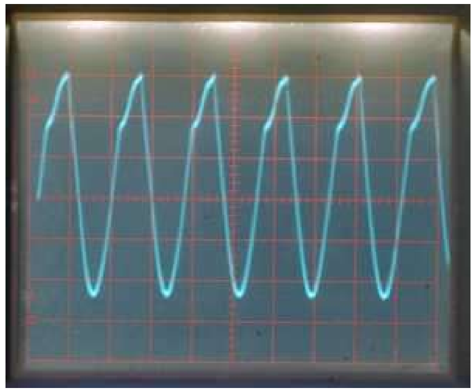
Measurement with test records

Test records currently available

We have obtained test records from MJ/DENON (Seibundo Shinkosha) and HFN (UK HiFi News). You can test the following items: HFN records come with a paper disc sheet with a combination of various protractors, which gives you a gist of how to adjust the cartridge position (Linear It's easy to see what Offset and Null Points mean.)

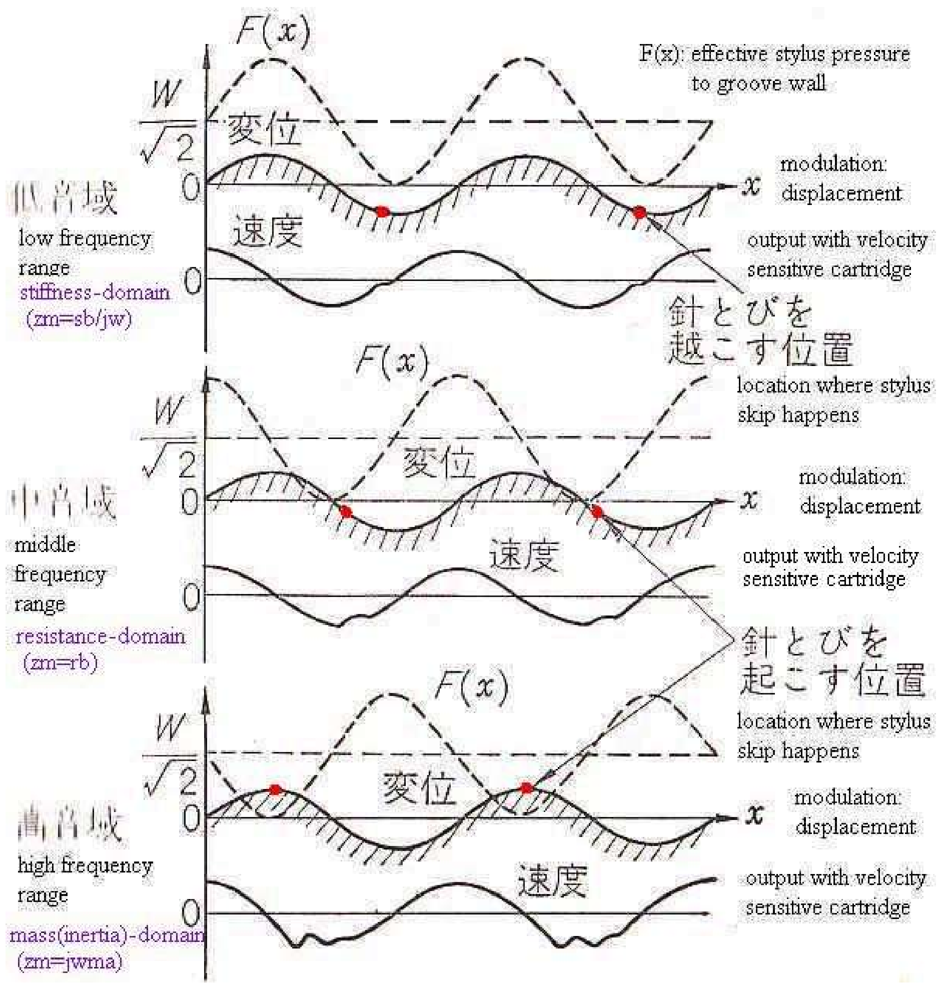
HFN/Producer's Cut by Len Gregory, `The Cartridge Man` (2002)			
MJ/DENON (1999) distributed by SEIBUNDO-Shinkohsha (Japan)			
		HFN	**MJ/DENON**
TEST ITEMS		Band	Band
1	Channel Identification	A1 (voice)	A1-4(L/R/L+R/L-R 1kHz)
2	Phasing Test	A2 (voice)	A28-31: 0.2Hz and 0.1Hz difference between R/L for observing xy Lissajous wave with oscilloscope (L+R)
3	Channel Balance	A3 (pink noise L+R) system balance	A1-4: L/R/L+R/L-R 1kHz
4	Pink noise	A4 (L) & A5 (R) -20dB pickup output balance	
5	Bias setting (anti-skate)	A6-9(300Hz) +12/14/16/18dB	A-21: Flat Zone without grooves
6	Tracking ability	B1 & B4 & B8 (300Hz) +15dB	A15-16: 300Hz 50µm & 70µm (peak velocity 9.4&13.2 cm/s lateral)
7	Lateral resonance	B2 (25-5Hz)	B1: Sweep3-100Hz 45micron at L channel B2: Spot3-15Hz 45micron at L channel with cue 1kHz at R channel.
8	Vertical resonance	B3 (20-6Hz)	
9	Cartridge alignment	B5 (L-R 300Hz)	
10	Residual system noise/Rumble noise	B6 (unmodulated groove)	
11	Full range frequency (RIAA)	B7 sweep 20Hz-20kHz: *This band is recorded at low level & groove radius around 8.5cm*	A5-14: Spot L+R -13dB (lateral peak velocity 1.12cm/s is equivalent to peak velocity 0.8cm/s for the output of stereophonic cartridges).
12	**Reference Level (0dB) at 1kHz**	*Reference level is not specified?*	A1-4 (L/R/L+R/L-R): peak velocity 3.54cm/s 45degrees for L or R and peak velocity 5cm/s for lateral (L+R) or vertical (L-R) so that one channel output of *reliable* stereophonic cartridge should remain same among these modulations.
13	Mechanical impedance at 100Hz		A17 amplitude 50µm (lateral peak velocity 3.14cm/s)
14	Wow-Flutter test		A18 3.15kHz (L+R)
15	IM distortion		A19-20 5kHz+5.4kHz and 8kHz+8.4kHz(L+R)
16	Crosstalk test	A4 (L) & A5 (R)	A22-27: 300/1k/5kHz(L) and 300/1k/5kHz(R)
17	Tuning tones		A32-35: 440/442/444/415.3Hz

