Background WHPVA slope rule change 2017

Since decades the HPV-community has been debating HPV racing categories. The original motivation for separate HPV-racing was to counteract the restrictions imposed by the traditional cycle-racing bodies, and also to compare the performance of not just athletes on similar bicycles, but also different types of vehicles.

To this end it was attempted to restrict not the vehicles, but the environmental conditions. IHPVA and later WHPVA categories attempted to reduce the influence of wind and gravity by restricting these to 6 km/h (at 2 m height) and 2/3 % slope, respectively. This is because the harvest of environmental energy is good from a practical point of view, but mixed power sources give uninteresting records or scientific data.

Besides the inherently linked performances of vehicle and rider, there is energy input from wind and gravity. and also water current for HPBs. Then there is also the double effect of altitude. This means a successful record must optimise the combination of many factors in six groups:

- vehicle (mass, resistances, ventilation, and drive train)
- human (power and endurance)
- best utilisation of available wind
- best utilisation of allowable slope
- altitude (highest best for vehicle)
- altitude (lowest best for rider, except with long high-altitude training)

Then there is also the question of energy storage. Even though most events disallow this and also the additional harvest of solar energy (encouraged in specialist events), there is no escaping the intrinsic storage of kinetic energy in the vehicle and rider themselves, and the effect of potential energy conversion if there are any altitude differences at all.

The wind and slope restrictions seemed severe at first, but today seem too lenient:

- The wind allowance gave at least a 150 W wind assistance in the case of the fastest HPB over 100 m, which had an air propeller.
- The slope allowance gives about 200 W gravity assistance in the timing section for today's fastest HPVs over 200 m, due to about 25 kJ converted potential energy in the run-up.

While both the IHPVA and WHPVA dropped the wind allowance for water vehicles, they kept this and also the slope for land vehicles, even though there were many attempts to change this. Endless discussions never reached any agreement and the IHPVA and WHPVA split up partially due to this. The IHPVA idea is to keep continuity with the existing 200 m records, almost all at the nearly optimal Battle Mountain site, open to all, but remote to all those not in the north-western USA. The WHPVA ideal is to enable any team to set records anywhere in the world at sites not too remote, and also to extend the "pure human power" principle - already used in the rules for water vehicles - also for the land vehicles.

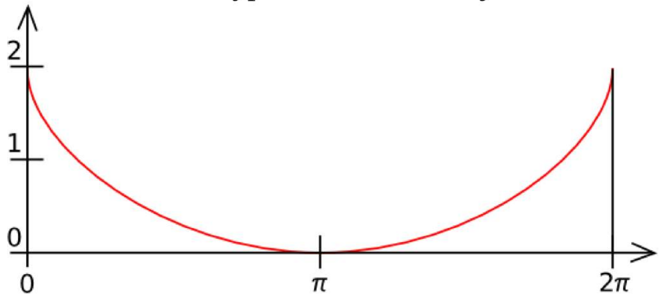
Now at last in 2017 rules have been worked out to this end. The remainder of this article deals with the technical differences encountered and the basis for the new rules.

The optimal course

There are two types of courses which can be considered optimal for vehicles. One is the perfect flat, or more exactly a line on an ideal https://en.wikipedia.org/wiki/Figure_of_the_Earth, such as the geoid, thus a line of constant altitude or elevation. In most courses the difference between flat and geoid is only a few millimeters in altitude, so in the following I'll use the expression "perfect flat" even though it would really be something like the geoid.

Profile of a straight megameter (1000 km) course on the geoid

The other is a modified https://en.wikipedia.org/wiki/Brachistochrone_curve with equal-altitude start and finish, which would give the fastest course from one point to the other. Brachistochrone-type courses are however highly impractical, as they are extremely rare in nature, expensive or small if artificially built (e.g. https://en.wikipedia.org/wiki/Half-pipe), and there would have to be a different brachistochrone-type curve for every set of conditions, i.e. course length and vehicle and power characteristics. There is no net gain of gravitational energy, but intense temporary conversion of potential to kinetic energy and vice-versa. The use of brachistochrone-type curves or even just available valleys is however not "cheating", as there is no net gain of energy if the start is no higher than the finish. But allowing these would be against the ideal of a course which *at the same time* has a *logical, elegant optimum*, and is also *readily available for all*, in as many places as possible. Therefore it is rational and fair to chose a *line of equal altitude as the ideal course*. It is obvious that this gives an ideal "pure human power" situation with respect to gravity.



Brachistochrone-cycloid for the frictionless case.

Unfortunately perfect flats or geoid-type surfaces are rare in nature except for frozen lakes or canals, which are often snow-covered, or even rarer dry lakes, e.g. with salt surfaces. Available roads or runways are surprisingly uneven with local hills and hollows even if not sloped. The good news is that this unevenness does allow finding a multitude of equal-altitude start-and-finish courses in many places. These will mostly be slower than the perfect flat, as can be shown with simulation programs, but a better choice than climbing a steady slope or doing a course in both directions, as is sometimes suggested. However some courses with a hollow (dip, valley) will be faster (even in both directions), the more they approach the optimal brachistochrone-type curve. The WHPVA Rules and Records Committee (RC) spent a lot of time trying to find a logical limit not as arbitrary as the original slope rule or some meters height tolerance. It couldn't find one, so the rule is simple: **no points of *lower* altitude than the *start*, in any *timed* section,** except in cases where it can be clearly shown that a local dip has no advantageous effect compared the ideal flat. Hills can be tolerated, because they are *always* physically disadvantageous compared to the ideal flat.

