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WELL TEMPERED TURNTABLE

Manufacturer's Specifications
Drive System: Belt.
Motor Type: 24-pole synchronous.
Speeds: 33⅓ and 45 rpm.
Dimensions: With optional dust cover, 19 in. W × 15½ in. D × 7 in. H (48.26 cm × 39.37 cm × 17.78 cm).
Weight: Approximately 38 lbs. (17.3 kg).
Price: Without arm, $975; with Well Tempered arm, $1,695; dust cover, $120.
Company Address: c/o Transparent Audio Marketing, Rte. 202, Box 117, Hollis, Maine 04042.
For literature, circle No. 90

After Bill Firebaugh had designed the Well Tempered tonearm, he decided to apply some of his ideas on viscous damping to the design of a turntable. The absorption of energy from external vibrations is something that most turntable designers are concerned about; however, most of them concentrate their efforts on reducing vibration problems in the low-frequency range. They do this by using a suspension system employing strategically located springs. The compliance of these springs is chosen so as to resonate with the mass of the turntable at some very low frequency, usually below 10 Hz. A suspension of this type tends to reduce the effects of outside vibrations and shocks on the reproduced sound.

One way of reducing vibration effects is to use very compliant springs to suspend a relatively low mass. Other designers use less compliant springs but make the suspended mass very large, which tunes the system to the same range. In this case, however, the Q is usually higher, so some method must be used to damp the springs.

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WELL TEMPERED TONEARM AND VAN DEN HUL MC-ONE CARTRIDGE

Manufacturer's Specifications

Tonearm

Type: Pivoted, with adjustable cartridge mount and viscous damping.

Pivot-to-Stylus Distance: 9 in. (22.9 cm).

Overall Length: 11⅜ in. (28.9 cm).

Effective Mass: 10 grams.

Arm Tube: Stainless steel, sand-filled.

Price: $720.

Cartridge

Type: Medium-output moving coil.

Stylus: Van den Hul Type I.

Cantilever: Boron rod.

Output: 0.45 mV for 5 cm/S at 1 kHz.

Tracking Force: 1.5 grams recommended; 1.3 grams minimum.

Estimated Vertical Compliance: 20×10^{-6} cm/dyne.

Mass: 7.3 grams.

Recommended Arm Mass: 6 to 12 grams.

Load Impedance: 15 ohms minimum.

Frequency Response: 20 Hz to 20 kHz, ±0.75 dB.

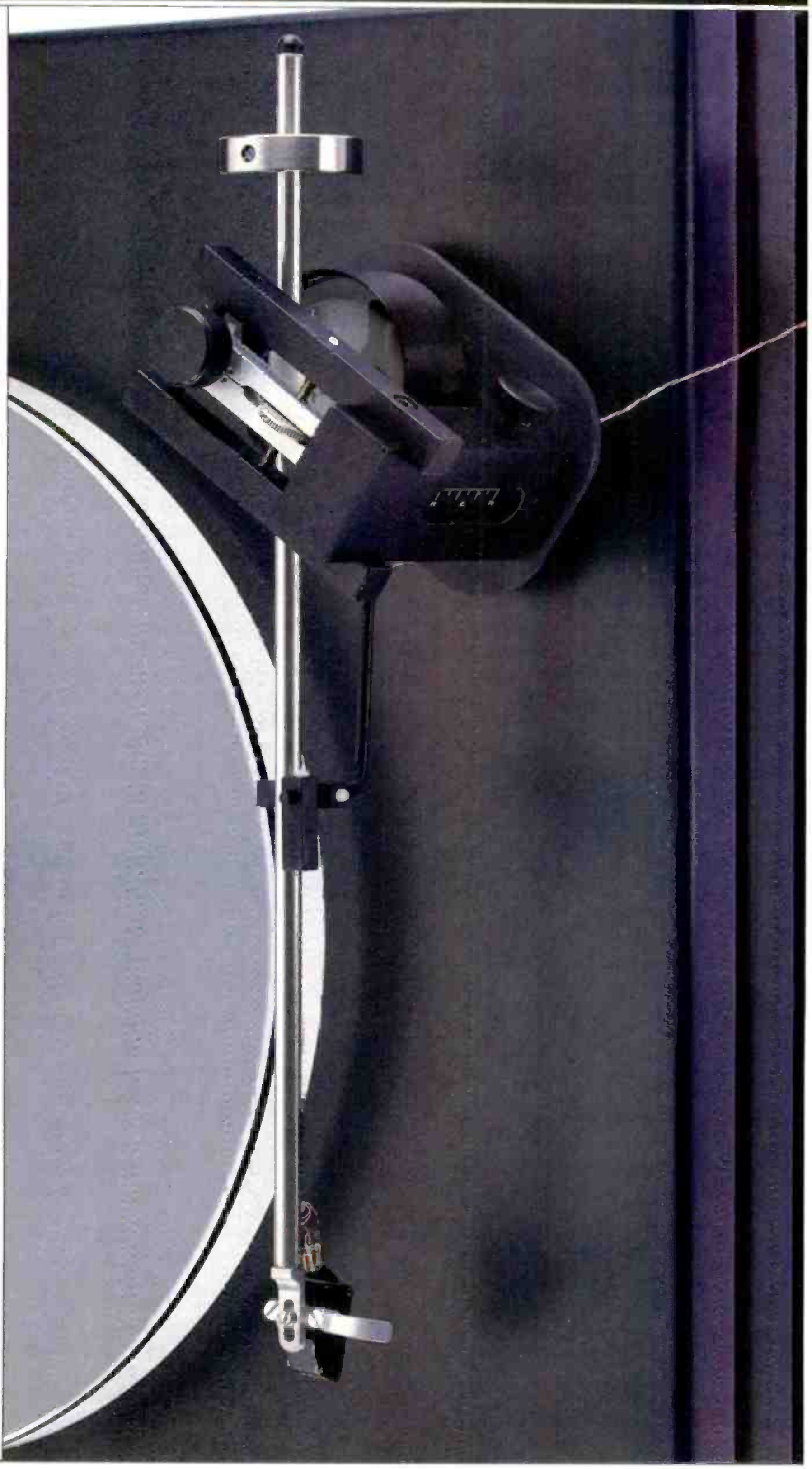
Channel Separation: 40 dB at 1 and 10 kHz; approximately 20 dB at 20 kHz.