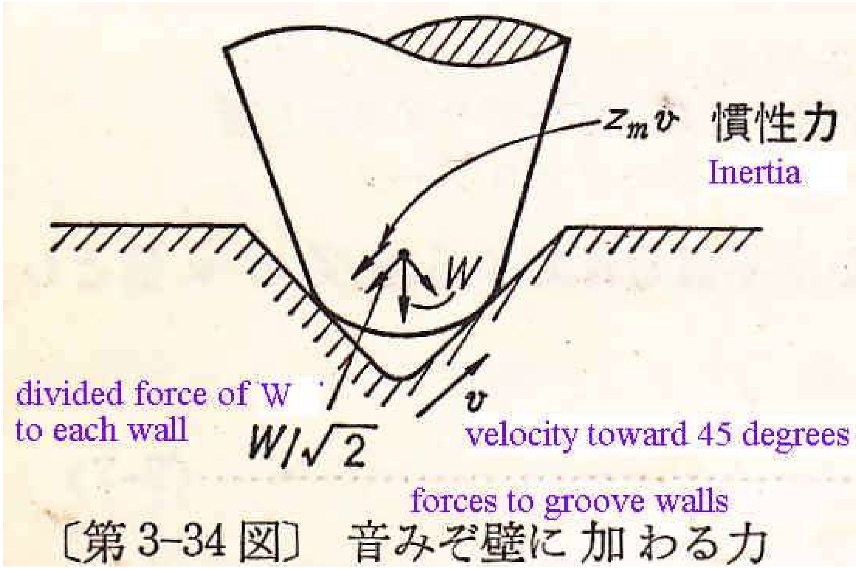
I **tested the Trackability** of item 6 above. This image shows when the needle pressure is less than the lower limit of the recommended value. Increasing the needle pressure is more effective than adjusting the anti-skating, and even with anti-skating 0, if the needle pressure is increased by 20% (the upper limit of the recommended value), a beautiful sine wave will be obtained. In addition, if the amplitude of the sound groove is small, needle skipping (not jumping out in the sense that the contact is separated from the groove wall on one side) does not seem to occur. Even with poor anti-skating adjustments, a similar waveform will appear in critical grooves.



Regarding the mechanism by which needle jumping occurs, there is the following explanatory diagram in Mr. Yamamoto's "Record Player" P.108-110 as "Force applied to the sound groove wall and the needle jumping phenomenon". The above oscilloscope waveform is from 300Hz, but stiffness It is presumed that needle jumping is occurring in the low range of the controlled domain. In this figure, stiffness It seems that the middle 1 kHz between the resistance control range is the mid range, and the mass control range of 10 kHz is the high range. Needle skipping occurs at the point where the instantaneous needle pressure F (x) becomes 0 or negative, but the location varies depending on the frequency of the sound groove. **Stiffness/resistance/mass in the actual cartridge It seems that there are differences in each controlled domain, and they determine trackability.** For example, if the equivalent mass of the oscillating system is light, the mass control range starts from a high frequency, and the high-frequency reproduction ability is relatively high (mechanical in that region impedance). The smaller the stiffness (= 1 / compliance) of the damper, the more bass can be reproduced with light needle pressure, and so on.

The following drawing No. 3-52 (Yamamoto) indicates some relations among variation of effective stylus pressure F(x) for 45 degrees, groove modulation (displacement) for 45 degrees and one channel output of stereo cartridge showing where the mistrackings occur.



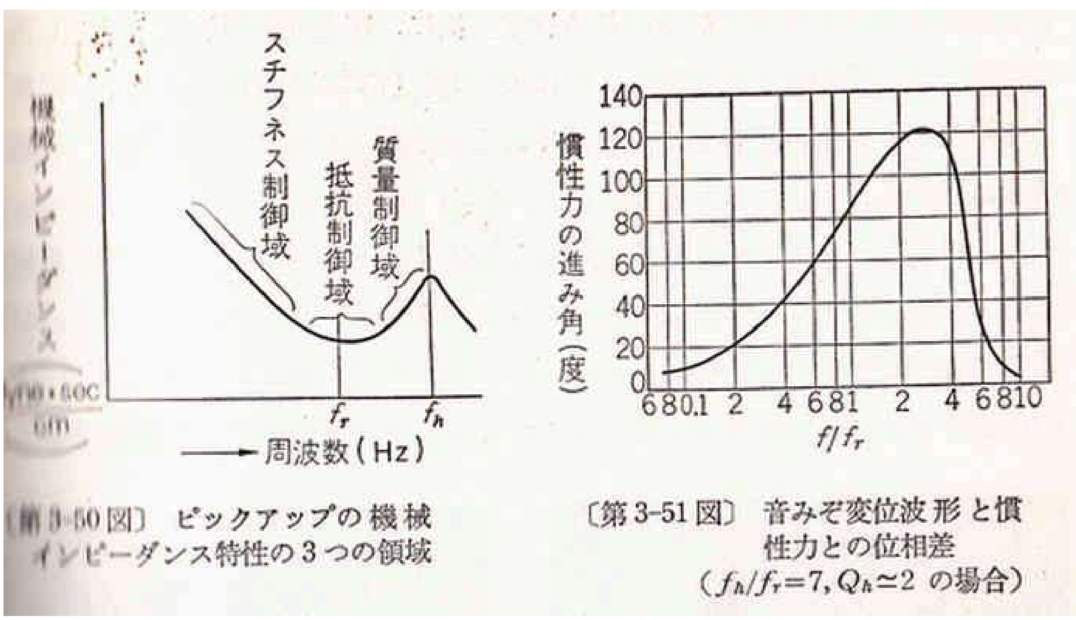


〔第3-34図〕 音みぞ壁に加わる力

Though it is too much complicated for me to explain in details, the background of the above is based on following explanatory drawings. No. 3-50 indicates three different (stiffness/resistance/mass or inertia controlled) domains of mechanical impedance curve (so to say bathtub), 3-51 indicates one sample of the phase difference in degrees between displacement and inertia force (fh/fr=7, Qh=2 as representative values because most cartridges have damping rate Qh around 2 for high frequency. :
Qh=SQRT(Ma(sb+sr)/rb)). Ma(effective mass of stylus virating system), sb(stiffness around armature) sr(record stiffness) rb(resistance around armature)

