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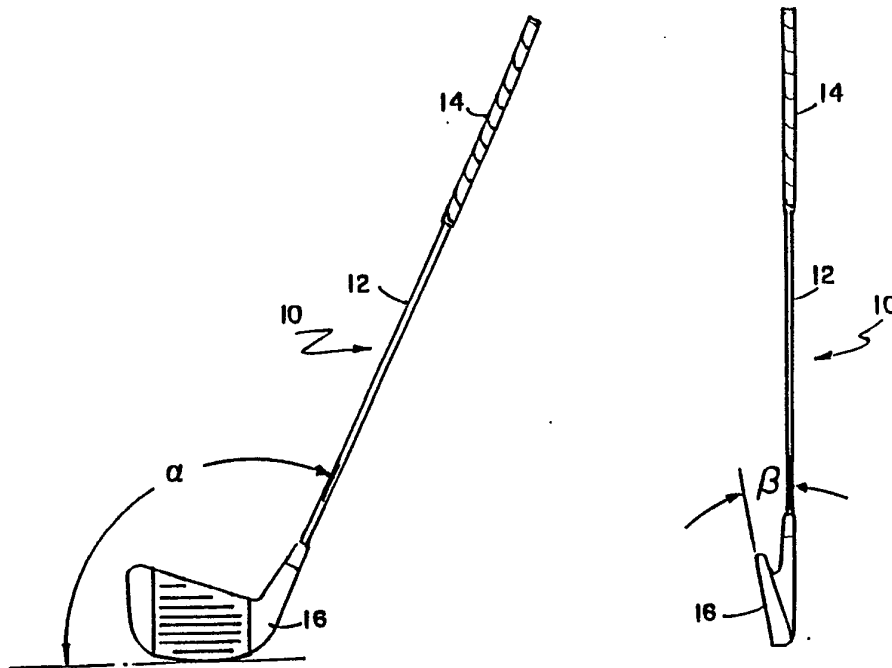
(57) Abstract

Golf clubs can be matched either to duplicate a favorite club or to produce a matched set of clubs by determining a spectral response curve of a club and then matching other clubs thereto at at least about its natural frequency.

GOLF CLUB MATCHING METHOD

Background of the Invention

        Many golfers have one or two favorite clubs, which they
prefer over the rest of the clubs in their set. The favorite
club(s) usually feels and performs better for the golfer. If
the golfer could duplicate the performance of this favorite
club and make each of the clubs in his set feel and perform
like his favorite club, the golfer could improve his game.

        That a golfer finds a difference in behavior of one club
from another in a set is not surprising due predominantly to
normal shaft manufacturing tolerances. Shafts made from the
same die can vary substantially. For example, steel shafts of
a leading manufacturer are permitted to vary by up to ±2.5% in
stiffness and still be within tolerance. With the difference
between "regular" and "stiff" shafts or "stiff" and "extra
stiff" being only about 2.5%, a shaft within a set can vary all
the way from "regular" to "extra stiff" even though all the
shafts in the set were made from a "stiff" die.

        Attempts at duplication of a golf club to copy a single
golf club or to produce a matched set of clubs are well known
in the art. A variety of different methods have been proposed
to accomplish these difficult tasks. One of the most popular
techniques involves the determination of and then matching the
natural frequency of the clubs or, in some instances, the club
shafts.   U.S. Patent Nos. 3,395,571; 4,070,022; 4,122,593;
4,555,112; and 4,736,093 and U.K. Application No. 2,223,951
each disclose methods of duplicating golf clubs and/or produc-
ing matched golf club sets by means of club or shaft natural
frequency matching.

        U.S. Patent No. 3,698,239 discloses a method of produc-
ing a dynamically matched set of clubs by starting with a favor-

ite club, determining its moment of inertia of mass for a se-
lected swinging axis by calculation from its length and weight,
and producing the remaining set to have the same moment of
inertia, by calculation. The use of the moment of inertia in
the duplication of golf clubs is also disclosed in U.S. Patent
No. 4,128,242.

U.S. Patent No. 4,175,440 discloses dynamic testing and
matching of clubs by measuring the angular velocity and centri-
fugal force along the axis of the club shaft as the club is
swung on an arcuate path using an adjustable power rotational
drive means.

Overall mass matching is used in U.S. Patent No.
4,415,156 to produce a matched set of clubs.