Price: $1,075.

Company Address: c/o Transparent Audio Marketing, Rte. 202, Box 117, Hollis, Maine 04042.

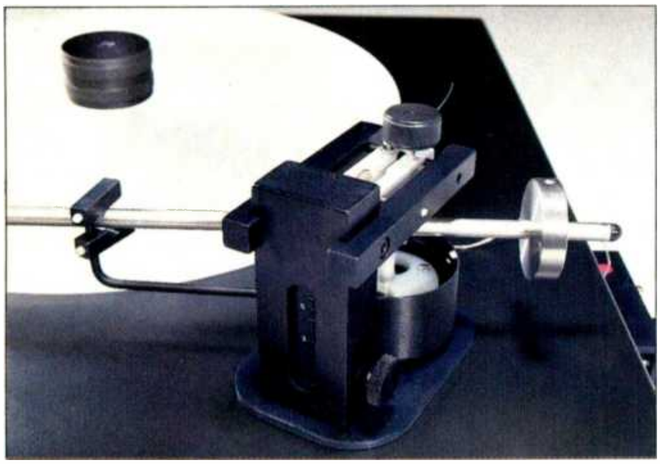
For literature, circle No. 91

One of the pleasant things about doing technical reports for *Audio* magazine is being able to investigate, in detail, the products of some very innovative minds. Most of the improvements in sound reproduction from phonograph records is due to certain individuals' dissatisfaction with the state of the art. Each of them looked at the way



Photographs: ©1988, Bill Kouirinis

The arm produced a subdued "deh" or "dah" when tapped, a sign that it would not introduce much coloration.



things were being done and said. "There must be a better way." Their improvements either found their way into others' products or spurred their colleagues to even greater innovation. We have all benefited from the work of people like Lou Souther, Ivor Tiefenbrun, Alastair Robertson-Aikman, Bernard Jacobs, Dave Fletcher, John Michell, Bruce Thigpen, Steve McCormack, Herbert Papier, Joe Grado, A. J. van den Hul, and others. (If I have left anyone out—and I most assuredly have—I can always blame the Editor!)

The Well Tempered tonearm is the result of the innovative thinking of Bill Firebaugh, and even its appearance is radical enough to win him the "Iconoclast of the Year" award. He started his quest for the perfect record player by taking apart his early AR tonearm, designed by Ed Villchur (there's a name I missed). As Firebaugh told me, "I had burned my bridge. I had no tonearm now. There was no turning back!" He liked the AR's viscous-damped vertical bearing, but he found himself adjusting it too often and decided that there must be a way to make it more consistent. As a mechanical engineer for a large aerospace company in Southern California, he had the background to tackle a job like that, but, as often happens during a quest for perfection, the trail he took resulted in something very far removed from the original AR design.