F(x) = W/SQRT(2)+[zm] v = W/SQRT(2)+[zm] jw v/jw

Since v/jw represents the displacement of groove modulation, the phase difference between inertia and sound wave shall be decided by the phase of [zm]jw.
In stiffness domain: inertia force is in-phase with displacement and delaying 90degrees in comparison with velocity.
In resistance domain: inertia force is in-phase with velocity and advancing 90degrees in comparison with displacement.
In inertia-domain: inertia force has reverse phase with displacement.
Details about mechanical impedance [zm] are explained in the technical sheet of DENON test record XG-7001



〔第3-50図〕 ピックアップの機械インピーダンス特性の3つの領域

〔第3-51図〕 音みぞ変位波形と慣性力との位相差 ($f_h/f_r=7, Q_h\simeq2$ の場合)

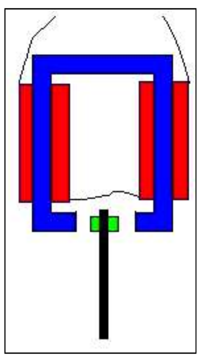
I tested the Bias setting in item 5 above with an HFN record. 300Hz (L+R) It is divided into four bands: +12dB/14dB/16dB/18dB. ADC with 45-degree peak output sensitivity of 1 mV/cm/s Approximately 7 mV (0 to peak), about 14 mV (0 to peak) in the +18 dB band (observed by calibrating the crest scale with the calibration signal of the oscilloscope, not the tester). From this, the **0 dB (300 Hz)** of the HFN record peaks in the horizontal direction. It seems that the peak is 1.77 cm/s in the direction of 2.5 cm/s and 45 degrees (recording level at 1kHz is not indicated, but after passing through the equalizer = not direct reading, but x1.88 when converted by the output ratio of 300/1000Hz phonostage, so 1kHz in the horizontal direction 4.7 cm/s, which is close to the peak of 5 cm/s). The final groove is close to the recording limit velocity amplitude (< linear velocity) of 20 cm/s on the inner periphery. When I actually traced it, the last band was distorted even with the maximum anti-skating bias at the upper limit of 1.5g. When the MA-505 was combined with this ADC cartridge, it was possible to trace the sound groove to +16 dB (horizontal amplitude of about 83 µm) without any problems when adjusting the needle pressure to 1.3 g and the bias elliptical needle position. The MJ also checks needle pressure and tracing at 300 Hz (L + R) horizontal amplitude of 50 µm (velocity amplitude 9.4÷√2 = 6.7 cm/s) and 70 µm (velocity amplitude 13.2÷√2 = 9.3 cm/s). For stereo cartridges, the horizontal peak velocity amplitude ÷√ 2 = peak velocity amplitude is simply because the horizontal amplitude is converted to a 45-degree amplitude. When playing mono (horizontal recording) with a stereo pickup, the output is 1/√2 = 71% compared to a stereo groove (single-wall recording) with the same speed amplitude - Ah, confusing NoteSee about stereo cartridge output. <b11>Shure The stock replacement needle of the M97 also says "Output voltages given for stereo cut record. For MONO cut record, output voltage at both left channel and Right channel cartridge terminal will be 71% of figures above."

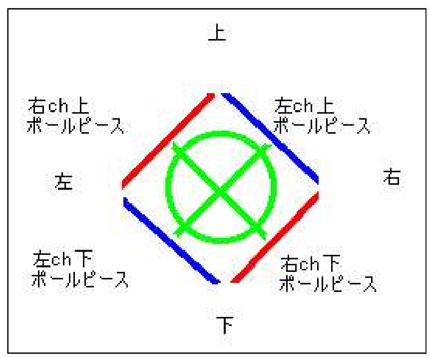
The use of the Cartridge alignment (Azimuth) adjustment band of HFN in item 9 is questionable. This is because if the cartridge is not a cartridge with output sensitivity = channel balance, etc., etc., it will not be the optimal azimuth when the mono = parallel reverse connection output is the lowest due to the output difference of L / R. For example, if the cartridge is tilted and adjusted so that the combined output is reduced, the output may be lower (and the crosstalk on one side is also reduced) if it is tilted, but the total channel separation on the left and right sides deteriorated. I feel that the separation is a problem with the cartridge and not with the user. Is it the hobby of audio that many people want to play with?

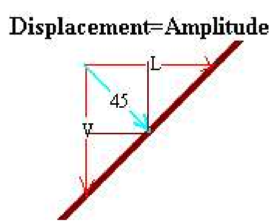
About Stereo Cartridge Output

The output measurement of the mono cartridge is performed by horizontal recording (Lateral Recording) = mono record, so it is easy, but stereo cartridges are measured by L or R single-wall recording or L+R horizontal recording in the 45 degree direction. To complicate matters, stereo L+R is horizontal recording mono if the signals are in phase (compatibility between 45/45 stereo and horizontal recording mono).

The bands of MJ's test records A1-A4 contain a 1 kHz reference signal (L single wall, R single wall, L+R horizontal, and L-R vertical). The speed amplitudes are 3.54, 3.54, 5 cm/s, respectively, but when traced with a stereo cartridge, they all produce the same output. Why? The pole pieces (MM) of the power generation mechanism of the stereo cartridge are staggered in the 45-degree direction. In 45-degree recording of L single wall / R single wall, 100% output on one side and 0% output on the other channel (in the figure on the right, the rotation axis of the green circle is 45 degrees, and the channel on the center axis side of rotation does not generate electricity). On the other hand, for horizontal and vertical recording, the output per channel is 1/√2 = 71%. If you pay attention to the green circle in the center of the figure on the right below< you will see a rotation > on the top and bottom axis and a rotation > on the left and right axis< respectively. In fact, since the fulcrum is not completely fixed, it leaks to other channels (low displacement, but fast velocity amplitude), and the separation seems to deteriorate in the high range.







Testing Arm Resonance (Low Frequency Resonance)

Now, let's verify what the effective mass of the arm and the compliance of the cartridge actually are. If there is a cartridge arm that becomes a standard, the value of each partner can be determined, but if you do not create **a reliable standard**, even if you know only the resonant frequency, you will not be able to apply it to another combination.

