Mechanism of the Bias Compensator and the Lateral Balancer

*** This paragraph describes the physical principles and the geometry of the SONY Tone Arm models PUA-237 and PUA-286**

Bias compensator

As the stylus rides in the groove, the friction between the stylus and the groove provides a forward force F which is tangential to the record groove.

$F=\mu N$ μ: coefficient of friction between stylus and groove
N : stylus force

Because the line of action of this forward force F is displaced $90°-\alpha$ from the line between the pivot and the stylus, this forward force provides a clockwise moment M about the pivot Q which tends to drag the stylus towards the spindle as shown in Fig. 1.

Fig. 1

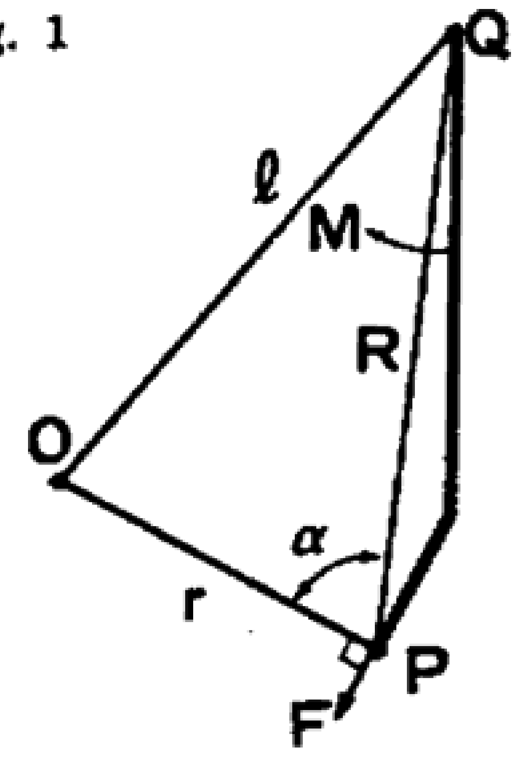


Fig. 2

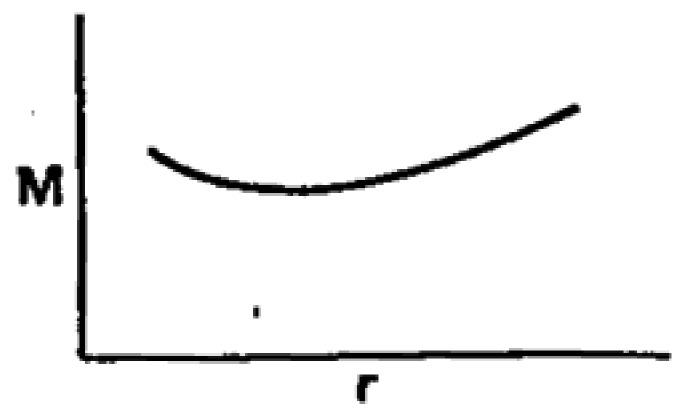
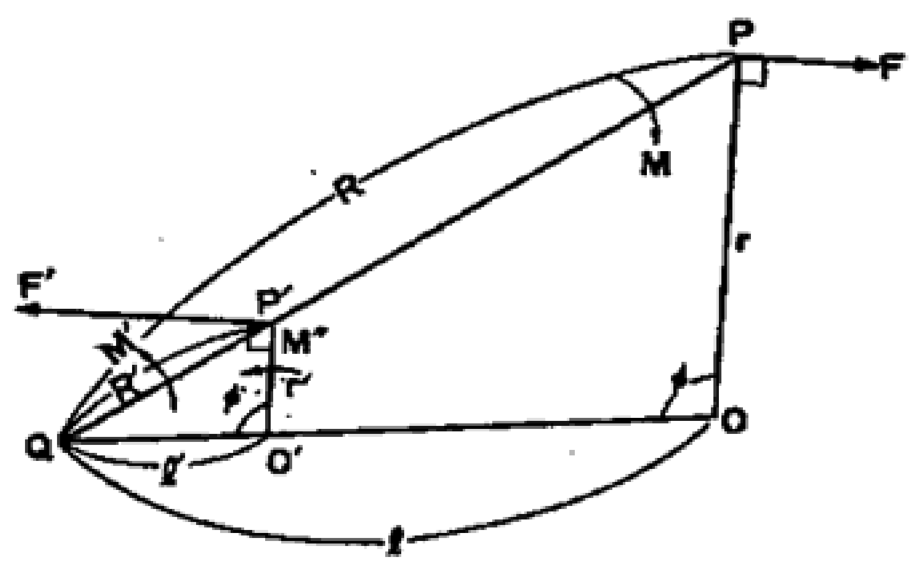


