Explanation and Manual

Tone Arm Alignment Gauge

System © Walter E. Schön

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distribution of sound
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This unique tone arm alignment gauge allows you to check the tone arm geometry of your record player and to install the pickup ideally aligned (offset angle and overhang) to keep distortion to a minimum.

Just how important this is for the audio quality is shown by a comparison of the distortion (harmonic distortion HD2) caused by the relative lateral tracking error when playing a record with the distortion in the signal processing in the phono preamp, preamp and power amp: it is higher by at least two orders of magnitude! If the tone arm geometry is not ideal, as is unfortunately often the case, or if the installation of the pickup system was not checked, the harmonic distortion HD2 caused by too high a relative lateral tracking error can reach values of more than 3%. In contrast to this, all electronic components of hi-fi systems combined show values below 0.1% or even under 0.01%. The optimization of the tone arm geometry using a good alignment gauge can therefore produce a much higher gain in audio quality than three-figure or four-figure investments in better electronics. But before we look into how you can achieve this gain in audio quality with the Schön gauge, we should look at some of the basic principles of tone arm geometry and at the relationship between „lateral tracking error“ and the distortion which results from it.

What is lateral tracking error and what causes it?

When a track is being recorded, a cutting stylus cuts the sound signal into the lacquer as a spiral groove. The cutting stylus is guided in parallel from the outside to the inside by a rigid arm on a carriage so that the cutting head axis always remains tangential to the arc of the circle of the groove when viewed from top.

If the stylus of the pickup should later track the wave of the groove corresponding to the music signal without distortion when playing the record, the pickup would likewise have to be guided in tangential alignment to the circle with the tracking radius. Tangential tone arms (Fig. 1), however, require a motor tracking which is precisely controlled, complex and so prone to disturbance. There is also a high effort involved in avoiding irritating rumbling due to a jerky tone arm tracking. Pivotal tone arms are therefore used which neither cause rumbling nor require tone arm tracking.

However, because a pivoting tone arm continuously changes its direction and would only be aligned tangentially to the course of the groove at one single radius (Fig. 2), a positive lateral tracking error would arise further to the outside (i.e. seen from above, an angle difference from the tangent counter clockwise) and a negative lateral tracking error further to the inside. Both cause equally audible distortion.

If, however, the pickup is attached to the tone arm at an angle of around 17° (on a 12" or 300 mm tone arm) to around 23° (on a 9" or 230 mm tone arm) towards the turntable axis, an exactly tangential alignment is possible for two radii and the amount of the lateral tracking error in the remaining range of radii is substantially smaller (Figs. 3 and 4).

The radii at which a tangential alignment, and so no lateral tracking error, is present are the "zero radii" or "null radii" (or "zero points" or "null points").

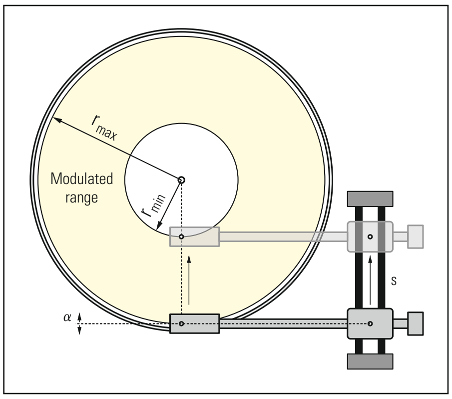


Fig. 1: A tangential tone arm guides the pickup system like a disc-cutting lathe guides its cutting stylus: along a radius that is always tangential to the circle. Such an arm may swivel within a narrow angle, but as soon as a very small lateral tracking error "α" emerges, the feed of the sled is released automatically (stroke "s").

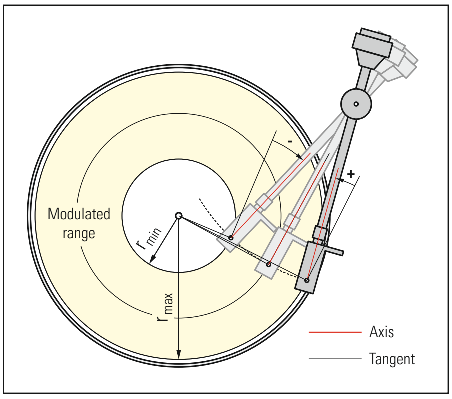


Fig. 2: The axis of a pickup can be tangential to the groove only at one radius if the tone arm is not angled.

The American Percy Wilson made some geometrical calculations on this in 1924 and proposed an offset tone arm with a pickup installed at an angle with zero points calculated so that the amount of the maximum (negative) lateral tracking error between these points will be just as large as the maximum (positive) lateral tracking error in the outer groove and inner groove. In this way, he achieved the smallest possible maximum lateral tracking error (as soon as it is attempted to reduce one of the three equal maxima by a change of the zero points, one of the other maxima, or even both, would become larger than on its or their optimization). Unfortunately, this was not yet the best possible solution, as was discovered more than a decade later.

Why does lateral tracking error cause distortion?

Mathematical attempts to explain why lateral tracking error causes irritating distortion and to describe the type of this distortion were made by the Swede Erik Løfgren in 1938 and, in a different approach, by the American H. G. Baerwald in 1941 - both with the same result. Both men discovered that the distortion resulting from lateral tracking error is almost exclusively made up of the so-called „2nd harmonic“ (a harmonic of double the frequency of the base tone). This result can fortunately be illustrated in graphical form without too much math (Fig. 5): When the stylus rides on the waves of the record groove at an oblique angle to

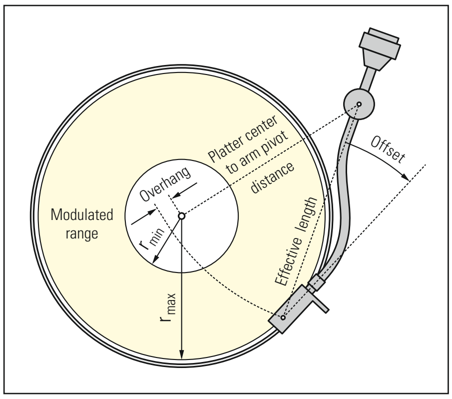


Fig. 3: The stylus of a pickup system on a pivoted tone arm traverses an arc over the record, and the horizontal axis of the pickup system does not remain tangential. The relevant parameters for the lateral tracking error are the platter center to tone arm axis distance, the offset angle and the effective length or overhang.

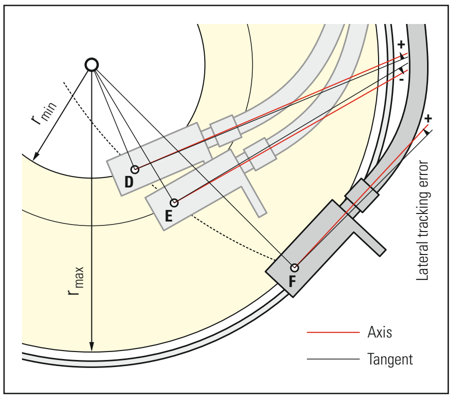


Fig. 4: The lateral tracking error of an angled tone arm varies a from positive to negative and back to positive.