The effective mass of the arm MA-505 is http://www.fl-electronic.de/analog/tonarme.html (Source: HiFi 14.5g according to Choice). The standard shell at that time was similar to the H-303 (9.7g), but I don't know if the shell is 14.5g.

Measurement conditions: Ambient temperature should be 17-18°C (preferably 20-25°C), humidity 40-50%

Data aggregation: The relationship between the minimum needle pressure Wc (g) and compliance that does not cause needle skipping at 100 Hz is the machine impedance [Zm] = 980 ・ Wc/vh in the test record of MJ with horizontal signal amplitude (a = 50 μm), Velocity amplitude vh = 2πfa, compliance c = 1/2πf • [Zm] to c = a/980 Wc = 50 x 10 (-4) / 980 Wc (cm/dyne)Become. In Mr. Yamamoto's formula, the needle pressure on the sound wall W/SQRT(2) < said that [Zm]x[v45] causes a time needle jump, but since the velocity amplitude v45 is the peak velocity in the 45 degree direction, if it is equivalent to the horizontal velocity amplitude v/SQRT(2), it will eventually be summarized in the MJ equation. This is because both mechanical impedance and compliance are actually different horizontally, vertically, and 45 degrees.

Mechanical impedance Zm=980xWc/Vh (dyne・sec/cm) ---(Eq 1)

where Wc=minimum tracking force starting mistracking, Vh=velocity of horizontal amplitude(cm/sec), horizontal amplitude=Ah(cm), Vh=2pifAh(cm/sec), gravity acceleration=980cm/sec2

Compliance (as 1/stiffness)=1/(2pifZM) (cm/dyne) --- (Eq 2)

Eq 2 can be modified after substituting Eq 1 as follows:

C=Vh/2πf・980・Wc=2πf・Ah/2πf・980・Wc=Ah/980Wc --- (Eq 3)

Thus if Wc(g) & Ah(cm) are given, then dynamic compliance at specific frequency is ascertained.

For example, when f(requency) is 100Hz, Amplitude(horizontal displacement) 50micron=50x10^-4(cm) and Wc is measured as 1g, then C=50x10^-4/980=5.1(10^-6)cm/dyne. **But this compliance is at specific frequency. How about resonance frequency?**

Arm:MICRO MA-505(Effective Mass:14.5g excluding shell?)	Dynavector DV-50A	Denon DL-110	Sony XL55Mono	Ortofon SPU-G Classic	ADC XLM improved MKII
Nominal Compliance (10^{-6}cm/dyne)	Static 20	Dynamic 8 at 100Hz	Static 17	Dynamic 8 at 10Hz	NIL
Head Weight (cartridge+shell) HW	20.9g(=4.4+16.5)	18.2g(=4.8+13.4)	24.5g monocoque	32g monocoque	14g (5.5+8.5)
Total Arm Effective Mass including HW	35.4g	32.7g	39g	46.5g	28.5g
Lightest VTF threshold for mistracking at 100Hz lateral displacement 50μm: Wc(g)	0.4g	0.75g	0.6g	1.7g	0.4g
Compliance (10^{-6}cm/dyne) at 100Hz calculated from Wc	13	7	9	3	13
Horizontal Resonance calculated from above data	7.4Hz	10.5Hz	8.5Hz	13.5Hz	8.3Hz
Horizontal Resonance? - measured	about 6Hz	about 7Hz	about 7Hz	about 10Hz	8-9Hz
Compliance (10^{-6}cm/dyne) at horizontal resonance frequency	20	16	13	6	about 12
Vertical Resonance - measured	unclear	8-10Hz	Unnoticed due to Mono pick-up	12Hz	around 12Hz
Compliance (10^{-6}cm/dyne) at vertical resonance frequency	?	more than 8	?	less than 3	about 6

Arm: Infinity Black Widow (Effective Mass:6g? 3g as per catalog in 1977)	Dynavector DV-50A	ADC XLM improved MKII
Nominal Compliance	Static 20	Static 50?
Cartridge Weight including screws/nuts (HW)	5g (4.4+0.6)	6g (5.5+0.5)
Total Arm Effective Mass including HW	11g	12g
Lightest VTF threshold for mistracking : Wc(g)	0.4g	0.4g
Compliance at 100Hz calculated from Wc	13	13
Horizontal Resonance calculated from above data	13.3Hz	12.7Hz
Horizontal Resonance - measured. *The use of silicon bath does not affect the resonance frequency so much as far as damping ratio is within certain value. Higher ratio of arm damping requires higher VTF to trace warped or eccentric records.*	11-12Hz	about12Hz(undamped)
Compliance at horizontal resonance frequency	about 17	about 13
Vertical Resonance - measured	around 16Hz	around 18Hz
Compliance at vertical resonance frequency	about 9	about 6

CAUTION:	The effective mass of cartridge is reduced to around 90% weight as seen from stylus point.
	The effective mass of detachable shell is reduced to around 75-85% weight as seen from stylus point.
	The mass of cartridge or shell is not centred (concentrated) above the stylus tip.

Effective mass = Weight*(shell or cartridge location from arm pivot^2/effective lateral length of arm^2)

The conclusion of this measurement:

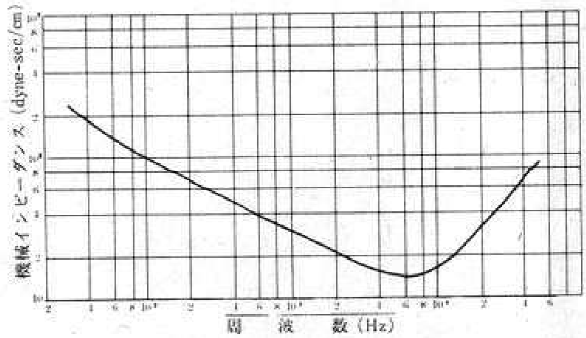
1. It is actually difficult to determine the resonance center frequency by sound. When the pilot signal of 1 kHz is observed by oscilloscope, it begins to oscillate from the frequencies before and after the resonance. The extremely low frequency that fluctuates the most (amplitude modulation) is the resonant center frequency. The minimum needle pressure Wc was also determined by observing with an oscilloscope.
2. Effective mass of MICRO MA-505 (excluding shell): In the above calculation, it was 14.5g without the shell, but it is actually 14.5g including the shell, and it seems to be about 7g excluding the shell (see table below). **Cartridge and Head to the effective mass of the arm Adding Weight to the effective mass of the entire arm is only an approximate calculation** (the effective head weight is a little lighter than the apparent weight because all of these material points are not concentrated at the needle tip position / are considered to be a little shorter than the effective length of the arm).
3. The resonant frequency bar (every 1 Hz) is too large for compliance. In fact, if it is not in units of 0.1 Hz, compliance is calculated by several tens of percent. Compliance = 1 / (resonant frequency ^2 * 4 * PI () ^2 * effective mass of the arm) shows the squared value of the resonant frequency, that is, 5 Hz >25 for a 1 Hz square, Since it is inversely proportional > 6Hz>36, 7Hz>49, 8Hz>64, 9Hz>81, 10Hz100, the compliance ratio is roughly 40:28:20:16:12:10. For vertical resonance, the frequency of the HFN test record is every 2 Hz, so the calculation of compliance based on that is rough.
4. I think compliance fluctuates with temperature, aging, etc. Dynamic We were able to confirm that Cb is less than Static Cb - Relationship between mechanical impedance and compliance =1/(2pifZM). Vertical/Horizontal of the cartridge measured this time Is it a coincidence that the Compliance ratio is 1:2 (the resonant frequency is 1.5:1)? Magnetic cartridges (MM/IM) with larger horizontal compliance will also have larger vertical compliance - so they are sensitive to arm height adjustment and needle pressure, and may not be suitable for beginners (low-compliance MCs usually sound good if you stick to the horizontal and recommended needle pressure). **Toshiba's engineers were selected for AES in 1968 Trackability presented at the Convention In the Test by Complex Tones and Biasing Force Effects of Phonograph Pickups, "High-compliance cartridges are more susceptible to needle pressure and side forces, and IM distortion may increase more than low-compliance cartridges, especially in grooves with large velocity amplitudes." In a high-compliance cartridge with light needle pressure, the residual side is required to stay within 10% of IM distortion. The thrust must be in the 50 mg range, which is not necessarily more advantageous than the low-compliance one."** 1969 Toshiba Photo-electric We applied for a patent for the pick-up in the UK (GB1281912) and Germany (DE1941407), but on the Japan side, we only applied for a utility model in 1968 [needle pressure and side Thrust can be measured, and the side thrust signal can be linked to the motor at the base point of the arm. It can also be a force canceller]. Lab researchers and utility model inventors are different. As **a by-product of these studies and experiments, the photoelectric pickup C-100P was developed** [the dedicated preamplifier SZ-1 has a Stylus It was equipped with a gauge meter, and I was able to observe the appropriate needle pressure with the turntable turned.
5. If you think about why MM cartridges are generally more compliant than MC types (as an analogy rather than academic): the damper that supports the vibrating section is often designed to wrap around the magnet in the MM, whereas in the MC the coil frame at the base of the cantilever comes into contact with the damper through the tension wireI think it is because of the structure (there is a conflict between compliance, which increases the degree of freedom, and the structure of the damper and support that constrains and brakes it).

Recalculation when Effective Mass of MA-505 is 14.5g including standard shell 9.7g	Dynavector DV-50A	Denon DL-110	Sony XL55Mono	Ortofon SPU-G Classic	ADC XLM improved MKII
Total Arm Effective Mass	27.9g	25.2g	31.5g	39g	21g
Horizontal Compliance (10^{-6}cm/dyne) at resonance frequency	25	21	17	7	17
Nominal specifications on catalogues (frequency is not mentioned except Denon & Ortofon)	***20***	***dynamic 8 at 100Hz***	***17***	***dynamic 8 at 10Hz***	***NIL. The compliance of MKII is smaller than 50cu of the first model XLM.***

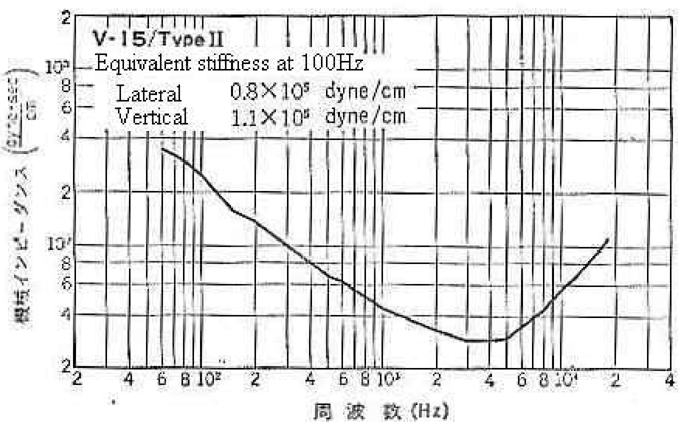
Mechanical impedance (a measure of tracking ability)

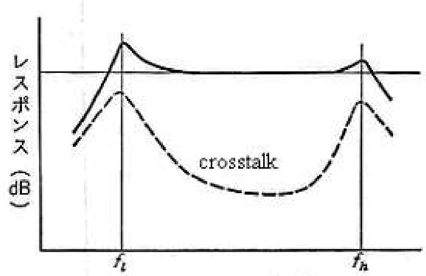
There is a curve that is about half in two octaves (-3dB/Oct) and low overall (DL-103D). We also found out why there was more compliance at the measured resonance point than at the calculated value based on Wc at 100 Hz. The mechanical impedance curve of the ADC happened to be close to -6 dB/Oct, which seems to be consistent with the calculated value. It was also found that the ADC, which claimed to have a light needle pressure, required a surprisingly heavy needle pressure (due to deterioration of the damper). Relatively old cartridges also have a high mechanical impedance overall, and their curve seems to be -6 dB/oct in the mid and low range. The DL-103D (1977) with light needle pressure (VTF 1.5g) seems to have used a different damper than the DL-103 and is a descendant of the DL-103S (1974). Damper stiffness is usually different between lateral direction and vertical direction. Usually vertical stiffness of old type cartridges is higher (compliance as 1/stiffness is lower vertically). But modern cartridges claim that the stiffness to any direction is almost unchanged. Compliance=1/(2πf·[Zm]) meaning that mechanical impedance Zm (dyne sec/cm) should have -6dB/Oct curve when compliance is perfectly constant in the stiffness controlled region (lower frequencies than 1kHz). But the mechanical impedance curve is not always so steep as theoretical -6dB/Oct. Then compliance is increasing toward lower frequencies. For example DL-103 having 5cu at 100Hz is measured to hapve more than 10cu (around 13cu in my estimation) around resonance frequencies. JVC book (1979) shows their measurement of actual resonances of DL-103 coupled to some arms. In my understanding the compliance of damper has non-linearity as JVC engineer in the above book (P.271) disclosed his thought: "Usual model of damper is simplified as spring and dashpot. But there is no exact equation available for representing the actual performance of rubber damper." The nature of rubber damper esp. for higher frequencies is much affected by temperature as shown in the end of my pages of frequency record. and recspecs.