When Bill came to my lab from Los Angeles to set up his turntable and tonearm (with the van den Hul MC-One moving-coil cartridge), I asked him if he had ever seen the Gray Professional tonearm, which was made in the 1950s for broadcast studios. He said he had only heard about it. I had owned one, and I described to him the problem of keeping the viscous-damped bearing adjusted. The Gray used a single half ball at the bottom of the tonearm post; the half ball was seated in a matching cup which contained viscous fluid. The glitch was that the arm used to settle, push the viscous fluid out of the way, and allow the ball to come in direct contact with the cup, thus negating the fluid's damping effect. The Gray had to be adjusted by pulling the tonearm up and holding it while the viscous fluid slowly settled back down toward the bottom of the cup. Thus, you needed a good deal of patience to complement your dedication to quality sound! The Well Tempered tonearm eliminates this tedious adjustment problem by suspending the bearing so that it never settles down into the viscous fluid. (If I had thought of that years and tears ago, I might still have my old 16-inch Gray!) But there are other features of the Well Tempered that make tonearms of yesteryear the quaint curiosities they are.

The MC-One is a moving-coil cartridge made by A. J. van den Hul, and it incorporates his patented stylus design, which is shaped to trace the difficult high frequencies pro-

MEASURED DATA

Well Tempered Tonearm

Pivot-to-Stylus Distance: 9.375 in. (238 mm).
Pivot-to-Rear-of-Arm Distance: 3.0 in. (76 mm).
Overall Height Adjustment: 1.25 in. (32 mm).
Tracking-Force Adjustment: 0 to 6 grams.
Tracking-Force Calibration: None, separate gauge required.
Cartridge Weight Range: 3 to 12 grams.
Counterweights: 20.9-gram aluminum and 61.5-gram steel.
Counterweight Mounting: Direct to armtube, with nylon set screw.
Sidethrust Correction: Caliper dial varies string-pivot spacing.
Pivot Damping: Viscous fluid in large cup.
Lifting Device: Aluminum finger lift attached to cartridge.
Headshell Offset: Cartridge offset adjustable in mount; no headshell.
Overhang Adjustment: Slots in cartridge mount.
Bearing Type: Armtube suspended by two strings.
Bearing Alignment: Adjustable pivot point.
Bearing Friction: Viscous fluid in cup.
Lead Torque: Very low.
Arm-Lead Capacitance: 25 pF, left and right.
Arm-Lead Resistance: 1.1 ohms, left and right.
External Lead Length: None supplied.
Structural Resonances: 550, 1200, 3800, and 4900 Hz.
Base Mounting: Single hole.

van den Hul MC-One Cartridge

Coil Inductance: 120 µH, left and right.
Coil Resistance: 15.7 ohms, left and right.
Output Voltage: Left, 0.10 mV/cm/S; right, 0.11 mV/cm/S.
Tracking Force: 2.0 grams recommended.
Recommended Load Resistance: 40 ohms or more.
Response to Load Capacitance: Unaffected by normal input capacitance.
Cartridge Mass: 7.25 grams.
Microphony: Very low.
Hum Rejection: Excellent.
Rise-Time: 11 µS.
High-Frequency Resonance: 33.3 kHz.
Low-Frequency Resonance: 10 Hz (in Well Tempered tonearm).
Low-Frequency Q: 1.67 (in Well Tempered tonearm).
Polarity: Plus, for CD-4 standard.

The vertical bearing design ensures equal up and down motions when the tonearm is tracking vertical warps.

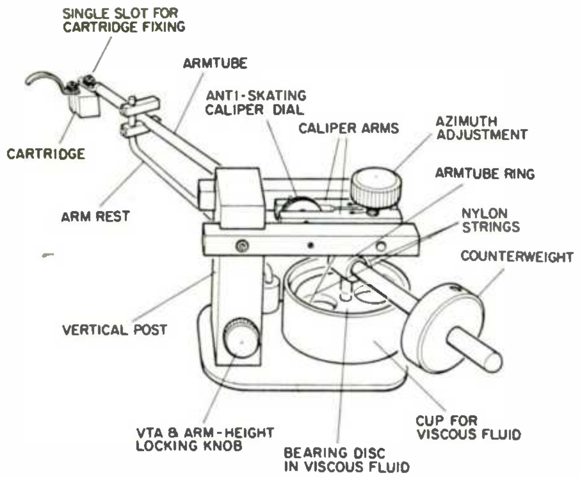


Fig. 1—The Well Tempered tonearm, showing the locations of various design features.

duced by the chisel-shaped styli used in cutting records. While this stylus is available for license by other cartridge manufacturers, most of them opt for a simpler, generic stylus with a long-ellipse contact area.

First Impressions

By its very appearance, the Well Tempered tonearm is different from any other arm. The main bearing is suspended by two nylon strings and sits in a bath of viscous fluid. Aluminum, stainless steel, and various types of engineering plastics are used in the arm's fabrication. The main armtube is one continuous piece, from the cartridge fixing point to the end which holds the sliding counterweight.