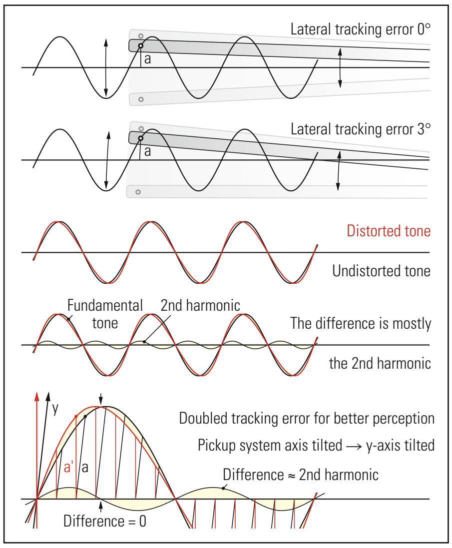


Fig. 5: With a precisely tangential aligned horizontal pickup axis, the stylus at the tip of the cantilever follows the modulation of the groove with an oscillation rectangular to the direction of the groove. With a lateral tracking error, the stylus oscillates with an oblique amplitude "a", and this results in a distorted electrical signal (= red curve). The difference between this distorted and the undistorted signal is called "harmonic distortion" because it consists predominantly of the second harmonic (a tone of the double frequency).

the groove instead of at a right angle due to a lateral tracking error ≠ 0, it detects the amplitudes just as in a coordinate system with a y axis tilted by the lateral tracking error. As can be seen (very magnified wave at the bottom in Fig. 5), the difference (yellow area) between the resulting electrical signal (red curve) and the correct desired signal (black curve) is a curve of double the base frequency with a small amplitude – just like the 2nd harmonic. Further harmonic portions contained therein have such low levels that they do not become audible and thus can be neglected.

This distortion is expressed in percent as the second harmonic distortion HD2. Fortunately, a low HD2 is not a problem in music since the tonal palette of the instruments also contains harmonics which are even very important. These harmonics and their intensity ratios allow us to recognize e.g. whether the sound is coming from a bassoon (high harmonic content) or from a flute (low harmonic content). However, if the added distortion HD2 exceeds a value of around 0.2% to 0.5%, even musically untrained ears perceive it as irritating and as audible distortion.

How does HD2 depend on the tracking error?

Løfgren and Baerwald therefore calculated the degree of distortion and found that the distortion HD2 is not just proportional to the lateral tracking error, but also inversely proportional to the radius. However this means (what Percy Wilson did not consider) that the distortion in the inner groove becomes much stronger than in the outer groove with an equal lateral tracking error. With today's LPs whose outer grooves have a radius of around 2.5 times that of the inner grooves, the distortion at the inner grooves would be around 2.5 times that at the outer grooves when the tone arm was optimized according to Percy Wilson. This is why it is not the tracking error, but rather the "relative tracking error" (= tracking error divided by the respective radius, given in °/cm) must remain small.

This can be explained with simple math: Since records rotate at a constant speed (33 1/3 r.p.m. with today's LPs), the periphery of the inner groove must contain just as many waves as the outer groove, which is almost 2.5 times larger, with a constant tone pitch. The waves inscribed in the groove (Fig. 5) are therefore increasingly compressed in the longitudinal direction as the radii decrease – in the inner groove almost by the factor 1/2.5 relative to waves of equal pitch in the outer groove. An oblique oscillation direction of the stylii in the inner groove must therefore have an effect which is 2.5 times worse than that in the outer groove.

How big can the maximum distortion HD2 be?

According to the calculations of Løfgren and Baerwald, the percentage of the harmonic distortion HD2 caused by the lateral tracking error on full modulation (maximum velocity = 10 cm/s) amounts to four times the relative lateral tracking error measured in °/cm.

A 9" tone arm without angling and with the same lateral tracking error in the outer groove and in the inner groove (as usual before Percy Wilson) produces a lateral tracking error of almost 11° in the inner groove of today's LPs (at a radius of 57.5 mm according to DIN IEC 98), which results in a relative lateral tracking error of 1.9°/cm and harmonic distortion HD2 of 7.6%.

With an angled tone arm of the same effective length, in accordance with Percy Wilson's proposal it would be possible to achieve an identical lateral tracking error of a minimum of 1.4° (with zero points at 65.8 mm and 127.7 mm) at the outside and at the inside. This produces a relative lateral tracking error of 0.243°/cm and distortion HD2 of 0.97% at the inner groove.

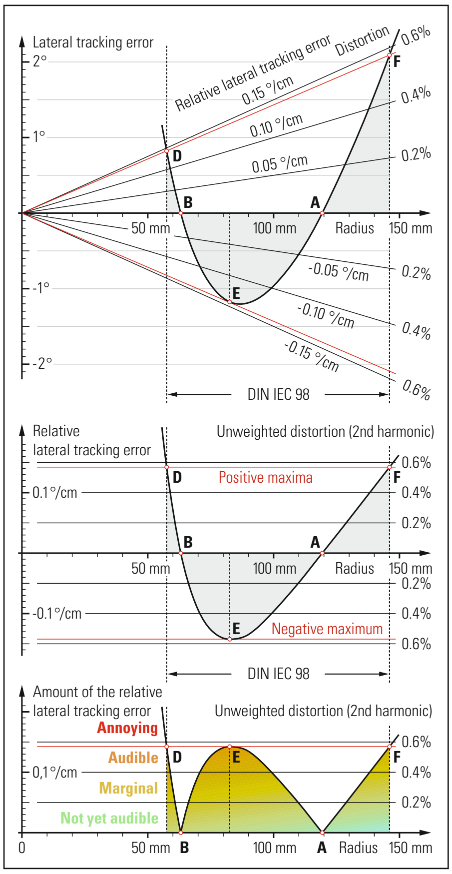


Fig. 6: The lateral tracking error of a 230 mm effective length tone arm optimized according to Løfgren and Baerwald for a minimum radius of 57.5 mm according to DIN IEC 98 with the resulting unweighted harmonic distortion for a velocity of 10 cm/s. Distortion increases with smaller radii because the relative lateral tracking error (= tracking error divided by the radius) is proportional to the distortion. The y-axis of the graph in the middle has therefore been scaled with the relative tracking error. As the distortion is independent of the sign (positive or negative) of the relative tracking error, the graph at the bottom gives the amount of the relative tracking error (the curve below the x-axis between the null radii A and B has been turned upward).

Because the distortion is proportional to the relative lateral tracking error according to the calculations of Løfgren and Baerwald, it follows that an optimization to the lowest possible maximum distortion has to be carried out over three equal maximum amounts of the relative, and not the absolute, lateral tracking error. Both men were also able to devise mathematical formulas for this which still apply today to all tone arms swinging about a vertical axis at a distance d from the turntable axis, irrespective of their shape (e.g. straight or S-shaped), of their effective length or of their material (e.g. carbon compound material or aluminum alloy). They apply to all maximum and minimum radii, to all record speeds and to mono and stereo LPs. The results which can be achieved only depend on the effective tone arm length, on the spindle to pivot distance and on the underlying outer and inner groove radii.