機械インピーダンス特性

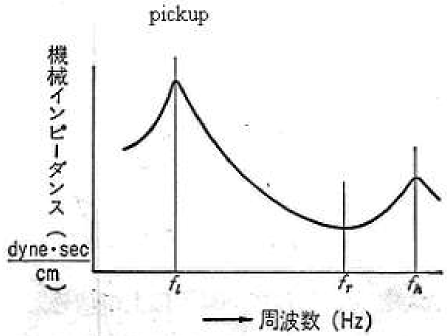


The followings figures are from a Japanese book (Record Player) in 1971 written by Yamamoto

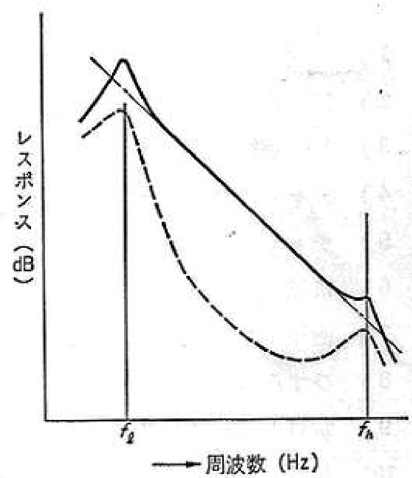




〔第 3-15 図〕representative frequency response of velocity-sensitive pickup



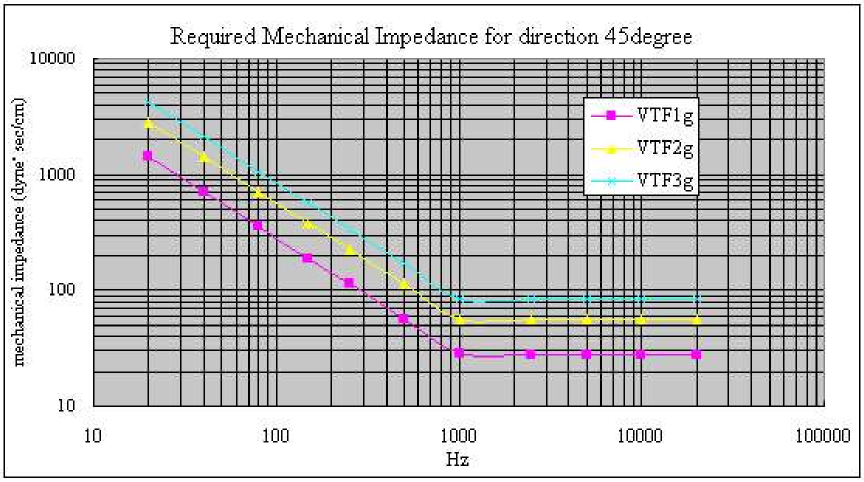
〔第 3-16 図〕Representative characteristics of mechanical impedances for pickup



〔第 3-17 図〕representative frequency responce of displacement-sensitive pickup

The figure below is an Excel reproduction of the table of the mechanical impedance > in the 45-degree direction, which is required to trace under each needle pressure < in Mr. Yamamoto's book. It is based on the results at the time of the actual record examination (the minimum LP groove pitch is 40 lines/cm, and the maximum velocity amplitude of 1 kH or more in the mid and high frequencies is about 25 cm/sec). The reason why it bends at the 1 kHz boundary is that it is the turnover point (constant amplitude below 1 kHz, and constant speed recording characteristics above 1 kHz). If the mechanical impedance is higher than the VTF line, the needle is likely to skip. It seems that the fact that the maximum speed amplitude of the mid and high frequencies is larger than the LP groove in the SP groove was the reason why the SP board required a higher needle pressure or compliance than the LP version, and there is a patent document that mentions this problem in the turnover-type cartridge of the SP/LP era - e.g. US Patent 2,681,388 (application date March 3, 1949/patented in 1954) invented by Goldmark and Snepvangers in SP "the maximum amplitude of excursion is approximately 0.002 inch", LP "the maximum amplitude of excursion of the lateral modulation is of the order of 0.0009 inch".

Yamamoto researched actual LP records on the market in the end of 1960s and reported that minimum pitch (40 lines/cm) and maximum recorded velocity for the range of frequency over 1kHz (peak around 25cm/s maybe in outer radius of LP and lateral). Based on such research, the following impedance chart is simulated for determining the required VTF and the trackability of cartridge. Note that Shure's trackability chart indicated traceable maximum velocity (cm/s) with a fixed VTF while Denon indicated mechanical impedance chart （dyne sec/cm) after measuring minimum VTF and comparing to a constant velocity by division. Both have same meaning for trackability, only differ the method of expression (cm/s vs dyne sec/cm). But there remain obscurity about the kind of velocity: lateral or 45/45 direction? As far as I know: in case of indicating mechanical impedance chart, mechanical impedance for 45/45 direction is to be measured usually.