Fig. 3



Due to this side thrust, the stylus bears against the inner groove wall, causing imbalance of the stylus force on the groove walls. As stereophonic records require that each of the groove walls be traced with the same stylus force for the optimum reproduction, this imbalance of stylus force may result in distortion, stereo imbalance and uneven record wear.
Therefore, this moment M must be canceled out completely at any position on the record.
This moment is expressed by the equation

$$M=FR\cos\alpha=F\frac{R^2+r^2-l^2}{2r}$$

While F, R and l are constant factors, r varies according to the position of the stylus. Therefore M can be expressed as the function of r. The relation between M and r is shown in Fig. 2.

Theoretically, it is known that moment M can be canceled by providing to the arm a compensation M′ that is equal to M but opposite in direction.
In conventional method, M′ is applied as a constant force. Therefore, the side thrust is completely canceled out at only a few positions on the record.

In the SONY tone arms, the bias compensator device " Bias Sensing Arm " varies the compensation force continuously according to the change of M, and on every position on the record the side thrust is canceled out completely as follows: As moment M varies in concave curve, as shown in Fig. 2, it is difficult to design the arm mechanism so that the arm accepts the counteracting moment M′ directly.

Therefore, the Bias Sensing Arm is mounted coaxially at the pivot Q; so that the Bias Sensing Arm catches the side thrust on the main arm and moves with the arm. M′ is applied to the Bias Sensing Arm and then through the Bias Sensing Arm, M′ is transmitted to the arm.

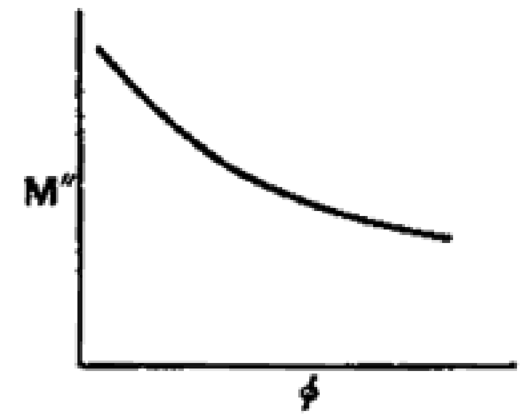
M′ is developed as follows: A triangle ⊿PQO consists of the lines which pass through the points of the stylus tip P, the pivot of the arm Q and the center of the turntable O.
Assume a similar triangle ⊿P′QO′ where O′ is a pseudo-center of the turntable, P′ is a pseudo-stylus tip, P′Q is a Bias Sensing Arm. The geometry of the two triangles is shown in Fig. 3.

To cancel out moment M, M′ must be equal to M.
If F′ exerts on the line r' normally, moment M″ is caused about O′. Then QP′ is moved by the F′, and F′ will cause the counterclockwise moment M′ about Q.
Consequently, if F′ acts on the Bias Sensing Arm QP′, side-thrust moment M is offset by M′.
This relation is expressed by the following equation.

$$\overline{M'}=\overline{R'}\times\overline{F'}=(\overline{l'}+\overline{r'})\times\overline{F'}=\overline{l'}\times\overline{F'}+\overline{r'}\times\overline{F'}=\overline{l'}\times\overline{F'}+\overline{M''}$$