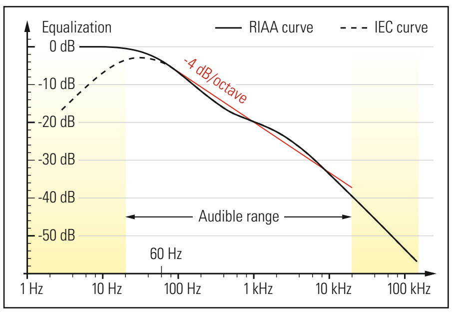


Fig. 7: During playback of a record, the RIAA equalization lowers the level of higher frequencies by about 4 dB per octave to compensate for the complementary emphasis during cutting of the record for better noise reduction and smaller amplitudes of low frequencies. This reduces the harmonic distortion resulting from the relative tracking error by about 63% (= weighted distortion) above 60 Hz. The IEC equalization also reduces the rumble. However, in most diagrams the unweighted distortion is used, and this is why we will do so, too.

These formulas deliver the zero points 63.1 mm and 119.2 mm for the range of radii according to DIN ISO 98. The distortion HD2 can thus be reduced in theory to just under 0.6% (short 9" tone arm, see Fig. 6) or to just above 0.4% (long 12" tone arm). This is around 60% of the harmonic distortion in the optimization according to Percy Wilson and a further improvement.

Reducing the distortion using RIAA equalization

In the same way as the Dolby® system reduces annoying noise by a dynamic preemphasis in recording and by a dynamic deemphasis during playback using tapes and cassettes, a low-noise reproduction is also produced (together with a smaller amplitude for the bass for narrower groove distances and so longer playing times) by raising the high frequencies during recording and an opposite lowering in playback. While this has nothing to do with our optimization of the tone arm geometry at first glance, it does have an indirect effect: Because the deemphasis in the playback takes place with a curve steepness of on average 4 dB per octave (Fig. 7) and because our distortion HD2 as a 2nd harmonic is precisely one octave higher than the base tone distorted by the lateral tracking error, it is also reduced by 4 dB. The unit dB stands for decibel which is a dimensionless logarithmic measure to indicate proportions, e.g. here between the harmonic distortion HD2' after the reduction of the higher frequencies and the harmonic distortion HD2 before it.

After transformation of the equation
$4\text{ dB} = 20 \cdot \lg(HD2'/HD2)$ we get
$HD2' = 10^{0.2} \cdot HD2 = 0.63096\ HD2 = \text{approx. } 63\%\ HD2$.

This means that the reduction in higher frequencies according to the RIAA equalization curve reduces the distortion HD2 caused by the lateral tracking error to around 63%. The harmonic distortion obtained by this „weighting" in accordance with the RIAA curve is called the „weighted harmonic distortion" and indicates the actual value decisive for audible distortion.

However, because it is not usually the weighted distortion HD2' later reduced in the equalizer pre-amp which is indicated in diagrams (such as Fig. 6) which give the relative lateral tracking error in dependence on the radius and contain a scale for the distortion HD2, but rather the unweighted distortion produced by the lateral tracking error, we will also keep to the unweighted HD2 here to allow direct comparability. It is after all irrelevant for the optimization of the tone arm geometry which number we read off the scale. What is most important is a uniform scale and that all three maxima (in the outer and inner groove as well as at the negative maximum between the zero points) become equal and thus as small as possible.

Looking for the ideal lateral tracking error curve

If the relative lateral tracking error is calculated with reference to specific data (effective tone arm length, platter center to tone arm pivot distance or overhang, offset angle and radii of the outer groove and inner groove), a rather asymmetrical parabola-like curve results which extends a lot more steeply over the inner groove region than over the outer groove region (see Fig. 6) and intersects the x axis at two "zero radii" A and B. It is noticeable that the position of these two zero radii does not depend on the data of the tone arm (effective length, overhang, offset angle), but only on the radii of the outer groove and of the inner groove.

Which radius of the outer groove and inner groove we choose for our optimization gives rise to some questions: 1. There are different standards with mutually differing values (problem can be solved). 2. Some record manufacturers ignore these standards and use their own standards (but the differences in today's LPs are small). 3. Most records do not utilize the full permitted range of radii because they have a shorter playing length (supposed audiophiles are in for a nasty surprise here). Let us first look at the standards:

Standard	Inner groove radius	Outer groove radius
DIN 45547	57.5 mm	146.3 mm
DIN IEC 98	57.5 mm	146.05 mm
IEC	60.325 mm (2 3/8 in.)	146.05 mm (5 3/4 in.)
NAB	57.15 mm (2 1/4 in.)	146.05 mm (5 3/4 in.)
JIS	57.6 mm	146.5 mm

The outer groove radius is not critical since the differences are low here and they only have a small influence on the zero points. DIN and IEC are the most widespread (JIS is a Japanese standard which was abandoned in 1994; NAB was used practically only for mono records in the US) and DIN 45547 was adapted to outer groove radius of the IEC on the introduction of the more recent DIN IEC 98. The outer groove radius should therefore be fixed at 146.05 mm.

In addition: 146.3 mm (instead of 146.05 mm) delivers the same zero point B at 63.1 mm and an only minimally displaced zero point A at 119.3 mm instead of 119.2 mm. The distortion values HD2 given in the figures remain the same because they only differ from one another in the third digit after the decimal point.

With the inner groove radius, all the standards are very close, except for the IEC, so that the old and new DIN inner groove radius of 57.5 mm is sensible. However, there are still arguments about this since most records do not utilize this limit value anyway. Some people say: Why take such a large groove range into account if more favorable values can be achieved for most LPs using a smaller range? Others say: Since the aim of optimization is to keep the largest possible distortion low („worst case" limit), you have to use the more critical smaller inner radius as your base.

A very precise calculation delivers some serious arguments in favor of the smaller inner groove radius: The asymmetric shape of the relative lateral tracking error and of the zero points has the consequence that if the larger inner curve radius of 60.325 mm or even more is chosen, as some supposed "audiophile" record lovers demand, the maximum relative lateral tracking error and so the maximum distortion HD2 reduces less than hoped, namely in the case of a 9" tone arm only from 0.57% to 0.52%. If then, however, an LP whose inner groove has a radius of actually only 57.5 mm is played with a tone arm/pickup adjusted as described, this adjustment produces a huge HD2 increase to an enormous 0.89%! Fans of the larger inner groove radius therefore pay for a modest improvement of 0.05% with a sevenfold increase by a painful 0.37% with records with the smaller inner groove radius.