The correlation between needle pressure and compliance is approximately as follows. For example, in order to *safely* trace the sound groove at 1g, the compliance is 15x Requires about 10^-6cm/dyne, and compliance is 5x If it is about 10^-6cm/dyne, the needle pressure is 3g or more. **Shure expressed Trackability in terms of each maximum velocity amplitude (cm/s) that can trace each frequency at a constant needle pressure, but Denon's mechanical impedance table (dyne sec/cm) is converted to a constant speed amplitude and the required needle pressure is calculated, which also expresses Trackability。** It seems that the reason for showing horizontal compliance at 100 Hz instead of the resonance point around 10 Hz was not to calculate the resonance point, but to use it as a guide for needle pressure - so it can be said that it is a useless specification for the user. CBS 60's test record STR-100 band 4B: 100Hz horizontal recording 0.001 / 0.002 / 0.003 / 0.004 / 0.005 cm band 5B: **compliance C = groove amplitude cm ÷ at 100 Hz with the same content vertical recording (980 x required needle pressure g)**It was said. Since the degree of "safely" varies depending on the setting of the maximum speed amplitude, it is calculated by about 3 times (safety factor) in the table below (the speed amplitude of 100 Hz deviation 0.005 cm is 3.14 cm/s, so it is calculated up to about 10 cm/s, that is, the maximum deviation is 0.015 cm). The MJ test record says that the needle pressure is adjusted at 300 Hz 0.005 cm, but the speed amplitude is 3 times that of 100 Hz 0.005 cm, so I think it means the same thing. JIS C5503-1979 (Pick-Ups) explains: "Conventionally, there has been no universal measurement method for needle tip compliance, including needle jumping. However, DIN45549 and IEC Standardization of tracking aviity measurement methods such as SC-60A for 98A is taking shape, and in Japan, the Japan Electronic Machinery Manufacturers Association is studying test record measurement methods with the cooperation of the Recording Industry Association of Japan. Therefore, in the main text, the provisions ended up as before, but I would like to change the wording to more specific in the next revision while looking at the above developments," but the 1979 version was the final version of the cartridge standard. Thereafter, 1984 test record JIS S8602 Low-frequency trace capability measurement by 315 Hz signal groove and high-frequency trace capability measurement by 10 kHz pulse, EIAJ A mid-low range tracing capability measurement with a 20Hz-1kHz sweep signal of the CP-310-8/33 was presented: measuring the maximum deviation (μm) that can be traced without distortion at a given needle pressure. These three levels of measurement are identical to the current IEC 98 (1987). In particular, when measuring high-frequency tracing capability, distortion is also measured. SC-60A is an IEC Sound It seems that various studies and discussions were held before standardization by the Recording Subcommittee. Tracking in IEC98A-1972 The ability items and test methods are indicated, but the content is insufficient (objections from Shure and others?) In 1987, IEC98 became a complex one with three types of signals: Tracking The definition of ability remains controversial.

Needle pressure required to safely trace the sound groove	1g	1.5g	2g	2.5g	3g
Compliance at 100 Hz (unit: x 10^-6)	15	10	7.5	6	5

Movement of the resonance point and evaluation of sound: It seems that it is difficult to say that when the resonance point is lowered, < a heavy bass > when it is raised, it becomes a <light bass>. Also, it seems that it is not possible to know whether there is really a problem when the resonance point is moved away from 10 Hz without taking other factors into account. **The force that causes resonance is not only in the groove in which the infrasound frequency is recorded, as in the test record, but also in fact due to the friction between the needle and the groove and the change of the needle due to various sound groove amplitudes, so the resonant frequency itself does not change much, but the degree (Q) also varies depending on the needle pressure and the anti-skating mechanism.**

Notes

1. Eccentric or warped record has subsonic frequencies: Off-center 0.55cycle （Lateral Wow） , Warp 1.1(one-fold) - 4.4cycles(4-fold) mainly （Vertical Wow） . According to Ladegaard (Fig 7. Velocity spectrum of phonograph records taken from Larry Happ & Frank Karlov, AES Preprint Number:926 1973 & JAES October 1976 under the title "Record Warps and System Playback Performance"), frequencies 0.5-7Hz caused by these warps have velocity 0.3-0.6cm/s max (which is larger than recorded velocity limit at 20Hz) while 10-18Hz has lower velocity around 0.2cm/s so that Ladegaard recommended to raise arm resonance frequency to 15-18Hz). Moreover 0.55cycle as amplitude modulation is not audible for itself or not reproducible with usual set of arm and cartridge but it is not so simple. When groove or hole is 1mm eccentric, then signal of 3.15ｋHz recorded laterally at radius 6cm is fluctuating between 3.1kHz ~ 3.2ｋHz by 1.8sec(one turn). Thus the rate 0.55(=once per 1.8sec) does indicate modulating frequency - such frequency modulation cannot be suppressed with usual subsonic filter.

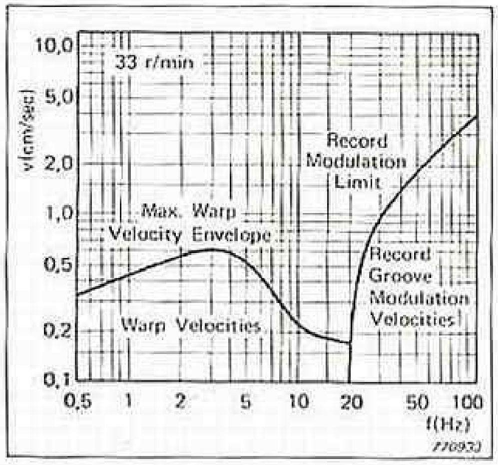


Fig.7. Velocity spectrum of phonograph records

According to D.L. Taylor at JAES December 1980: Measurement of Spectral Content of Record Warps, "the horizontal variations are seen to reflect simply the center hole offset and are uncorrelated with the vertical warps. The worst case envelope for vertical warps is shown to be somewhat lower than that used by previous investigators. More importantly, the average vertical warp is seen to be an order of magnitude less than the worse case."

Our ears are said to be most sensitive to modulating frequency or wow cycle 2-4Hz so that we should avoid such wow - but what we can do for warped record ? Maybe by using stabilizer weight on record in order to flatten warped record.

2. Motor Rumble: around 25 to 30 cycles/sec with 4-pole synchronous belt-drive motor 1800rpm/60Hz or 1500rpm/50Hz (24-pole synchronous motor 5Hz? with 250-300rpm, DD motor 0.55Hz? with 100/3rpm)

3. Motor Hum: 50/60Hz and its double frequencies

4. Turntable/cabinet/plinth support resonance: around 3-10Hz? This is questionable and changing with the mass of turntable and supporting materials: Fr=(1/2pi)*SQRT(K/Mp) where K=stiffness (N/m), Mp=Mass (Kg). With conversion of above formula in SI to gravity system unit (stiffness gf/cm and Weight gram), then Fr=(1/2pi)*SQRT(980K/Mp). Being stiffness = 1/compliance, this formula is just same as that for arm-cartridge resonance. Is this vertical resonance and affecting vertical mode of arm/cart resonance only?