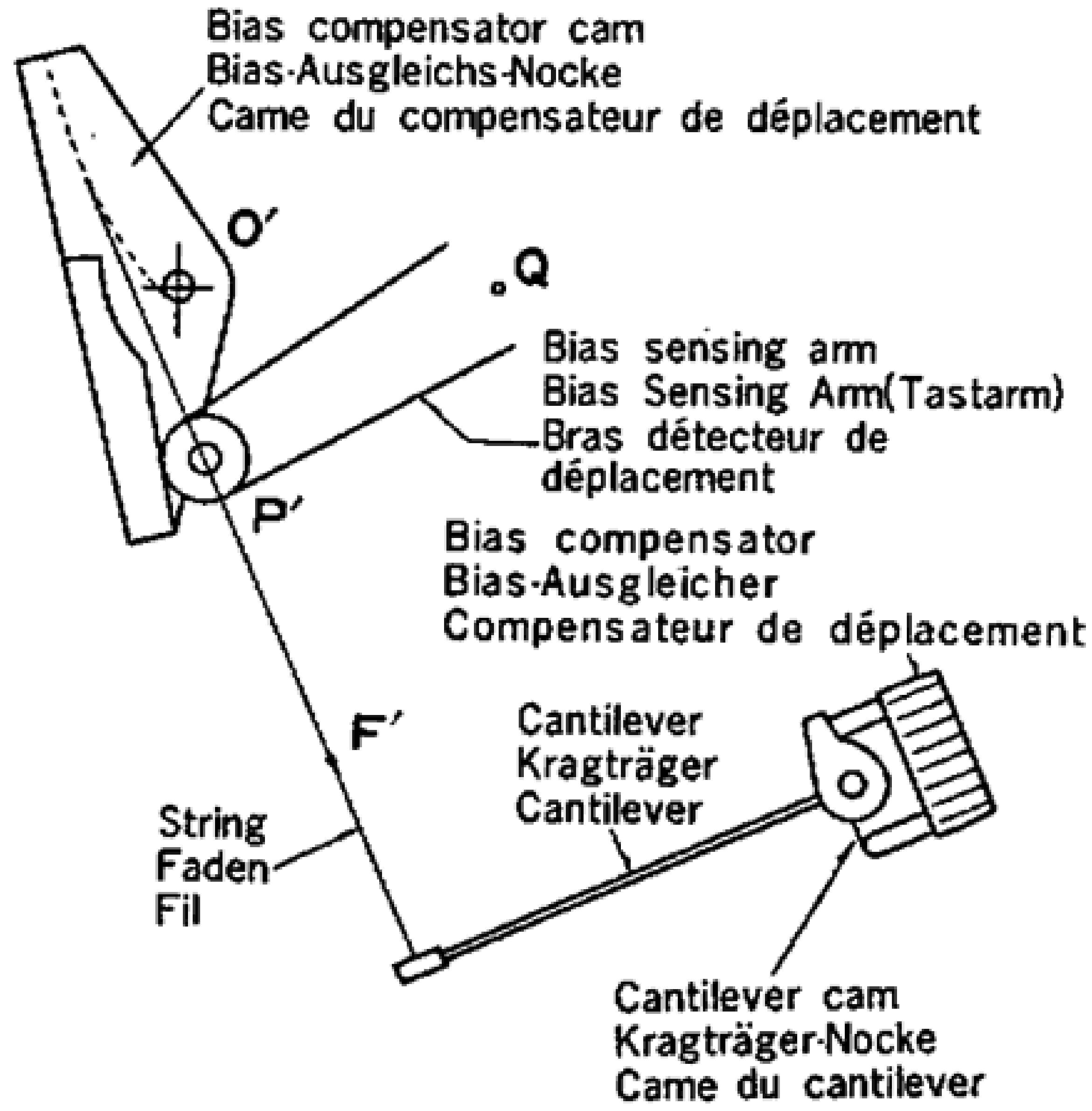
Because $l'\times F'$ is independent of arm movement, the same result of applying M′ to Q can be obtained by applying M″ about O′.