If the „audiophile" (?) record aficionado follows the Clearaudio recommendation and optimizes to an inner radius of 65 mm, 70 mm or 75 mm, this profit and loss calculation becomes catastrophic: The gain in the range of radii reduced in this manner is only 0.13%, 0.20% and 0.26% respectively. However, if a record is played with the still permitted inner groove radius of 57.5 mm, HD2 increases by a huge 0.90%, 1.56% and 2.27% respectively (Fig. 8). Is this really acceptable for someone who claims the title of „audiophile"?

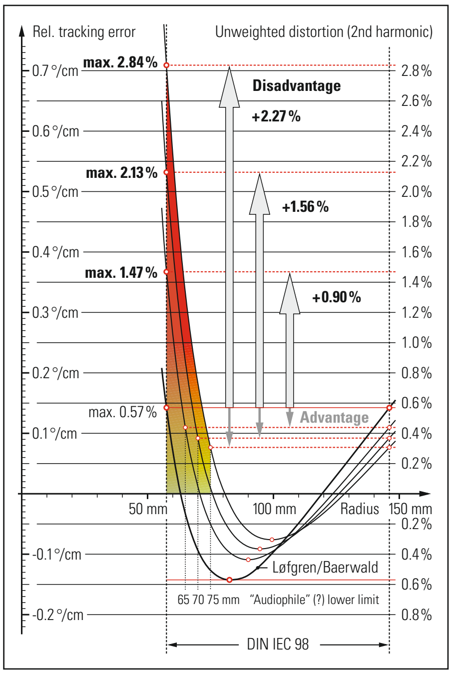


Fig. 8: The high increase in the harmonic distortion at very small radii up to the minimum of 57.5 mm (DIN IEC 98) compared with the almost negligible benefit within the supposed "audiophile" range above 65 mm, 70 mm or even 75 mm reveals a fatal missunderstanding.

Are there records with inner grooves of 57.5 mm?

Because the immediate counter-argument will now be raised that there are hardly any records with so small inner groove radii, it is worth looking at our own collections. Just a fast, random check of only 40 LPs from the author's collection from the three fields of classic, jazz and pop/rock produced the following albums with inner groove radii of even less than 57.5 mm:

CBS 78219, George Szell, „Mussorgsky, Strawinsky, Prokofieff, Kodaly" (A side of disc 1) with 55.8 mm.

DG 2530597, Herbert von Karajan „Berlioz: Symphonie fantastique" (B side) with 57.2 mm.

Atlantic 450186-J, Klaus Doldinger „Jubilee '75" (A side) with 57.0 mm.

EMI 172-04222/23, Pink Floyd „Umma Gumma" (B side of disc 2) with 56.8 mm.

The author does, however, admit that he did not primarily buy his records according to the criterion of an „audiophile" to test his hi-fi system, but rather to enjoy the music, hopefully like most record collectors.

What tolerances apply during the alignment?

All previous points indicate that we should follow the optimization proposals and formulas found by Løfgren and Baerwald and use a range of radii from 57.5 mm to 146.05 mm. The following formulas for the calculation of the zero points

$$r_A = 2\sqrt{2} \cdot r_{min} \cdot r_{max} / [(\sqrt{2} + 1) \cdot r_{min} + (\sqrt{2} - 1) \cdot r_{max}]$$

$$r_B = 2\sqrt{2} \cdot r_{min} \cdot r_{max} / [(\sqrt{2} - 1) \cdot r_{min} + (\sqrt{2} + 1) \cdot r_{max}]$$

produce the radii r_B = 63.10 mm and r_A = 119.17 mm.

No one will dispute that the zero tracking errors given here with two places after the decimal point cannot be followed with 100% accuracy in practice due to unavoidable tolerances. The check of the tangential alignment of the pickup axis to be carried out at both zero points is also never possible with 100% accuracy, but is rather always subject to more or fewer errors. Løfgren and Baerwald did speak about possible tolerances, but before the present author no one ever thought of actually including them in the optimization calculations! It is a matter of course in the development of industrial products to take tolerances into account. Let us take the example of photographic lenses: If it is found in these products that the tolerances which cannot be avoided in production (e.g. the observation of lens element radii, lens element distances or the centering accuracy) would result in noticeable degradation of the imaging quality relative to the theoretical ideal, the parameters are changed for so long until a solution is found in which the tolerances do not have such a serious effect even though the theoretically achievable ideal is now slightly degraded. It is better always to achieve a result which is as good as possible rather than one which may be somewhat better in some cases, but which is often a lot worse due to the unavoidable tolerances.

We should follow the same procedure in the alignment of the pickup for ideal tone arm geometry. The question which then has to be asked is what is the extent of the adjustment tolerance to be considered. Two tolerance causes must be taken into account:

First, the visual check to be used for the tangential alignment (using parallel lines on the alignment gauge) is not infinitely accurate.

Second, it is not the alignment of the outer edges of the pickup (which we have to use for orientation on the adjustment) which is decisive, but rather the direction of the connection line (not recognizable during adjustment) of the stylus tip to the cantilever's pivot, which may differ slightly. Regrettably, all people do not have an equally good visual check, nor is the cantilever installed with an alignment of the same precision to the housing edges in all pickups.

Who can say that they can recognize a canting of 0.3° relative to the housing edges when looking at a 5 mm long cantilever of a pickup from below? This would namely mean that the stylus is only offset relative to the point of rotation of the cantilever by

$\tan 0.3° \cdot 5$ mm = 0.026 mm = about 1/40 mm ≈ 1 mil.

However, during the alignment, we only see the pickup from above, which makes the tangential alignment

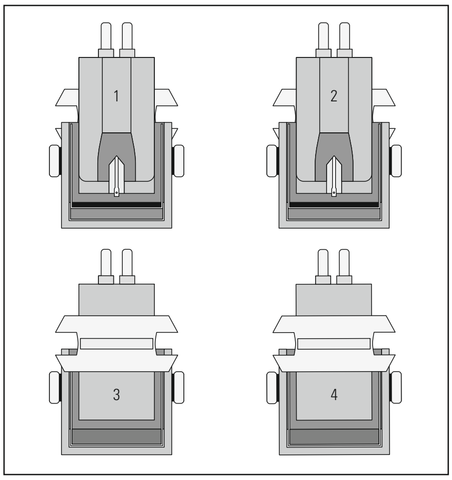
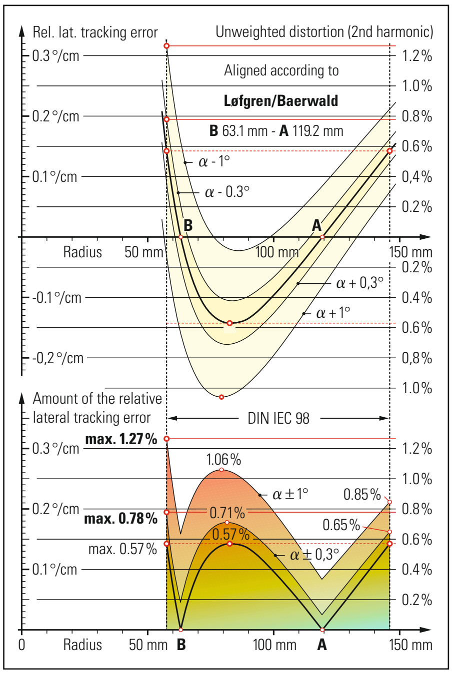
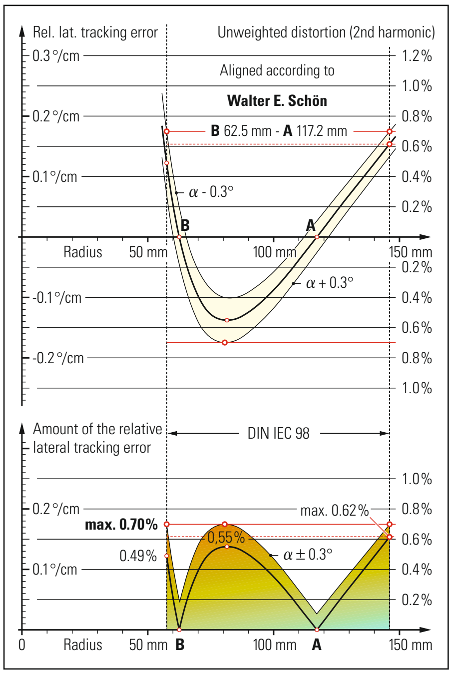