I usually check for bearing integrity by holding the main arm post in one hand while trying to pull, push, and twist the armtube. The design of the Well Tempered arm precludes this, since the bearing is free to move in the viscous fluid. I did tap the armtube, and the sound varied from "deh" (as in delicious) when tapped at the cartridge end, to a very subdued "dah" (as in "ah! That's nice!") when tapped near the pivot. This test told me that the amount of sound coloration introduced by the armtube would indeed be very low.

The finish is black and natural stainless steel and is very good quality. The lack of a headshell is also unusual; the cartridge must be mounted by a single screw to an aluminum extension fitted into the end of the armtube. There are no conventional calibrations anywhere on this tonearm, with the exception of a scale on the main arm post which can be used to set the VTA of the cartridge. The caliper-like device used to set the sidethrust or anti-skating force is something I have never seen before on a tonearm.

Features

As I describe various features, you can refer to Fig. 1, a line drawing of the Well Tempered tonearm. The first thing to notice is that this is basically a unipivot design. Most unipivot bearing designs hold the armtube from below, but this arm is unique in that the pivot, while below the armtube, is suspended from above by strings. The exact position of the main bearing is somewhere near the center of the nylon bearing disc, which is suspended by two nylon strings; it is not fixed in position, as is true with ordinary unipivot designs. The exact position of the horizontal bearing is affected by the azimuth adjustment, while the vertical position will be affected by the height of the cartridge used and the VTA setting. With most cartridges, the vertical bearing center can be positioned slightly above the record surface. This causes the stylus to move up and down equally when tracking vertical warps, which is desirable.

The nylon disc, which has two large holes in it, sits in a bath of viscous fluid that just covers its surface. This viscous fluid provides excellent damping, especially at the usual low-frequency resonance caused by the mass of the tonearm and the compliance of the phono stylus. A short aluminum post extends upward from the nylon disc and connects to a thin but wide aluminum ring with a hole in it. The armtube is securely fastened in this ring. The armtube, which is 0.256 inch in diameter and 0.010 inch thick, is made from 0.250-diameter stainless steel tubing and is 11½ inches long. It is filled with fine-grain sand to damp out any resonances and weighs about 23 grams, including the cartridge fitting and end cap.

The phono cartridge mounting is by a single screw, since the fitting at the end of the armtube is about ¼ inch wide and has only a single slot. This is a trade-off: The rigidity of the cartridge mounting has been compromised to keep the effective mass of the tonearm low. The aluminum finger lift is attached directly to the cartridge, through the cartridge's remaining mounting hole. Of course, this can be eliminated, if desired, to keep the effective mass as low as possible, but since there is no other easy way to raise and lower the tonearm, I left it attached.

The offset adjustment for the phono cartridge is made by rotating the cartridge on its single mounting screw. The offset angle and the overhang are set by using a plastic template which slips over the turntable spindle. The overhang is adjusted by rotating the whole tonearm base around the main pillar, which fits up inside the large, rectangular vertical post.

Many interdependent adjustments must be made to get all this right. As mentioned before, the vertical azimuth, which is adjusted by turning the knob directly over the armtube, affects the position of the horizontal bearing; it also affects the overhang. The sidethrust correction is adjusted by turning the caliper dial, which can be seen sticking up between the vertical post and the azimuth knob. Turning this dial varies the distance between the two aluminum caliper arms to which the nylon strings are attached, thus adjusting the sidethrust correction. Even at the minimum setting, with the beams close together, there is some sidethrust force because of the way the strings are attached. I found this setting worked best with the van den Hul cartridge.

Loosening the knob at the bottom of the vertical post allows you to set the proper tonearm height for the cartridge chosen; it also is used to adjust the VTA. The adjustment must be made by sliding the tonearm up and down by hand.

The van den Hul cartridge and Well Tempered arm had a distinctive sound that correlated well with the results of my measurements.

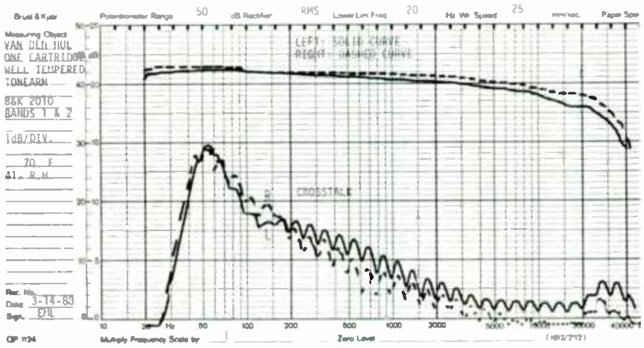


Fig. 2—Frequency response and crosstalk of the van den Hul MC-One phono cartridge in the Well Tempered arm, using B & K 2010 test record.

