutes = 90 minutes. That is the way any scientist or engineer would interpret the graph. The only tuners I know spending that kind of time waxing are on the World Cup Circuit and you wouldn't want to pay for the wax they use in 90 minutes.

As can be seen on the above graph, there is little difference in the amount of wax absorbed between 70°C (158°F) and 100°C (212°F) (a change of 30°C), but a dramatic difference is observed when the temperature is only raised an additional 20°C to 120°C (248°F).

Toko, in its manual, also offers a photomicrograph that clearly indicates a maximum penetration that is about .014 inches deep for waxing at 120°C (248°F) for 6 minutes. The question that arises in this engineer's thinking is why isn't the penetration greater given all the effort applied?

My resulting thoughts are as follows. The spaces in the P-Tex represent the potential to absorb wax. But that potential can never be completely realized with hot waxing for two reasons. In normal ironing procedures the P-Tex surface at the start of hot

waxing is quickly covered by initially melting and spreading the wax before any real absorption can be obtained thereby trapping the air in the P-Tex. As we continue to apply the iron and the wax begins to penetrate the P-Tex, but quickly loses temperature and solidifies because the surrounding P-Tex is cooler than the wax. What is really happening with extended time is that the P-Tex is getting hotter at deeper zones of the P-Tex keeping the wax molten so that it can continue to be absorbed. But it is, in fact, impossible for the P-Tex to be deeply absorbed because there is no way to expel the air occupying the spaces in the P-Tex that we are trying to fill. As we raise the temperature of the P-Tex we are also raising the temperature of the trapped air. Raising the temperature of the trapped air causes it to expand, creating resistance to penetration even if the wax is still molten. To further extend this train of thought, one might speculate that as the P-Tex cools after hot waxing, the warm air in the spaces of the P-Tex will also cool and contract creating a vacuum to draw more wax in. I doubt a vacuum effect because I believe the mentioned air compression due to heating is more likely only being reduced by the cooling and because the wax is now solid, it can only move to a limited degree.

With regard to hot waxing we often hear people mention the additional benefit of migration of wax to the surface due to the ski flexing during use. I doubt the existence of this behavior for several reasons. Any one who has hot waxed skis has noticed that as you apply heat to the base it expands and the ski loses its camber. As the ski cools before scraping the camber returns due to the cooling. This force induced by the contracting of the cooled base tries to push wax both out to the surface of the ski and inward in response to the reduced air expansion due to hot waxing. Scraping removes the wax that was pushed out during the cooling phase. Now we put the ski on the snow and it gets cold and the wax becomes stiffer and less mobile. The kicker here is that the base during skiing never sees a compression load to provide the energy to drive wax to the surface. The ski goes from flat (a tension load on the base because the camber has been removed) to an even higher tension load when the ski is bent while carving an arc. Unload the ski and it returns to its unloaded cambered state. So where is the compression loading necessary to move the wax to the surface? It doesn't exist! Too bad, because migration is a very appealing marketing justification for hot waxing.

Since most non-World Cup tuners don't want to spend 90 minutes waxing, we need to ask ourselves two questions. Why is deep absorption important and what is a meaningful depth of wax absorption?

Deep absorption is important because one begins to see very minor "base burn" (a gray/white abrasion pattern that appears along the edge of the P-Tex where it meets the steel edge) even after one run with a ski that has been carefully and thoroughly hot waxed. "Base burn" is abrasion and wax protects against abrasion by providing lower friction and a barrier layer protecting the P-Tex.

I suggest that the ultimate test of deep wax absorption is that after a day of skiing, there should still be a residue of wax in the P-TeX. This would suggest that the P-TeX is still receiving some protection from abrasion and providing the glide benefits desired. If you have a clear P-TeX base and use wax with a graphite filler, you can visually see the retained graphite as evidence.

The bottom line here is that hot waxing is very risky and not as effective a process as popular opinion and lab data has suggested! If one wanted to maximize the wax loaded into the ski, one would put the ski in an oven, very gradually raise the temperature of the whole ski to 240 ish° F and then apply the wax in the oven. This way one would be assured that the wax would achieve the greatest theoretical penetration possible. Here I am just arguing for maximum absorption even though I believe absorption does not provide what the marketing suggests.

Our real goal in a wax application should be to use a easy process that provides the desired benefits and avoids the risks and shortcomings of hot waxing with sufficient penetration to ensure a residue of wax within the P-TeX at the end of a day of skiing.

Such a process might employ a tool that uses high pressure to drive the wax into the P-TeX without the negative and self-limiting effects of hot waxing. In an alternative speculation, I can imagine a material, liquid at a temperature slightly elevated above room temperature that has a chemical affinity for P-TeX, that is liquid enough to be self-absorbing into the P-TeX, that is highly hydrophobic and has a low coefficient of friction. It would also have to solidify at room temperature. Sounds like a tall order. Now all we have to do is find someone to invent it.

Thanks for thinking along with me!