Fig. 9: The length of the cantilever is only about 5 mm. This makes it difficult to recognize an oblique orientation relative to the edges of the housing if the angle is very small. However, you cannot see the cantilever from above during alignment. You can only take your cue from the orientation of the edges of the case. But these edges would indicate an incorrect orientation if the cantilever is a little bit oblique. But furthermore, it is not possible to recognize the parallelism of the short edges of the pickup's case with the parallel lines on a protractor without tolerances! Do you think you could recognize with absolute certainty if neither or one or both cantilevers (upper row) or pickup systems (lower row) is/are oblique, and if so, which and by which angle? Please see the last page for the correct answer.





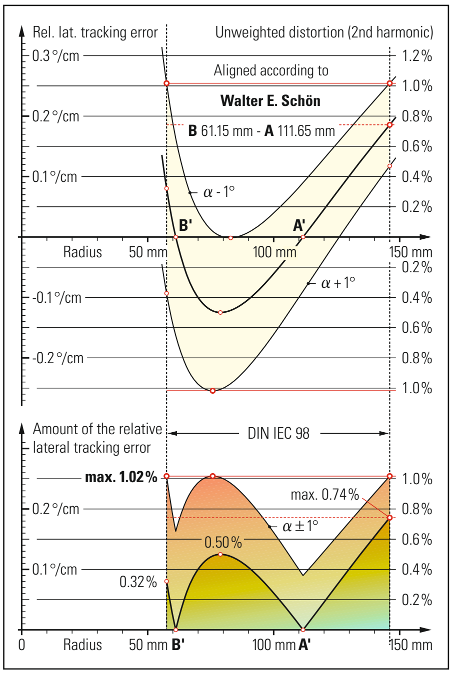


Fig. 10: The bold curve in the diagram shows the course of the relative lateral tracking error for a 230 mm effective length arm aligned according to Løfgren and Baerwald for a radius range from 57.5 mm to 146.05 mm (DIN IEC 98) with the zero tracking error points A at 63.1 mm and B at 119.2 mm. The yellow zones on both sides of the theoretical ideal curve show within which ranges the real curve may vary when the alignment tolerance is ±0.3° or ±1° respectively: The unweighted harmonic distortion at the minimum groove radius can rise from 0.57 % to 0.78 % (when the tolerance is ±0.3°) or from 0.57 % to critical 1.27 % (when the tolerance is ±1°).

Fig. 11: This is the curve of the relative lateral tracking error for the same 230 mm effective length arm and the same range of radii when optimized for a tolerance of ±0.3° with null points A at 62.5 mm and B at 117.2 mm. The inner maximum distortion is significantly lower, the middle maximum value is slightly lower, and only the outer maximum is slightly higher. The zero points are shifted by -0.6 mm and -2.0 mm (compared with the ideal curve) in order to provide three identical maxima of the zone of tolerance for a better result of only 0.70 % harmonic distortion instead of 0.78 % in the worst case of real world practice which is not free from tolerance.

Fig. 12: When the housing of the pickup system does not have straight rectangular edges, but has a conical or rounded shape, a larger angular tolerance of about ±1° has to be taken into account. This results in the zero points A' at 61.15 mm and B' at 111.65 mm. Then the middle curve has a 0.14 % higher maximum value of 0.74 %, but the other maxima are lower than the maxima of the standard curve. However, the decisive maximum is not the maximum of the bold middle curve but that of the border curve of the tolerance range! This maximum is only 1.02 % instead of 1.27 % harmonic distortion in the worst case of +1 % or -1 % tolerance.

even more difficult because it is only possible with reference to housing edges which may deviate from the direction of the cantilever (Fig. 9) and these edges are often not at right angles, but are rounded or conical (which the pickup manufacturers should avoid!).

The author had already evaluated a test series of harmonic distortion measurements at around 70 tone arms and measurement results in a number of hi-fi magazines to assess the total tolerances in 1981. The distortion measurements were carried out in a hi-fi test lab after three different lab engineers had each realigned the tone arms completely. A mean fluctuation of the relative lateral tracking error was then calculated from the obtained HD2 fluctuations for the three alignment positions of each of the 70 pickups and this value was used to calculate the mean angle tolerance in the alignment of these pickups as approx. ±0.3°. If the alignment is not carried out by experienced engineers, even higher tolerances are likely.

The evaluation of measurement results of various hi-fi magazines produced very similar tolerance values in a completely different manner. The effective tone arm lengths and offset angles as well as the radii of the zero tracking errors of the lateral tracking error curve measured in the test labs of these magazines are given for the tone arms of the record players tested there. From the given zero points r_A und r_B and the effective tone arm length teff, using the formula

$$\alpha = \arc\sin [(r_A + r_B)/2\, t_{eff}]$$

the offset angle α can be calculated and, as was to be expected, the given measured value always differed somewhat from the value calculated from the other data, and indeed up to 0.8° in one case and even up to 0.9° in another case. A value of just above 0.3° resulted as the mean error of all values checked in this manner. This appears reason enough for the author also to assume a mean tolerance of at least ±0.3°.

The optimization is different when tolerances apply

If the tangential alignment of the pickup at the zero points A and B contains errors, we do not obtain the lateral tracking error curve in accordance with the formulas of Løfgren/Baerwald, but rather a slightly deformed and displaced curve which runs higher or lower. If we assume the mean tolerance ±0.3°, the real curve can be found somewhere inside a tolerance zone around the ideal curve (Fig. 10) which surrounds it like a tube. The tolerance zone does not, however, remain equally wide over the range, but its upper and lower boundaries rather run further and further apart from the outer groove to the inner groove (from right to left).