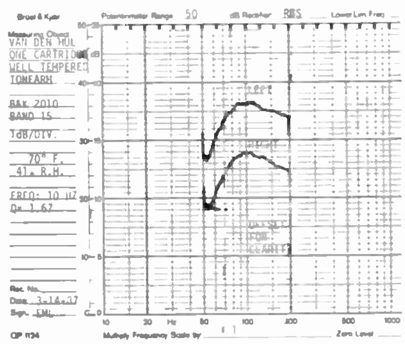


Fig. 3—Low-frequency tonearm cartridge resonance is at 10 Hz. Its Q is 1.67, which is very good. (Curves offset for clarity.)

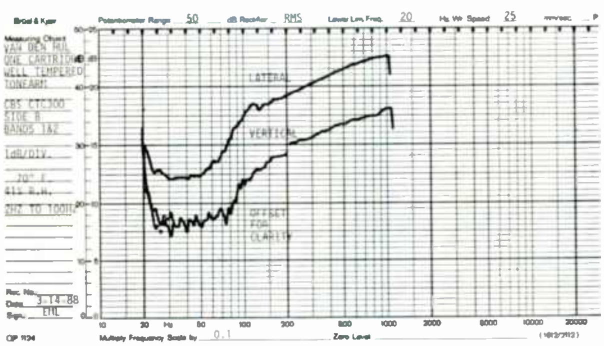


Fig. 4—Response to vertical and horizontal modulation from 2 to 100 Hz (slow sweep). Note that arm cartridge resonance is almost completely damped. (Curves offset for clarity.)

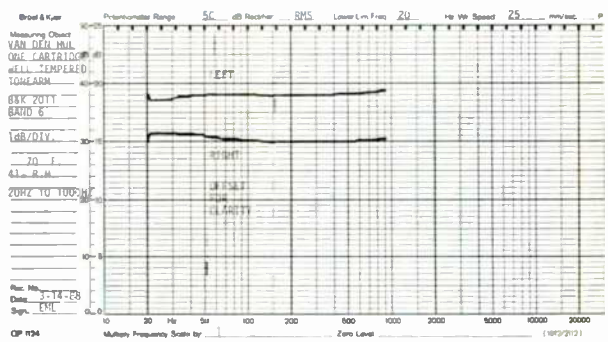


Fig. 5—Slow sweep from 20 Hz to 1 kHz, to check for structural resonances in the arm. Resonances can be seen but are very subdued. (Curves offset for clarity.)

A calibrated scale on the arm post (not shown in Fig. 1) can be seen through an opening on the side of the rectangular vertical post. The scale is marked from +3 to −3, with zero in the center. Once at the proper height, a line can be drawn on the post in line with the zero. (The arm's height may cause interference with some turntables' dust covers.)

Vertical tracking force is adjusted by sliding one of the two supplied weights along the rear of the armtube. The counterweight should be as close to the pivot as possible, so choose the heaviest practical weight. The circular counterweight should be locked by the nylon set screw. A separate tracking-force gauge must be used, since there are no calibrations on the armtube or counterweights.

Gold-plated connectors are used at the cartridge end of the fine Litz-wire phono leads, which exit the armtube just in front of the armtube ring (visible under the rear horizontal bar). These leads are twisted together and have plenty of slack, so they can be dressed for lowest lead torque. Two gold-plated phono sockets and a five-way binding post for grounding are mounted to an extruded aluminum channel, which can be attached on the rear of the turntable base.

Measurements and Listening Tests

The correlation between the technical measurements and the written comments made by members of the listening panel seems to be very good. The combined "sonic signature" of the Well Tempered tonearm and van den Hul cartridge was different enough from that of the reference system to make this easy. Remember, the reference system is not intended to represent the ultimate goal to match; only live sound could serve that purpose. The sound of the system being evaluated can be judged better or worse than the reference, but that is not its purpose. The reference merely acts as a point from which the listening panel members can rate the systems from 0 to −5 and make comments about the sound as they perceive it for each of the 12

The low crosstalk figure helps account for the good imaging of this arm/cartridge pairing.

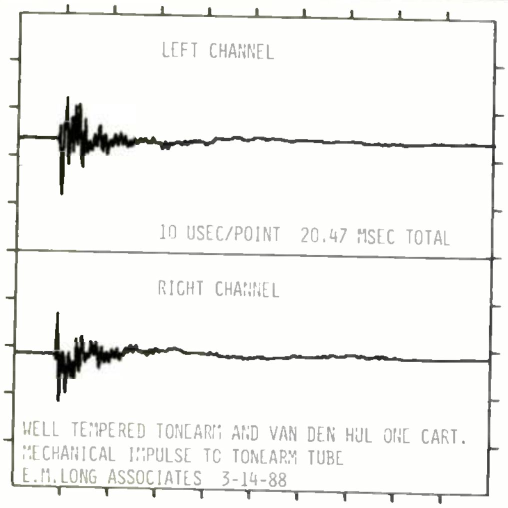


Fig. 6—Output vs. time of arm cartridge when mechanical impulse was applied to armtube, with arm floating.