In U.S. Patent No. 4,900,025 a correlated set of clubs
is made by matching the shaft flexure characteristics such that
the deflection of a reference point is substantially uniform
when a given torque is applied at the point.

None of these techniques, however, have developed enough
or in some cases the right information about a particular club
to enable one to accurately and completely duplicate the club
so that the duplicate club performs and feels like the club be-
ing duplicated.

Also, none of these techniques have developed enough or
in some cases the right information about a particular club to
enable one to accurately and completely match other clubs in a
set so that the matched club(s) perform and feel like the first
club.

Accordingly, it is an object of the present invention to
develop a method and device to either duplicate a golf club or
to produce a matched set of clubs so that the golfer using the
produced clubs can not tell the difference between the clubs.

Summary of the Invention

The present invention is directed to a method of dupli-
cating a single golf club, a method of producing a matched set
of golf clubs, and a device for carrying out the duplication or
matching process. As used herein, the term "duplicating" means
producing a golf club which feels and performs substantially
the same as the golf club being duplicated when used in the
same manner.

The duplicating or matching process generally comprises
attaching a golf club to be duplicated or matched to an oscil-
lating means at the club's grip end, oscillating the golf club
over a range of frequencies, measuring at each frequency the
excursion of the golf club head from a stationary position, and
thereafter plotting the excursion versus the frequency of the
club head to form a curve which is defined herein as a "spec-
tral response curve." The curve formed by such plotting normal-
ly has a distinctive peak that appears at about the natural fre-
quency of the golf club. The natural frequency is the frequen-
cy at which the maximum excursion occurs. Once a spectral re-
sponse curve for the golf club to be duplicated or matched has
been measured and plotted, a golf club shaft having substantial-
ly the same spectral response curve, at least at about the por-
tions of the curve near the natural frequency of the club, is
selected.

Preferably a multiplicity of golf club shafts are pre-
tested to determine their spectral response curves by oscillat-
ing each shaft with dummy club heads attached thereto. Thus,
when it is time to select an appropriate shaft, all that needs
to be done is to select a shaft having a spectral response
curve that is substantially the same as the spectral response
curve of the club to be duplicated at least at about the por-
tion of the curve corresponding to the natural frequency of the
club. This comparison process may be carried out in any suit-
able manner including manually by using transparent overlays
and electronically by using an appropriate computer program.

After an appropriate shaft of the same length is locat-
ed, a club head of the same weight, size, loft, and lie as the
head on the club being duplicated is attached to the new shaft.

Other properties and dimensions of the golf club which
contribute to producing a duplicate of a golf club or a matched
set of clubs include: the club swing weight and the overall
weight of the club, the torque of the shaft, the flex point of
the shaft, and the grip diameter of the grip end of the club.
In duplicating a golf club or matching a set of golf clubs
these properties and dimensions may also be duplicated or match-
ed to produce the new club.

Brief Description of the Drawings

Fig. 1(a) is a plan view of a golf club.

Fig. 1(b) is a side view of the golf club of Fig. 1(a).

Fig. 2 is a top view showing the operation of an oscil-
lating means according to the present invention.

Fig. 3 is a side view of the oscillating means of Fig.
2.

Fig. 4 is a graph showing matching spectral response
curves according to the present invention.

Fig. 5 is a front view of Fig. 2 showing the measurement
of the torque.

Fig. 6 is a plan view showing a counterbalance used to
measure the swing weight of the golf club.

Fig. 7 is a plan view of an oscilloscope showing the
measurement of the phase angle.

Fig. 8 is a plot of a curve showing the relationship be-
tween club length and natural frequency of each club in a set

of clubs for a set of golf clubs deemed to be a matched set for a set based upon an inherent frequency gradient of 10 cpm/inch.

Fig. 9 is a plot of the spectral response curve for two matched golf clubs from the Example.

Detailed Description of the Invention

As shown in the drawings, a golf club 10 comprises a shaft 12 having at one end a grip portion 14 and at the other end a club head 16. As is well known in the art, the club head may be either a "wood" head or an "iron" head. The term wood head refers to a particular type of club well known in the art used to drive golf balls longer distances than irons. It may be manufactured from a variety of conventional materials including metal, wood, graphite, and polycarbonate. Iron heads are generally made of materials such as cast or malleable iron or plastic composites and are generally used to drive golf balls shorter distances in comparison to the woods. The shaft may be made of any of a variety of conventional materials including steel, aluminum, graphite, or fiber-filled polycarbonate. A set of golf clubs generally comprises iron wedges such as the sand and pitching wedges, short irons (7-9 irons), long irons (2-6 irons), short woods (3-5 woods), and long woods (1-2 woods), though more or less clubs may be in an actual set.