The fact that the tolerance zone increases continuously from the outside to the inside, that is from the outer groove over the negative maximum up to the inner groove, can be seen from the fact that the maxima of the ideal curve (Fig. 10) all have the same relative lateral tracking error or distortion of 0.57%, while the maxima of the tolerance zone increase (distortion HD2 increases from 0.65% over 0.71% to 0.78%).

As we already know from the theoretical ideal curve, the smallest possible maximum results when all three maxima are equal. Because the positive maxima of the outer groove and of the inner groove lie on the upper boundary curve of the tolerance zone, but the negative maximum lies on the lower boundary curve, this can be seen more clearly with reference to the lower representation with an upwardly folded negative curve portion. With an optimization to equal tolerance range maxima calculated by the author for a tolerance of ±0.3°, the curve (Fig. 11) shows three identical distortion maxima of only 0.70% instead of 0.78% (in Fig. 10). This is undoubtedly an improvement even if it is admittedly not a very large change.

The colored areas below these curves show how irritating the distortion becomes: Green = below the audible threshold; Red = annoying distortion audible. The transition is not exactly the same for everyone and is fluid. With smaller radii, the distortion becomes audible faster – illustrated by the somewhat slanted color area – because further distortion (including the pinch effect, vinyl material deformation due to „compressed" waves) is added there to the harmonic distortion caused by the lateral tracking error.

Schön gauge provides the best possible alignment

As the first and currently only tone arm alignment gauge, the Schön gauge is based, on the one hand, on the still valid formulas of Løfgren/Baerwald and on the range of radii according to DIN IEC 98 of 57.5 mm to 146.05 mm demonstrated to be expedient above; on the other hand, however, it also takes account of the tolerances unavoidable on the alignment. These tolerances are partly given ex works (parallelism of the cantilever axis to both lateral housing edges and right angularity to the pickup end surface) and increase due to the alignment of the pickup at the tone arm (headshell) to be carried out only according to imperfect visual judgment with reference to very short housing edges which may even be conical or arched. The zero points B at 62.5 mm and A at 117.2 mm which are used on the Schön gauge and which can be observed precisely thanks to the inscribed grooves (for the avoidance of the skating effect) are calculated so that the smallest possible distortion maxima result with a mean angular tolerance of ±0.3° (which has been shown to be realistic by measurement series).

For everyone who place less trust in their visual judgment, the old Schön gauge had two alternative zero points B' at 61.15 mm and A' at 111.65 mm calculated for the angle tolerance ±1° in accordance with this principle. They have been left off the Type 2 Schön gauge since they were rarely used and since the gauge is clearer without the additional zero points.

How to measure and to align

Some record players or tone arms come with an alignment gauge which is based on unfavorable zero points or on a range of radii without any practical relevance. Some alignment gauges of expensive tone arms quote an incorrect spindle to pivot distance. The offset angle is frequently not correctly matched to the effective tone arm length, but rather often seems only to have been chosen to match the "design". A good alignment gauge is therefore indispensable. This new Schön gauge is the best possible tool for a precise optimization of the tone arm geometry to minimize the maximum relative lateral tracking error and thus also the distortion. It also offers you more measuring options than any other alignment gauge.

1. The optimization criterion is the minimization of the maximum relative lateral tracking error ("minimax principle") since this is what causes the distortion which is audible and irritating from a certain level.

2. This optimization is mathematically correct for all tone arm lengths. Some gauges can only be used for one single tone arm length and produce more or less pronounced deviations with other lengths; a fact some gauge manufacturers often do not reveal.

3. Its base range of radii is not the standard IEC range of 60.325 mm to 146.05 mm, which produces a huge increase in harmonic distortion with a small inner groove radius, but rather the more practice-orientated range of DIN IEC 98 from 57.5 mm to 146.05 mm. A small increase in the maximum harmonic distortion, e.g. with a tone arm length of 230 mm from 0.52% to 0.57%, is less irritating than if it escalates with records with a long playing time, in this case to 0.89%.

4. Only the Schön gauge takes account of tolerances which are unavoidable during alignment. The angle errors which occur even when the greatest care is taken in aligning the small pickup to the parallel lines of the gauge due to the restricted visual judgment and the production tolerances of the pickup of around ±0.3° are only taken into account in the calculation with this gauge. Since the tolerances have a much greater effect with smaller radii than with larger ones, the mathematical calculation of the zero points results in the smaller values of 62.5 mm and 117.2 mm rather than in 63.1 mm and 119.2 mm for DIN IEC 98.

5. An accurate measuring tool and for checking the manufacturer's data as well as for a comparison of the relative lateral tracking error before and after the alignment (control of success) are also all only possible using the Schön gauge. You can measure the effective tone arm length, the pivot to spindle distance, the overhang (even if the tone arm cannot be pivoted to the turntable center!) and even the value of the relative lateral tracking error over the full range of radii and then the corresponding curve for your tone arm.

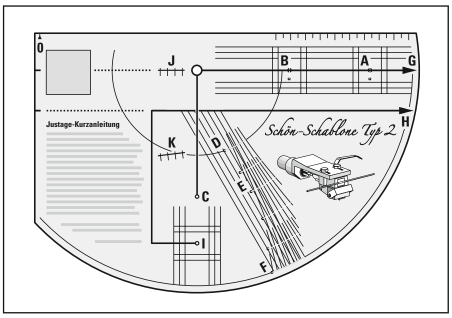


Fig. 13: The new "Schön-Schablone Typ 2" alignment gauge for optimizing and measuring the tone arm geometry is clearly arranged and even more versatile.

Effective tone arm length (Stylus tip to arm axis)

The effective tone arm length is the horizontal distance of the stylus tip from the vertical pivot axis of the tone arm. Before starting the measurement, use a fine fiber-tip pen to mark the position of the pivot axis by drawing a dot on the tone arm bearing and to mark the position of the stylus tip by drawing a dot on the

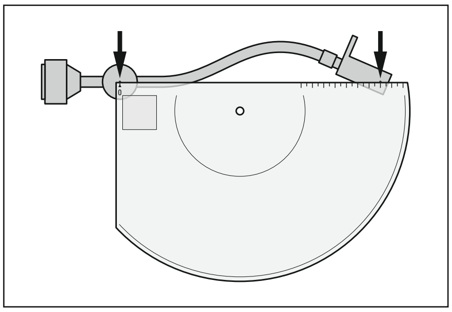


Fig. 14: Before measuring the effective tone arm length it may be helpful to mark the position of the axis of the tone arm pivot and the position of the stylus on top of the headshell of the cartridge with a thin fibertip pen.

headshell. You can measure the effective length up to 250 mm (around 10") by placing the zero mark of the gauge at the pivot axis of the tone arm (see Fig. 14) and by placing the millimeter scale over the stylus tip.

You should use a ruler if the tone arm is longer.

Spindle to pivot distance (turntable axis to arm axis)

You can use the same millimeter scale to measure the spindle to pivot distance. It is easier to measure in the horizontal direction if you place an oblong object such as a book or a CD jewel case onto the turntable so that a perpendicular edge abuts the center spindle of the turntable from the left (see Fig. 15).