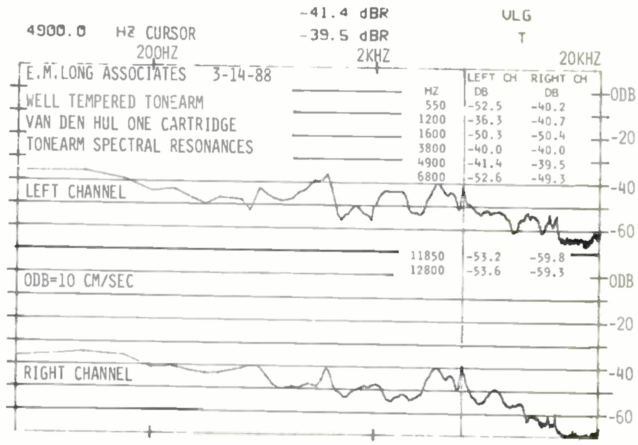


Fig. 7—Spectral output (averaged) of arm cartridge due to 16 mechanical impulses applied to armtube. Most of the energy is in the middle register, which could add to perceived brightness.

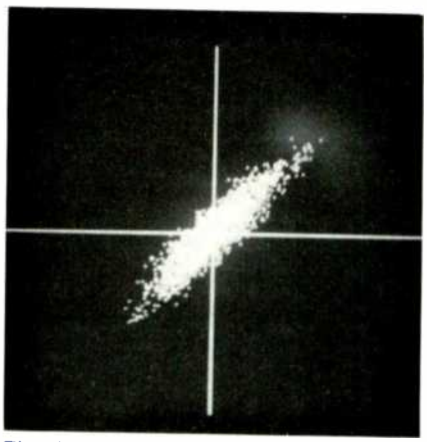


Fig. 8—Interchannel phase, using pink noise from B & K 2011, band 7.

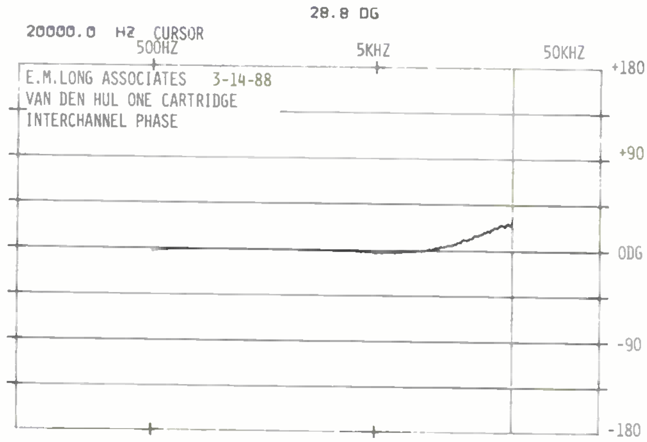


Fig. 9—Interchannel phase difference vs. frequency for B & K 2011, band 7, pink noise. Phase difference at 20 kHz is 28.8° (4.0 µS).

musical selections played. The reference system should be a very good one—and it is—but its main value comes from the fact that it is a known, measured, and repeatable quantity. The rating and comments can be looked at in light of these measured differences.

All panel members commented that the reference system sounded sharper on the sounds of cymbals, brass and string overtones, etc. Figure 2 shows the amplitude versus frequency response of the WT/vdH combination. There is an apparent roll-off of the higher frequencies, which would account for these comments. These remarks were not negative in tone: some wrote "smoother highs on cymbals," "sonorous," etc. The crosstalk measurement usually indicates very distinctly the high-frequency resonance of the cartridge, but it is barely visible for the van den Hul, being somewhere in the region around 30 kHz. This means that the resonance is well controlled, which is good. I made other tests for this, and determined that the high-frequency resonance is at 33.3 kHz. The amount of crosstalk is very low, which helps account for the good comments made about the imaging of this arm/cartridge combination. Comments about the balance of the sound being "forward" might be explained by the shape of the curves, which show more output in the fundamental range of instruments and voice, but other data correlates with this as well.

Figure 3 is the left- and right-channel response from 5 to 20 Hz, with the curves offset for clarity. It shows the low-frequency resonance caused by the effective mass of the

The ability of this arm and cartridge to track high-level mid-frequencies proved exceptional.