According to the present invention, any golf club, whether it be a wood or an iron and notwithstanding the construction of the shaft or the materials used to form the shaft or head, may have its performance duplicated by the method herein.

The method according to the present invention comprises attaching the golf club to be duplicated or matched at its grip end to an oscillating means such as an oscillating motor and oscillating the club over a range of frequencies. Other oscillating means which may be employed include a linear motor attached to the grip end of the club, a servo motor programmed to oscillate back and forth, and a magnetically induced oscillating motor. While the specific frequency range used for the oscilla-

tions will depend upon the particular club and materials used to make the club, the range of frequencies used is generally from about 200 RPM to 800 RPM, preferably from about 225 RPM to 375 RPM. At each frequency, the excursion of the club head from its stationary position is measured. The excursion may be measured by any suitable means including a visual scale such as a ruler or the like or an optical sensor array. It is presently preferred to measure the excursion by a sensor array so that the phase angle, a parameter discussed hereinafter, may also be measured. If a visual scale such as a ruler is used, the phase angle measurement is not possible. According to an embodiment of the present invention and best shown in Fig. 2 to 3, a rotating motor 22 connected to an oscillating arm 24 by means of a pin 26 mounted on the outer edge of a disk 25 which is attached to the motor shaft 27. The pin 26 fits into a slot 28 in the oscillating arm 24. It is presently preferred to employ a rotating synchronous AC motor driven by a variable frequency controller which can hold a set point of speed at ± 1 RPM. By this arrangement, the rotational movement of the motor is translated into oscillating movement in the oscillation arm 24, which is attached to surface 29 by means of a pin 31 so as to form a pivot at the grip end of the club. Attached to the oscillating arm 24 is a vise 30 used to hold the golf club 10 at its grip end 14. A screw 32 is used to tighten and loosen the vise. A tachometer 33 which is electrically connected to the motor is used to measure the speed of the motor. In this embodiment, an optical sensor array 34 arranged in a semi-circular path is used to measure the excursion of the club head. As shown, a set of light emitting diodes (LED's) are arranged in a semi-circle under the path that the clubhead subscribes with a sinusoidal generator (not shown) whose output magnitude is proportional to the highest order LED covered by the clubhead as it swings at each frequency. As an alternative to the optical sensor array, a strain gauge placed on the shaft of the club near the clubhead with an analog output could be employed. The analog output is a continuous voltage which is roughly proportional to the displacement of the clubhead. Still another measuring technique which could be employed is to use a strain

gauge to measure the phase angle (hereinafter discussed) and an optical sensor with a short term memory to scan the LED's to sense the highest order LED intercepted by the clubhead. As shown, when the oscillating means is operating, the club head oscillates from one position shown at X to another position shown at Y. These X and Y points will change as the frequency of the motor is varied. The excursion of the club head is shown in Fig. 2 as the distance "d" which will also change as the frequency changes.

The frequency and excursion measurements are then used to plot a curve, defined herein as a "spectral response curve." Fig. 4 shows such a curve 20 for a golf club. As shown, the spectral response curve has a distinctive peak. The peak is at the natural frequency (f_o) of the club. The shape of the curve at about the natural frequency of the club (the portion generally extending from the beginning of the upward slope and the ending of the downward slope shown as W in Fig. 4) provides important information about the performance of the club. Both the height of the peak at f_o and the width of the peak at various percentages of the heights of the curve at f_o are useful parameters in the process of duplicating or matching a golf club.

As shown in Fig. 4, the width of the spectral response measured at about 70% of the height "h" of the peak at f_o, shown as Q, represents the ability of the club to forgive off-speed swings. It also is a measure of mechanical gain which is in conflict with forgiveness; i.e. narrow peaked shafts result in high mechanical gain and non-forgiving clubs. Only players with very repetitive swings or those who hope to achieve distance at the expense of accuracy should play with narrow peaked shafts. When determining the characteristics of a club to produce a matched set of clubs therefrom, the width of the peak Q is important to consider. Width measurement of the curve at other points such as about 10% and 70% of the height of the peak at f_o may also be used in matching the spectral response curve of the club to be duplicated or matched.