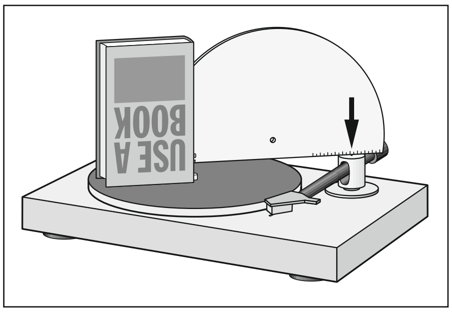


Fig. 15: For measuring the distance between the platter center and the horizontal arm pivot, position the zero mark above the platter center as shown. A book held against the rod may help to measure horizontally.

If you lean the gauge against the perpendicular edge, the zero mark coincides with the axis of the pin and the long edge with the millimeter measurement has a horizontal extent. You can read off the spindle to pivot distance on the millimeter scale at the center (axis) of the tone arm bearing previously marked by a dot.

Overhang (arm pivotable over the platter center)

The overhang states by how much the effective length of the tone arm is larger than the spindle to pivot distance. It is a very critical parameter for the alignment of the tone arm. It is later used to carry out the fine matching of the effective tone arm length to the spindle to pivot distance (see Fig. 18).

Place the gauge onto the turntable like a record. If your tone arm can be swung over the center of the turntable (if not, a further measuring method will be

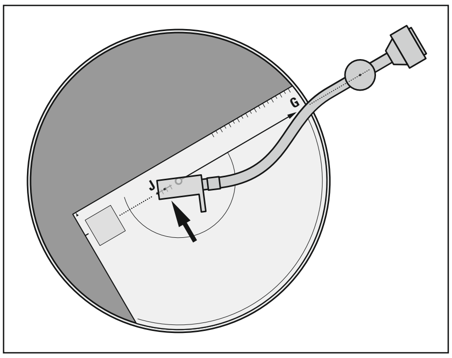


Fig. 16: For measuring the overhang directly, rotate the gauge so that the line G points precisely to the axis of the tone arm pivot. Swivel the tone arm over the platter center and read the overhang at the stylus position.

presented below), turn the turntable with the gauge until the line with the tip of the arrow **G** running through the centering hole points exactly toward the pivot axis of the tone arm. Swing the tone arm toward the center of the turntable without displacing the gauge. You can then read off the overhang on the millimeter scale **J** below the tip of the stylus.

Overhang (arm not pivotable over the platter center)

If your tone arm cannot be swung over the center of the turntable, turn the gauge on the turntable until the line a little further down with the tip of the arrow **H** is aligned exactly with the pivot axis of the tone arm

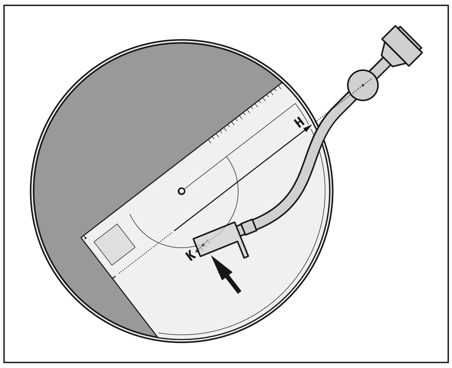


Fig. 17: For measuring the overhang indirectly, rotate the gauge so that the line H points precisely to the tone arm pivot. Swivel the tone arm to the second overhang scale at the circle of the inner groove. Read the value.

(Fig. 17). Then swing the tone arm up to the second overhang scale **K** without displacing the gauge and put the tip of the stylus down there. Check whether the line with the tip of the arrow **H** still points exactly to the pivot axis of the tone arm and correct the alignment as required. Then read off the overhang at the point the tip of the stylus was placed down.

This indirect measurement is just as exact as the direct measurement with medium-length tone arms.

Very short or very long tone arms produce a very slight deviation (less than 1/100 mm), that is well below the reading accuracy, so that it can be totally neglected.

How to find the correct spindle to pivot distance

When installing a separate tone arm into a turntable, it is necessary to observe a pivot to spindle distance matched to the effective tone arm length with very high precision. If the pivot to spindle distance is too small or too high, so that this error cannot be remedied by changing the overhang (the movement path of the pickup in the headshell's oblong holes is restricted!), the tangential alignment cannot be achieved at both zero tracking errors. An incorrect overhang cannot be fully compensated later by the offset angle; only a middling good compromise then remains.

You should therefore first measure the effective tone arm length before installing the tone arm. The pickup should be screwed at a middle position of the oblong holes so that it can be moved back or forward for any required correction of the overhang. Use the following diagram (Fig. 18) to determine the overhang exactly matching the measured effective tone arm length.

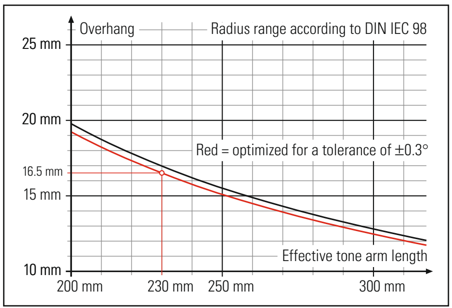


Fig. 18: These curves give the relation between overhang and tone arm length (the black curve is calculated without tolerance). Add effective length and overhang for platter center to tone arm pivot distance.

The marked dot shows an overhang of 16.5 mm for an effective tone arm length of 230 mm. The correct pivot to spindle distance is the effective length minus the overhang, in this case 230 mm - 16.5 mm = 213.5 mm.

The black curve applies to an optimization according to Løfgren/Baerwald without considering the tolerances with the zero points 63.1 mm and 119.2 mm.

Measurement of the relative lateral tracking error

The lateral tracking error is the angle by which the direction of the cantilever projected onto the record plane differs from the tangential direction to the circle with the respective radius. The relative lateral tracking error, that is the lateral tracking error divided by the respective radius, is, however, decisive for the resulting distortion. Only the Schön gauge provides the precise measuring facility you need for this.

As shown on the gauge, to increase the checking precision, you should use Scotch tape or self-adhesive modeling clay to stick the lead of a mechanical pencil to the pickup – to the front if it has a smooth front or otherwise to the front edge of its screw plate. Place the gauge onto the turntable and place the stylus tip of the tone arm swung to the outer groove circle into the applied groove at point **F** (Fig. 19).

Then compare the direction of the pencil lead or, if you were unable to stick any lead on, the direction of the front edge of the pickup with the parallel lines on the gauge. Turn the turntable slowly clockwise (in the direction records turn) until the lines on the gauge extend parallel to the pencil lead or to the front edge of the pickup. You can read off the amount of the relative lateral tracking error at the outer radius 146.05 in degrees per centimeter (°/cm) at the point where the tip of the stylus is located. Mark this point on the corresponding radius line on a copy of the master diagram shown at the bottom of this page (Fig. 20).