Fig. 4



As r' is normal to F' constantly $M''=r'F'$; M'' is proportional to r'. This relation is also difficult to utilize in the design in an arm system.
If M'' is expressed as a function of ϕ, the M'' is expressed by the following equation.
$M''=r'F'=rF=F\,(l\cos\phi\sqrt{\pm l^2\cos^2\phi-l^2+R^2})$
As F, l and R are known value, the relation between M'' and ϕ can be obtained as shown in Fig. 4.

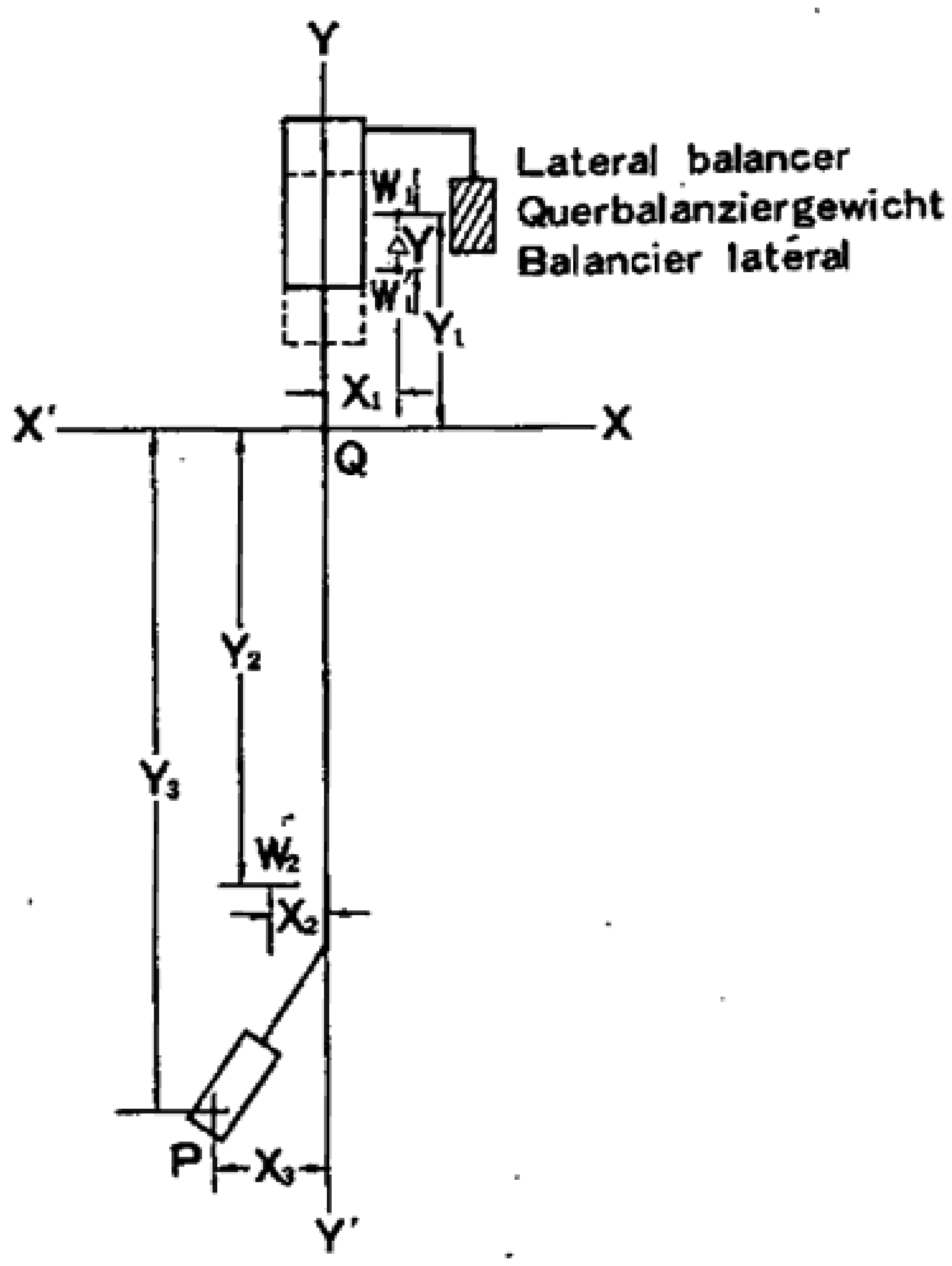
Fig. 5



Now this relation is expressed in a decreasing curve, it is possible to employ this relation with the cam device. The simplified mechanism of the cam and the Bias Sensing Arm is shown in Fig. 5.