Once the spectral response curve for the golf club whose
performance is to be duplicated is determined, the next step in
the process is the selection of a club shaft which, when a club
head substantially equal in weight to the club head being dupli-
cated is attached thereto, has substantially the same spectral
response curve as the golf club that is being duplicated or
matched, at least at about the portions of the curve correspond-
ing to the natural frequency of the golf club. As used herein,
"substantially the same spectral response curve" means that the
amplitudes of the two curves at the portions of the curves at
about the f_o peaks are within about ± 10%, more preferably
within about ± 6%, and most preferably within about ± 3%, and
at other frequencies of the curves being matched within about ±
15%, more preferably within about ± 10% and most preferably
within about ± 7%. Preferably, the natural frequencies f_o,
at which the peaks occur, are within ± 1%, preferably ± 0.5%,
and most preferably ± 0.1% The spectral response curve for a
suitable new club is shown, by means of example only, in Fig. 4
as a dotted line 23.

To obtain a more precise duplication, the spectral re-
sponse curves of the club being duplicated can be matched with
the new club over the same and entire frequency range measured.

Since the spectral response curves for various golf
clubs may vary significantly from one golf club to another due
to shaft design and shaft manufacturing tolerances, it is pres-
ently preferred to measure the spectral response curves for a
large variety of shafts with various golf club heads or dummy
heads simulating a golf club head attached thereto. Such spec-
tral response curves can then be placed on file and matched to
the spectral response curve of a golf shaft to be used to con-
struct a golf club which a customer desires to duplicate or to
which other clubs in a set are to be matched. The matching of
the spectral response curves may be accomplished by any suit-
able means including using transparent overlays to match up the
curves or using conventional electronic means such as a comput-
er with appropriate programming to match the curves.

To make the duplication process more precise, two other parameters not directly associated with the spectral response curve may be measured and matched. Those two parameters are the flex point and the torque of the club shaft. The flex point is determined by oscillating the club as described above at a frequency of $2f_O$ and observing and identifying the point on the club shaft which is substantially stationary while the remainder of the club oscillates. This point is approximately two thirds of the distance from the grip end of the club to the club head. Two clubs having shafts of identical longitudinal stiffness but differing flex points may present a detectable "feel" variation to the golfer. Thus the flex points should be matched to more precisely duplicate the golf club. When the flex point of two clubs is being matched it should be at the same distance from the grip end of the club ± about 0.5 inches, more preferably ± about 0.25 inches, and most preferably ± about 0.1 inches.

The torque of the club is generally defined as the resistance to twisting of the club shaft. As shown in Fig. 5, it is measured by marking the sole plate 42 on club head 44 of the club 46 being duplicated with chalk or other suitable mark 48 and using a synchronized strobe light (not shown) to read the angle of deflection (Δ) when the club is oscillated at its natural frequency (f_O) using a suitable oscillating means 45 such as the device shown in Fig. 2. This deflection is caused by the center of gravity of the club head being located off the center of the shaft. The torque of the duplicate or matched club should generally be about equal to or stiffer than the club being duplicated, which translates into an angle Δ for the duplicate club of about equal to or less than the angle Δ possessed by the club being duplicated.

One method according to the present invention of obtaining a fairly precise duplication is to match each of the following parameters: (1) the natural frequency f_O (± about 0.1%); (2) the height of the peak at the natural frequency f_O (± about 1.0 inch); (3) the width of the peak Q at 70% of the

height of the peak measured from the bottom of the curve at the
natural frequency (± about 2.0 CPM); (4) the width of the peak
at 10% of the height of the peak measured from the bottom of
the curve at the natural frequency (± 4.0 about CPM); (5) the
flex point (± about 0.5 inch); and (6) the torque (an angle
about equal to or less than Δ of the club to be duplicat-
ed.) This method will result in matching the curves at about
the natural frequency of the two clubs within the tolerances
recited hereinabove.

Once the curves and any other desired parameters are
matched and the appropriate new shafts thereby determined, the
shaft is cut to an appropriate length. The length for the dup-
lication of a golf club is substantially the same as the length
of the initial golf club. A club head substantially the same
as the club head of the golf club being duplicated is then at-
tached thereto. A club head which is substantially the same
should be of the same weight ± about 2.0 grams, more preferably
± about 1.0 grams, and also have the same lie ± about 0.5°,
more preferably ± about 0.2°. It is not necessary, however,
that the club head be made of the same materials as the head of
the club being duplicated. The lie of the club head is the
angle α shown in Fig. 1(a). The loft is the angle β shown
in Fig. 1(b). The loft is more conventionally represented by
the club number, e.g. 5 iron, 3 wood. Thus, two 7 irons will
generally have substantially the same loft. The variations of
loft and lie angles between successive clubs in a set are well
known.