5. Lowest music frequency is 16Hz pipe organ. Dr. Olson said "Under very favorable conditions most individuals can obtain tonal characteristics as low as 12 cycles" (Music, Physics and Engineering: Chapter 7.4 Psychological Characteristics of Music)

These frequencies are actually differing each other - phase/vertical/lateral modes of mechanical vibrations are uncertain or unspecified usually. In USP4275888(1981) by Shure I find an interesting passage: "*Although typical sources of vibrations at the resonance frequency, such as floor vibrations and record warps, have a predominantly vertical component, it has been discovered that they also have a substantial horizontal component. Some of the impact energy from a warp or a floor vibration may also be translated into lateral vibrations by passing through the tone arm suspension system*".

To avoid overlapping these frequencies, 8-12Hz (resonance frequency between arm mass and cartridge compliance) is estimated as reasonable, in other words, any resonance frequency under 20Hz is possible if other factors are not affecting each other in actual product - to my regret I don't know such perfect product both on soft and hard side.

IMHO: Ladegaad in his document [Audible Effects of Mechanical Resonances in Turntables] does not refer explicitly to Psychological Characteristics of Human Ears. High or low - which is more audible? What I am inspired by Ladegaard papers is that resonance of arm/cartridge is most important factor in connection with many other resonances which affect sound.

Subsonic noise filter (HPF) or IEC suggestion about equalization (introduction of an additional time constant 7950µs/20Hz) might be made with the above consideration on arm resonance & rumble noise. -3dB difference at 20Hz (-7db at 10Hz) between recording and reproduction results from additional time constant 7950µs （20Hz) recommended by IEC60098(clause 10.2.1) year 1987.

The following equation is taken from a pamphlet attached to MJ test record:
Resonance Q=2pi*ft*mt/(rb+rp)=(1/(rb+rp))*mt/SQRT(mt*C)=(1/(rb+rp))*SQRT(mt)/SQRT(C)
where rb is armature resistance at cartridge, rp is resistance at arm pivot.

The following table is based on the above equation. Note that ft x Q becomes a constant irrespective of additional weight if combination of arm+cartridge is unchanged. This is natural result from equation ft x Q=(1/(2pi*SQRT(mt*C)))x(1/(rb+rp))*SQRT(mt)/SQRT(C)=(1/(rb+rp))*(1/2pi)/C. Note on damping factors (rb&rp): what is the relation between rb (armature resistance) and rp (resistance around arm pivot)? Yamamoto in his book (1971) explained as follows: "**There are two ways of controlling the arm resonance at low frequency, that is, by equivalent resistances shown in Fig 3-13: one is armature resistance (rb) and another is resistance at arm pivot (rp). Fig 6-4, 6-5, 6-6, 6-7 shows the cases by controlling arm resonance by each factor independently. In case (Fig 6-4&6-6) of control by rb, the mechanical impedance for mid frequency increases. In case (Fig.6-5&6-7) of control by rp, the mechanical impedance for lowest frequency increases. In order to trace the record with light VTF, the mechanical impedance must be low enough for full range. Hence rb is set so as to make the high frequency flat and mechanical impedance matching. Arm resonance shall be controlled mainly by rp. But if rp is made too large, then the impedance at lowest frequency will be increased so that heavier VTF is required to trace on the warped or off-centered record.**"

The effect of additional weight on shell/cartridge				mt (g)	ft (Hz)	Q
The Relation among mt, ft & Q		when		10	10.06584	2.108185
Compliance=	between 5-50	25	*10^(-6)cm/dyne	15	8.218726	2.581989
rb+rp=	between 100-1000	300		25	6.366198	3.333333
IMO: Any imaginable improvement in sound by additional weight on shell might be applicable for high resistance for rb+rp such as heavy damped arm + low compliance cartridge only.				35	5.380419	3.944053
				45	4.745084	4.472136
Q (resonance amplitude) rate increases as resonance frequency shifts lower.						

Non-linear and asymmetric compliance issues: Mr. Grado applied for a patent for a linear tracking arm in Japan in his later years (Patent Publication S55-42399) - the invention (**a device to free the needle tip from extra forces other than grooves***See note below) is questionable, but I was intrigued by the analysis of the force applied to the needle tip. Since the damper compresses in the longitudinal direction due to needle pressure, the actual cartridge compliance is often less in the longitudinal direction and greater in the transverse direction. In order to compensate for this, a damper of the deformed shape (Debeso) (Denon DL-7) may be used. There are many other ways to devise the dampers: double placement in front and behind armaure: dampers (realized in some Denon/Ortofon products), devising a way to make the hardness of the damper hard in the center and soft on the outer circumference to maintain high compliance (double doughnut JP57018006 and dome-shaped damper JP57008903), In order to prevent changes in high-frequency characteristics due to changes in ambient temperature, the material of the damper is changed to silicon rubber mixed with conventional butyl rubber (TTDD = US4232869 from Technics, Japan JP56094503 from Columbia), etc. *Note: **Relieving the needle tip from any extraneous force other than the groove** presents an interesting problem. If the compliance (= 1/stiffness) of the damper is too small, it will be a motion loss in itself, so it is desirable that it be a certain amount. Therefore, compliance has been limited to the range of 5cu~50cu. The effective mass of the arm, including the LP era cartridge, is also at least 9g for linear tracks and around 50g at the maximum. The combination of arm and cartridge is selected so that the low-frequency resonant frequency is usually in the range of 8~16Hz. Stylus due to friction between the needle tip and the vinyl record The drag is the tension between the needle tip and the arm fulcrum, which affects the effective compliance of the cartridge. In actual products, not only compliance, but also arm rotation sensitivity and frictional resistance often differ in the vertical and horizontal directions, so I feel that no matter how much theory is developed, it is often ineffective. Laser using optics I think Turntable is an example of escaping the pesky problems of stylus drag.

Pick-up system (arm+cartridge) and reference on needle pressure and needle geometry (JVC/Yamamoto/Stevenson/Bastiaans/Hunt) etc.) The description was deleted in April 2021. I decided that it was my study material and should not be published here.

Recently (April 2021) I omitted some referenes to Stevenson/Bastiaans/Hunt/Yamamoto/JVC and others since these references are for my reading only and nobody cares now.

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