As the forward force F of the arm is a product of the stylus force and coefficient of friction, the greater the stylus force, the greater the force F. According to the applied stylus force, the drag force of the cam F'' is adjusted as follows; when the bias compensator is set to the proper value according to the stylus force, the initial deflection of the cantilever is changed by the compensator adjustment, and the drag force of the cam F'' is changed according to the cantilever movement.

Fig. 6



Lateral balancer

Lateral balance is defined as the balance of moment in lateral plane with respect to the line Y which is normal to the rotation axis of the vertical movement of arm and also passes through the pivot of the arm.

In conventional method, as shown in Fig. 6, the arm is in equilibrium in longitudinal plane by balancing the moment of counterweight side and the cartridge side and in lateral plane by balancing the moment of both sides of Y.

In longitudinal plane $W_1Y_1=W_2Y_2$
In lateral plane $W_1X_1=W_2X_2$

XX′ : rotation axis of the vertical movement of the arm
W_1 : the weight and the center of gravity of the counterweight side
W_1' : W_1 displaced with the stylus force
W_2 : the weight and the center of gravity of the cartridge side
P : stylus tip
Q : pivot of the arm

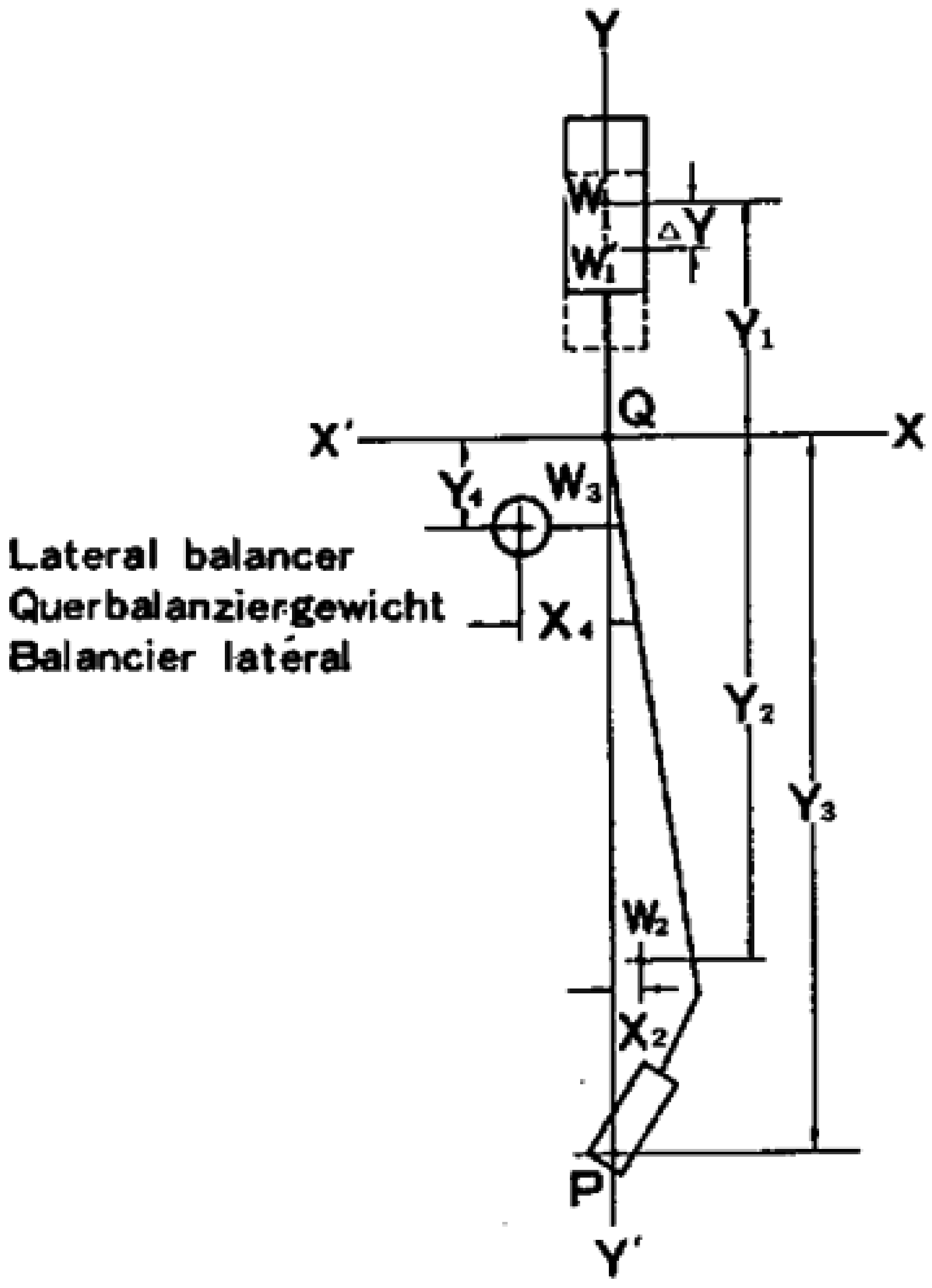
In this system the stylus force F is applied by displacing the center of gravity of counterweight side W_1 to W_1'; the stylus force is expressed by the following equation.