In the same way, measure the relative lateral tracking error for the other radii 140 mm, 130 mm, 120 mm, etc. down to 50 mm (while 50 mm is not relevant, it does improve the curve accuracy for the range of small radii). After marking all the measurement points, draw a smooth curve which follows the course of your measured points as closely as possible.

Because your measurements (like the alignment) are not free of tolerances, your measured points may be above or below the smooth course of the curve. When drawing your curve, use shape of the pale ideal curve of a 230 mm and 300 mm tone arm as your guideline.

The quickest alignment of the tone arm geometry

The fastest way to align the overhang and the offset angle using the alignment point **I** of the Schön gauge with the line **H** pointing to the tone arm pivot axis (Fig. 21): put the stylus down there and adjust both overhang and offset angle for a parallel pencil lead.

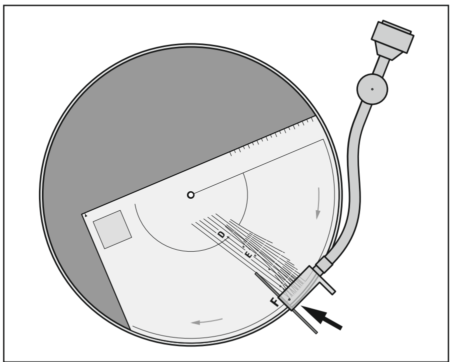


Fig. 19: For measuring the relative lateral tracking error, set the stylus down in the outer groove at point F. Then rotate the gauge till the pencil lead is parallel with the parallel lines on the gauge. Repeat for the other radii.

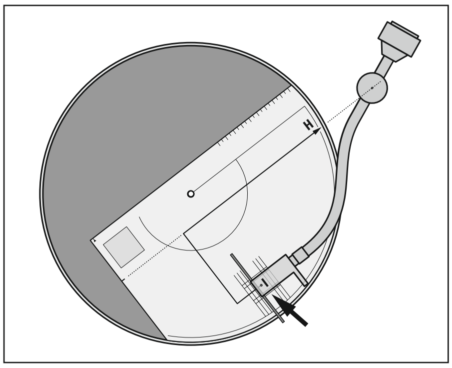


Fig. 21: For the fastest alignment or a final check point line H to the tone arm's pivot axis. Shift and rotate the pickup system until the stylus can be set precisely on point I with the lead parallel to the lines on the gauge.

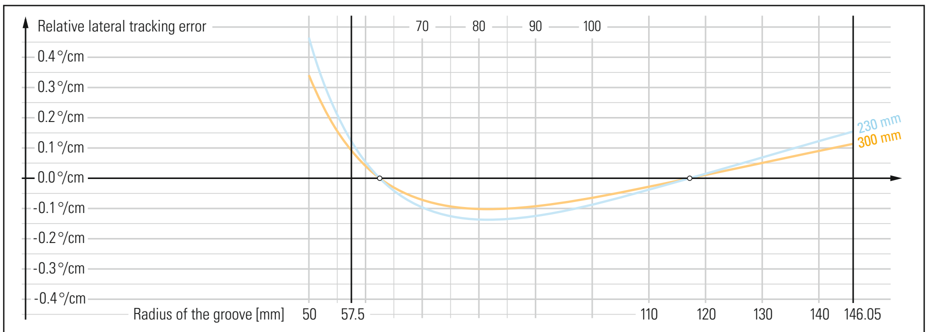


Fig. 20: Plot the results of your measurements into a copy of this diagram, not into this original. Then you can make as many new copies as you need at a later date for more measurements. The curves printed in pale blue and pale orange show the relative lateral tracking error of two tone arms with effective lengths of 230 mm and 300 mm after having been aligned perfectly according to Walter E. Schön. Your alignment should result in a very similar curve.

Most exact zero positions - Alignment for purists

First roughly set the overhang. To do this, turn the turntable with the gauge so that the line with the arrow tip **G** running through the centering hole points exactly toward the tone arm axis (Fig. 22). Then swing the tone arm over the gauge up to point **C** – without displacing the gauge. If you cannot put the stylus down exactly at the point **C**, move the pickup in the oblong holes of the headshell so that you are exactly on the point **C**. Then, to make sure, check whether the arrow tip **G** is still pointing toward the tone arm axis.

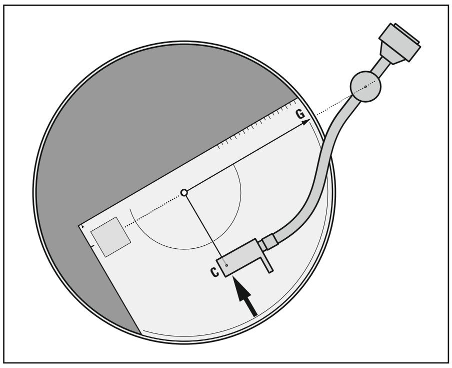


Fig. 22: For the fastest setting or the final check of the overhang rotate the gauge till line G points to the tone arm's pivot axis. Shift the pickup system in the headshell until the stylus can be set precisely onto point C.

Alternatively, the overhang can be determined from the effective tone arm length in the overhang diagram (Fig. 18) and can be set at the overhang scale **J** or **K**.

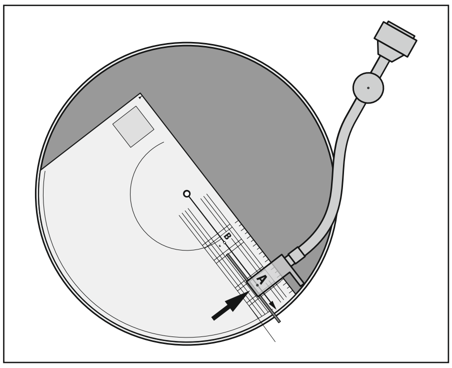


Fig. 23: For the first step of aligning of the offset angle set the stylus onto point A. Check the parallelism of the pencil lead or the edge of the pickup system with the lines on the gauge and rotate the pickup if necessary.

Place the stylus down in the groove exactly onto point **A** (Fig 23). If the pencil lead or the pickup edge now runs parallel to the parallel lines on the gauge, the alignment is complete. If this is not the case, loosen the fastening screws on the pickup and turn it a little (without displacing it!) until you have a parallel alignment at point **A**. Then tighten the screws again.

If you then alternatively put the stylus down at the start of the groove in front of point **B** and in front of point **A** (where a point has been marked in each case) and slowly rotate the gauge clockwise until the pencil lead is parallel to the lines on the gauge, you can read off at the two scales below the stylus how much the overhang has to be corrected at **B** and how much the offset angle has to be corrected at **A**. Only the overhang may be changed at **B** and only the offset angle at **A**. Repeat both checks until the pencil lead or the pickup edge is parallel to the gauge lines at **A** and **B**.

If everything is then correct, you have finished the alignment of the tone arm and you can now enjoy your music in the best possible audio quality.

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Answer to the question below fig. 9: The cantilever of pickup system 2 is oblique by -0,2°, and the whole pickup system 4 is oblique by -0,3°; this results in a total error of -0,5°. · This manual has been printed environment friendly and CO_2 neutral.