To complete the duplication of the club, the new club
shaft should preferably have substantially the same grip diame-
ter as the club being duplicated. The grip diameter should
generally not vary from the original by more than about ± 1/32
inch, more preferably by not more than about 1/64 inch. In
addition, the new club should have a swing weight (described
below) within about ± 1, more preferable about ± 1/2, swing
weights of the club being duplicated. The overall weight of
the two clubs should be within about ± 9 grams, more preferably

± about 4 grams, most preferably ± about 2 grams.

Fig. 6 shows one method for the measurement of the swing
weight of a club. A club 50 is placed on a counterbalanced
scale 52 on a flat surface 54 and is balanced on the fulcrum 56
using a sliding counterweight 58. A swing weight is a scale
factor defined when an increment of weight is added to the club
head such that the counterbalance is moved one scale increment.
The scale that is used is arbitrary. It is important, however,
that the same scale be used in measuring the swing weight for
the club being duplicated and the new matching club.

While not necessary to duplicate a club, a parameter de-
fined herein as the "phase angle" may be duplicated to obtain
very precise duplication. As described previously, the motor
used to oscillate the club during the duplication process is an
AC driven motor. An AC voltage used to drive the motor produc-
es a sine wave when displayed on an oscilloscope. Such a sine
wave has a magnitude and a phase angle. The optical sensor ar-
ray, which may be used to measure the club head excursion, pro-
duces a voltage which exhibits a sine wave. As shown in Fig.
7, the sine wave 60 of the motor and the sine wave 62 of the op-
tical sensor may be displayed on a dual trace oscilloscope 66.
The phase angle θ of the golf club is measured as shown.
In order to match phase angles of two different shafts for the
purposes of duplicating a club, the phase angles of the two
clubs should be within the range of about ± 5 degrees, more pre-
ferably within about ± 2 degrees, of each other.

Once the spectral response curve of a particular club
has been determined or a particular club has been duplicated,
an entire set of clubs or any subset thereof may be made having
analogous characteristics to the particular club. Generally,
each number club differs from the next numbered club by about
1/2 inch in shaft length. For example, a 5 iron is normally
about 1/2 inch shorter than a 4 iron which is normally about
1/2 inch shorter than a 3 iron, etc. In order to manufacture a
set or subset of golf clubs having the same performance charac-

teristics, the spectral response curve for a single club is determined in the manner described above. While the single club (or clubs) to which other clubs in a set is to be matched will preferably be the user's favorite club, other techniques for identifying the appropriate starting club may be utilized. For instance, a player can evaluate on a practice tee a calibrated selection of test clubs to identify the club which he prefers. Or a player's swing can be videotaped and superimposed upon images of other player's swings (for which a preferred club is known) until a match is found and then producing clubs of the same spectral response curve as those of the known player.

Thereafter, the remaining clubs are produced by selecting shafts and appropriate club heads which have substantially the same spectral response curve as the favorite club's curve excepting that the spectral response curve is shifted. In a plot of the relationship of length of club (directly proportional to the club number with the driver or 1 wood being the longest and the wedges the shortest) versus the natural frequency (in cpm) the shift in the spectral response curve when going from one club to the next higher or lower club produces a backward "S" curve such as the one shown in Fig. 8. As shown, the curve becomes convex between about the eight iron and sand wedge (SW) and concave between about the four wood and the driver. The curve between the 8 iron and the 4 wood is less severe, but is not a constant slope. Fig. 8 shows a backward "S" curve for shafts having an inherent gradient (slope) of 10 cpm/inch. Each golf shaft model has a specific inherent gradient which usually ranges from about 8 to about 15 cpm/inch. As a result of this variation, the specific shape of the backwards "S" curve and the increments between successive clubs in a set produced in accordance with the present invention will vary, depending upon the shaft model selected. The shaft model to be selected will depend upon obtaining the best match of spectral response curves.