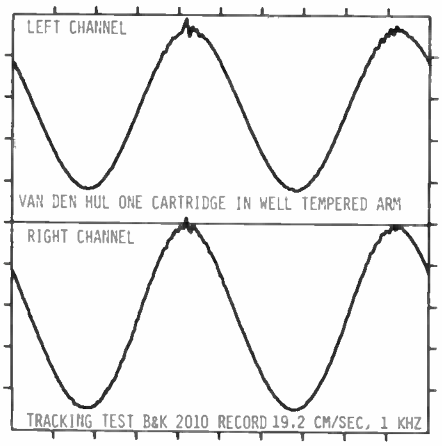


Fig. 10—Tracking of arm/cartridge with 1-kHz test tones at 19.2 cm S (B & K 2010), a level most cartridges find difficult to track. A small jitter is visible at the top of the waveform.

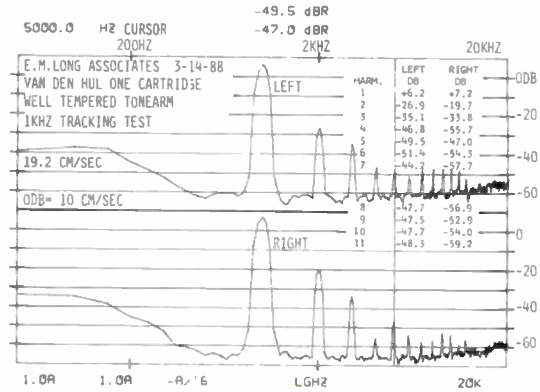


Fig. 11—Spectral analysis of the cartridge output when reproducing the 19.2-cm S signal of Fig. 10. The fifth harmonic (at the cursor position) is 0.19% in the left channel and 0.20% in the right.

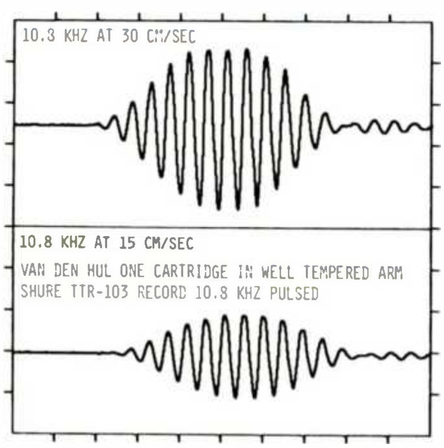


Fig. 12—Output from 30- and 15-cm S, 10.8-kHz pulse test, using Shure TTR-103 test record.

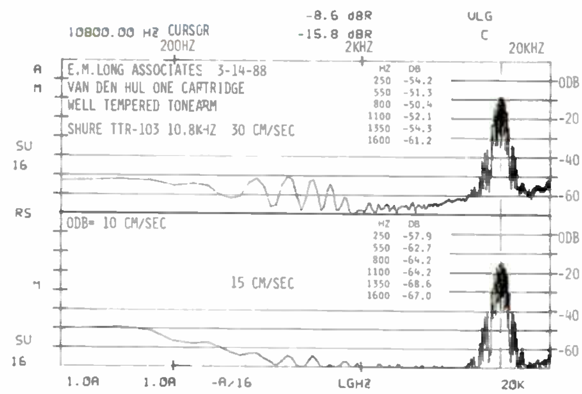


Fig. 13—Spectral analysis of distortion from signals shown in Fig. 12 (average of 16 samples at each level). The level at 250 Hz is 0.2%, which is very good. Output at 30 cm S is +8 dB above the 10-cm S, 0-dB reference level.

Well Tempered tonearm interacting with the compliance of the stylus of the van den Hul cartridge. The resonance is at 10 Hz and is very "well tempered" or damped by the viscous fluid at the pivot of the tonearm. Other tonearms with damping near their pivots have not shown results as good as this. The quality of the bass is excellent with this arm and cartridge. One panel member said it provided "tighter" sound, while the overall comments and ratings indicate a tie with the reference system. Figure 4 shows the combination's response from 2 to 100 Hz for lateral and vertical groove modulation. The resonance is more apparent in the lateral mode, which indicates that the damping is greater in the vertical plane of tonearm movement.

Figure 5 shows the response of the Well Tempered tonearm/van den Hul cartridge combination to a slow sweep from 20 to 1,000 Hz. Any resonant "rattles" caused by loose fittings will show up during this test. There are very tiny indications of resonances, especially in the right channel, but nothing really severe.

Figure 6 shows the WT vdH's response to a mechanical

Some listeners liked this pairing very much. It was very precise, dry, and analytical, and tied the reference for clarity.

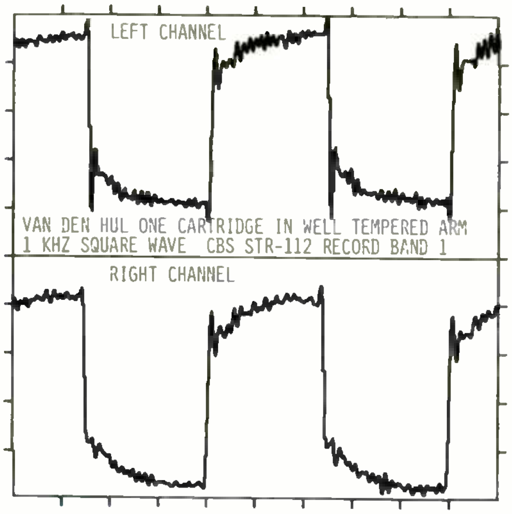


Fig. 14—Output from 1-kHz square wave, using CBS STR-112 test record.