$$F=\frac{W_2Y_2-W_1(Y_1-\Delta Y)}{Y_3}$$

As W_1Y_1 is equal to W_2Y_2, $F=W_1\frac{\Delta Y}{Y_3}$

The center of gravity of the counterweight side W_1 moves parallel to Y, the balance of moment of both sides of Y does not upset with the stylus force adjustment.
When the arm is placed on the record, a counter force F', which is the same value as F, acts against the stylus tip in the opposit direction of F.

Fig. 7



In this case, however, as the stylus tip is displaced by X_3 from Y, this counter, force provides moment $M=F'X_3$ about Y, which upsets the balance of moment in lateral plane, thus effecting tracking ability of the arm.
For optimum sound reproduction, the arm should be kept in the lateral balanced condition even when the arm is placed on the record.
The SONY tone arms are designed as shown in Fig. 7, the center of gravity of counterweight side W_1, pivot of arm Q, stylus tip P are on the line Y and the center of gravity of the lateral balancer W_3 is at left side of Y.

XX′ : rotation axis of the vertical movement of the arm
W_1 : the weight and the center of gravity of the counterweight side
W_1' : W_1 displaced with the stylus force
W_2 : the weight and the center of gravity of the cartridge and the arm pipe
W_3 : the weight and the center of gravity of the lateral balancer
P : stylus tip
Q : pivot of the arm

To balance the arm in lateral plane the lateral balancer is equipped to be adjusted so that W_3X_4 becomes equal to W_2X_2.
When applying stylus force, W_1 is displaced on the line Y. The balance of moment of both sides of Y is not upset with the stylus force adjustment.
When the arm is placed on the record, contrary to the conventional system, the counter force F′ at the stylus tip does not provide any moment about Y, because the stylus tip is on the line Y.
Thus the arms are kept in truly lateral balanced condition.