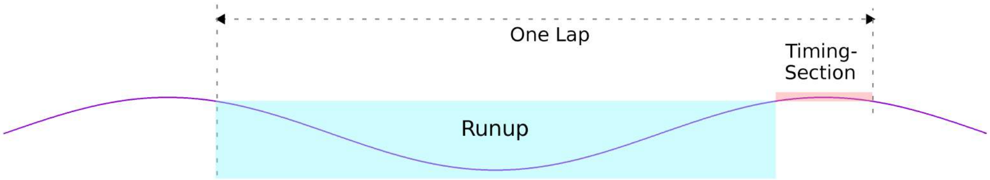
For run-ups to flying-start events the rule however must be the opposite: **no points of *higher* altitude than the *exit* in any *run-up* section** except in cases where it can be clearly shown that a local hill has no advantageous effect compared the ideal flat. Hollows can be tolerated, because they are *always* physically disadvantageous compared to the ideal flat.

The reasons for this: In a run-up with a hill, a rider could climb to the top with low power and speed and *effectively* start from a position of higher altitude. While the effect of a small and short hill can be negligible, a long downslope preceding the timed section can give substantial gravitational assistance as is the case with the old rules. A hollow however does nothing but shorten the run-up and effectively removes the rider's control. It results in a higher speed where it is not wanted and increases the average speed, thereby increasing air-drag losses. This gives a lower speed at the exit unless the rider works harder.

Finding good courses

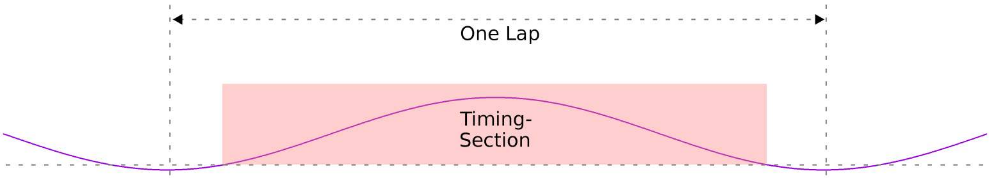
As perfect flats are seldom available, finding a good "legal" **flying-start course** involves looking for an "S"-shaped profile with any hollow in the run-up and any hill in the immediately following timing section. Both as slight as possible.

This also makes a further type of course possible: the **round circuit on a slope**. Velodromes and big circuit speedways are rarely flat, even not considering turns with raised banks. A perfect circle on a slope has an altitude profile in the shape of a sine wave and a real circuit on a slope something similar, so within a single pass, will give a run-up from one half to almost one full lap, and a timing section from very short to one half lap. Most round circuits are actually irregular, but there is always a highest point around which the timing section can be centered. If the timing section is short and does not contain a pronounced peak, this also means that most probably any number of laps or parts thereof could be used for the run-up.



A flying-start run-up nearly as long as one lap and a short timing section.
The vertical scale is greatly exaggerated.

For standing-start events, the timing section can also be centered around the highest point. This means that the start of a short timing section will in general not be at the same location as that of a long timing section.



A standing-start timing section nearly as long as one lap.
The vertical scale is greatly exaggerated.

Long-distance courses on big circuits and even velodromes are of course possible like they always have been. The new rules however ask that the timing start is near the lowest point. For courses with many laps this requirement can be relaxed if it can be shown that the effect is negligible.

Dealing with banks

Velodromes and motordrome big circuits usually have inclined and raised banks in the curves. For standing-start courses this makes no difference if the above principles are applied. However events with flying-starts and multiple laps on velodromes would mean that the timing section must be centered on one of the banks, or more practically, that vehicles are observed to not use the raised banks.

If a course with strict adherence to the rules isn't feasible

Often it is difficult to find a course or to place timings sections exactly as suggested above. A record could still be acceptable if it can be shown that there is no advantage compared to the hypothetical perfectly flat course, that the advantage is negligible, or if it can be treated like an error and the measured results error-corrected.

The WHPVA Rules and Records Committee can advise whether record attempts in particular locations are likely to succeed if accurate elevation data is available, e.g. a professional survey, or in some cases profiles derived from public data accessible online.

Courses which do represent an advantage compared to the ideal course of equal elevation, e.g. a hill in a runup-section or a valley in a timed section, may still be usable if the elevation divergency can be calculated as an error and subtracted. For example, an advantageous variation of potential energy (resulting in a gain of kinetic energy) could be subtracted and the measured time T and corresponding measured speed V corrected to give the official record speed v and record time t.

The following equation can be shown to be applicable in most cases: $v = (V^2 - g \cdot h)^{-2}$

where g is the gravitational acceleration due to gravity, usually about 9.8 m/s^2 and h the maximum disallowed height of the potential energy (= error) in m. The speed v is then in m/s and the record time t = (length of timed course) / v.

Worked example: The runup-section of a 200 m timing-section has a 2 m hill in the middle, an "error" of 2 m against the rule. A vehicle is timed with T = 10 s. Thus V is 20 m/s (72 km/h). The above correction formula gives v = 19.5 m/s and t = 10.25 s.

Coexistence of old and new records

For the flying-start events, the new records are clearly not comparable with the old ones, as the speeds are lower, so they must be recorded separately. For the long-distance events, the differences are negligible, so can be recorded together with the old ones, and only if the speeds are actually higher..

Document prepared by Theo Schmidt for the WHPVA Rules and Record Committee
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