Table 1 provides appropriate approximate frequency increments between successive clubs for inherent shaft gradients of

8, 10, 12, and 14 cpm/inch. The frequency increment for shaft models having a gradient of 10 cpm/inch between the driver and 2 wood is 2.2 cpm, between 2 wood and 3 wood 2.8 cpm, etc.

TABLE I

Club	Length of Standard Club	Frequency Increments Between Successive Clubs at Various Gradients (CPM)			
		8	10	12	14
Driver	43"				
		> 1.0	> 2.0	> 3.0	> 4.0
2 Wood	42½				
		> 2.0	> 2.5	> 3.7	> 4.5
3 Wood	42				
		> 2.3	> 3.5	> 4.3	> 5.6
4 Wood	41½				
		> 3.0	> 4.0	> 5.2	> 6.0
5 Wood	41				
		> 3.4	> 4.3	> 5.4	> 6.4
6 Wood	40½				
		> 3.5	> 4.4	> 5.5	> 6.5
1 iron	40				
		> 3.6	> 4.7	> 5.6	> 6.6
2 iron	39½				
		> 3.8	> 4.8	> 5.7	> 6.7
3 iron	39				
		> 3.9	> 4.9	> 5.9	> 6.8
4 iron	38½				
		> 3.8	> 5.0	> 5.7	> 7.0
5 iron	38				
		> 3.6	> 4.5	> 5.4	> 6.5
6 iron	37½				
		> 3.3	> 3.5	> 5.2	> 6.3
7 iron	37				
		> 3.1	> 2.0	> 4.5	> 6.0
8 iron	36½				
		> 1.0	> 0	> 2.0	> 4.0
9 iron	36				
		>-5.0	>-4.8	>-4.0	>-2.0
PW	35½				
		>-5.0	>-4.5	>-4.0	>-3.5
SW	35½				

The increments shown in Table 1 are appropriate for duplicating shafts with nominal inherent gradients (slopes) of 8, 10, 12, and 14 cpm/inch. Other shafts, for example those with a 13 cpm/inch, require extrapolation of the increments shown in Table 1. As the inherent cpm/inch value for shaft model shifts, the increments must be adjusted accordingly. In all cases a plot of the relationship of length of club versus the natural

frequency of a set of clubs produces the backward "S" curve relationship. In this manner an entire set of clubs can be manufactured with each club having the same performance characteristics as a single specific club.

The following Example illustrate the duplication of a single golf club and preparing other clubs therefrom. It is illustrative of the invention and should not be considered as limiting the invention.

EXAMPLE

A driver (1 wood) was oscillated using an oscillating means as shown in Fig. 2 except a ruler was used instead of an optical sensor array to measure the excursion of the club head. The frequency and excursion measurements were taken over a range of frequencies of from 200 to 800 cycles per minute (CPM). The frequency and excursion measurements were then plotted to form a spectral response curve unique to the club. The curve is shown in Fig. 9 as a solid line. From a stock of other shafts with predetermined spectral response curves a shaft having substantially the same spectral response curve was selected and a dummy head having approximately the same weight as the head of the club being duplicated was attached. Its curve is shown as the dotted line in Fig. 9. As can be seen from Fig. 9, the frequencies of the two curves were within about ± 2 CPM at all points, the height of the peak at the natural frequency of the club being copied was 1.0 inch higher than the height of the f_o peak of the new club. The width of the peak at 50% of the height of the peak for the master club was 22 CPM and the width of the peak at 50% of the height of the peak for the new club was 24 CPM, giving a difference of 2 CPM. At 70% of the maximum heights, i.e. Q, the difference is even less. The new club was then provided with a club head of the same loft and lie as the master club and a grip diameter substantially the same as that of the master club. The club head and grip were selected to appear the same as on the master club. When used on a driving range, a player could not distinguish between them.

A 5-iron is prepared to match the characteristics of the above driver (which had been prepared from a shaft having an inherent gradient of 10 cpm/inch). In accordance with Table I and Fig. 8, 5-iron is produced having (i) a length 5 inches shorter than the driver, (ii) a natural frequency of 300 cpm, i.e. 40.1 cpm greater than that of the driver, and (iii) a spectral response curve having a maximum height of 13.4 inches and a width Q of 23 cpm. The 5-iron is produced by selecting a commercially available shaft of the same shaft model and having the desired spectral response curve, cutting that shaft to the appropriate length, and attaching a 5-iron head and grip. When used on a driving range by the player for whom the driver was prepared, the 5-iron feels substantially the same.