Fig. 8

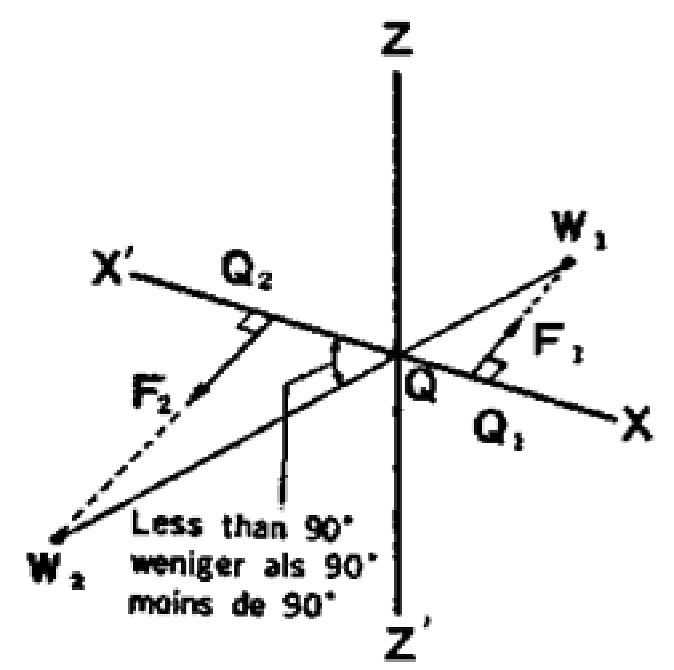
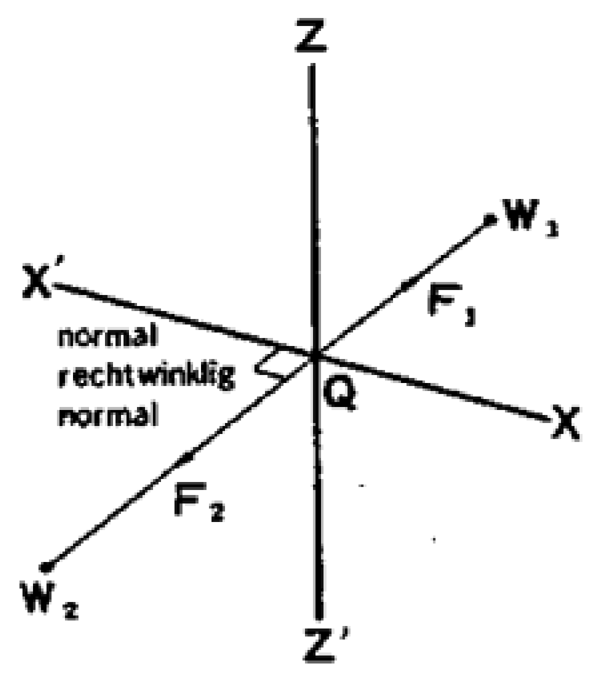


Fig. 9



Dynamic balance

As a standard term " Dynamic Balance " means a condition of balance of inertia forces; forces created by rotation of the arm about the pivot should not disturb the balance conditions that exist at rest. To keep a tone arm in dynamic balance in lateral plane requires that the line between the centers of gravity on each side of the arm pasess through the pivot and also is normal to the axis of rotation. Fig. 9 shows the arm which balances dynamically in lateral plane. The SONY tone arms are designed in this way.
Fig. 8 shows the arm which does not balance dynamically.

W_1 : the center of gravity of the counterweight side
W_2 : the center of gravity of the cartridge side
XX′ : rotation axis of the vertical movement of the arm
ZZ′ : rotation axis of the lateral movement of the arm
Q : pivot of the arm
F_1, F_2 : centrifugal force

If the arm is rotated about XX′, the centrifugal force F_1 F_2 will be created as shown in Fig. 8 and Fig. 9.
In Fig. 8, each centrifugal force F_1 F_2 acts on two different points Q_1 and Q_2 and the forces drag the points Q_1 and Q_2 counterclockwise. When the arm is moved vertically by a wrapped record, XX′ tries to rotate about ZZ′ and the arm will lose the dynamic balanced condition in lateral plane.
In Fig. 9, both F_1 and F_2 act on one point Q and the inertia moments of F_1 and F_2 offset each other.
Thus, the vertical motion of the arm does not create any inertia moment on lateral plane about the pivot, and the dynamic balanced condition in the lateral plane is kept independent of the vertical motion of the arm.

3-790-731-14 (1)

SONY CORPORATION

Printed in Japan