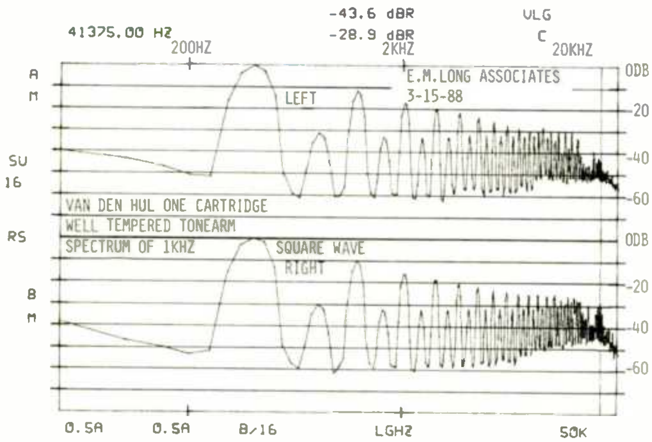


Fig. 15—Spectral analysis of 1-kHz square wave (STR-112).

impulse. The internal damping of the tonearm is good: The output decays rapidly without showing any serious delayed reflections. Figure 7 shows the spectrum of the response to an average of mechanical impulses applied to the tonearm. Some panel members commented that the sound of individual violin and orchestral strings was "brighter": this might be due to the fact that the Well Tempered tonearm shows more energy in the range between 3.5 and 5 kHz. Energy around 1.2 kHz may also have been partly responsible for male voices sounding "bright" and "forward" to some panel members.

Figure 8 shows the left-channel versus right-channel output when playing a recording of pink noise. A perfect match between channels would result in a 45° straight line. Figure 9, which shows the phase versus frequency response for the same recording, indicates that the interchannel phase difference occurs mainly above 5 kHz. This interchannel difference appears to be trivial: The panel members rated imaging performance the same for the tested arm/cartridge combination and the reference system.

The ability of the WT/vdH combination to track high-level middle-register signals (Fig. 10) is very good, if not exceptional. The 19.2-cm S, 1-kHz signal is very difficult to track, and the performance of this combination puts it in the company of some of the best arm/cartridge pairings. The spectrum produced by this tracking test (Fig. 11) indicates that the third and fifth harmonics, especially in the right channel, will cause the sound to be perceived as being a bit bright, which correlates well with most of the comments from the listening panel.

Figure 12 shows the output due to a 10.8-kHz tone burst. There is a little compression at the top of the 30-cm S burst which could affect the sound of high-level high frequencies. In this regard, however, the rating and comments of panel members about the sound of cymbals, for instance, put the WT/vdH slightly above the reference system. The spectrum produced by the 10.8-kHz tone burst (Fig. 13) is a very good indication that this arm/cartridge combination does not produce a lot of low-frequency modulation garbage which can cloud the sound of loud passages that include high-level, high-frequency sounds.

Figure 14 shows the output produced when playing a 1-kHz square wave. The rise-time of the van den Hul cartridge is extremely fast but well damped. This damping also correlates well with the amplitude versus frequency response (Fig. 2), which shows a gentle roll-off above 20 kHz. I thought it might be interesting to see the spectrum produced by this 1-kHz square wave (hence Fig. 15). Calculating such spectra for each tonearm/cartridge combination might prove valuable for reference and to indicate their tonal balance.

Conclusions

At the end of a long and detailed discussion of the measurements and sound quality of a combination such as this, I am supposed to say something pithy and concise so you won't have to read through all the details. It isn't easy in this case. Some of the panel members liked the WT/vdH very much, and I must admit that, on a lot of program material, it was very precise, dry, and analytical. It was judged slightly better than the reference system on strings, guitar, and piano as well as for general clarity; it was judged not quite as good on voice, bass, rock, and for spaciousness. The two systems tied on brass, drums, and full orchestra, as well as image stability.

You can't accidently damage the stylus by dropping the tonearm because it takes about 1 S to fall from a horizontal starting position. The Well Tempered arm can tame cartridges that require good damping. The height of the arm base, however, may cause problems with some turntables unless the dust cover is removed.

I found the high-frequency tracing capability of the van den Hul stylus to be excellent, and I never lost my temper while using the tonearm. For the rest of the conclusions and comments of the listening panel, you will have to read the report.

Edward M. Long