What is claimed is:

1. A method of duplicating a golf club comprising at-
taching a golf club, having a grip end and a club head end, to
be duplicated to an oscillating means; oscillating the golf
club over a range of frequencies and measuring at each frequen-
cy the excursion of the club head; plotting the frequency vs.
the excursion measurements so as to form a spectral response
curve; determining the natural frequency of the golf club;
selecting a golf club shaft which, when a golf club head is
attached thereto and when oscillated over a range of frequen-
cies, has substantially the same spectral response curve at
least at about the portion of the curve at about the natural
frequency of the golf club being duplicated; and attaching a
golf club head to the selected shaft.

2. The method of Claim 1 wherein the golf club shaft
that is selected has substantially the same spectral response
curve over substantially the entire curve as the golf club
that is being duplicated.

3. The method of Claim 1 wherein the spectral
response curves at the portions of the curves being matched of
the two golf clubs have amplitudes at each point on the
respective spectral response curves that are within about 4%
of each other.

4. The method of any of Claims 1-3 further comprising
measuring the torque of the golf club being duplicated and
selecting a golf club having substantially the same torque or
less as the golf club being duplicated.

5. The method of any of Claims 1-4 further comprising
measuring at least one of the flex point, length, phase angle,
swing weight, overall weight, grip diameter, lie and loft of
the club being duplicated and selecting a club having substan-
tially the same flex point, length, phase angle, swing weight,
overall weight, grip diameter, lie and loft which has been

measured.

6. The method of any of Claims 1-5 further comprising measuring the peak of the spectral response curve at the natural frequency of the club being duplicated and then selecting a club having a natural frequency peak of substantially the same height.

7. The method of any of Claims 1-6 further comprising measuring the width of the selectivity Q of the curve of the club being duplicated and selecting a shaft which, when a club head is attached, has substantially the same selectivity Q.

8. A method of preparing a new golf club comprising determining (i) at least a portion of the spectral response curve and (ii) the natural frequency of a first golf club; and selecting a new club having a spectral response curve which is substantially the same as the spectral response curve of the first golf club, at least at about the portion of the curve at about the natural frequency of the first golf club, except that the natural frequency for the new club is shifted from that of the first club in such a manner that for each adjacent club in a set of clubs the natural frequency shift forms a backwards S curve when the natural frequencies of a set of fourteen different clubs is plotted on the vertical axis vs. the length of each club on the horizontal axis.

9. The method of Claim 8 wherein the determining of the spectral response curve is performed by attaching a first golf club having a grip end and a club head end to an oscillating means; oscillating the golf club over a range of frequencies and measuring at each frequency the excursion of the club head; and plotting the frequency vs. the excursion measurements so as to form the spectral response curve.

10. The method of any of Claims 8 or 9 wherein the backwards S curve is convex from about the eight iron through the higher numbered irons and concave from about the four wood

through the lower numbered woods.

11. A method of producing a matched series of golf club irons between a 2-iron and a sand wedge which comprises: attaching a first golf club having a grip end and a club head end to an oscillating means; oscillating the golf club over a range of frequencies and measuring at each frequency the excursion of the club head; plotting the frequency versus the excursion measurements so as to form a spectral response curve; determining the natural frequency of the first golf club; selecting at least 2 different clubs each having spectral response curves which are substantially the same as the spectral response curve of the first golf club at about the portion of the curve at about the natural frequency of the first golf club, except that the natural frequency for each adjacent club in the series shifts in a manner so as to form a curve which is convex from the 8-iron to the sand wedge when the natural frequency of the series of irons is plotted on the vertical axis versus the length of each club on the horizontal axis.

12. A method of producing a matched series of golf club woods which include at least 2 different woods between a 5-wood and a driver which comprises: attaching a first golf club head end to an oscillating means; oscillating the golf club over a range of frequencies and measuring at each frequency the excursion of the club head; plotting the frequency versus the excursion measurements so as to form a spectral response curve, determining the natural frequency of the first golf club from the curve; selecting the at least two different woods each having a spectral response curve which is substantially the same as the spectral response curve of the first golf club at least at about the portion of the curve at about the natural frequency of the first golf club, except that the natural frequency for each adjacent club in the series shifts in a manner so as to form a curve which is concave from the 5-wood to the driver when the natural frequency of the series of woods is plotted on the vertical axis versus the length of each club on the horizontal axis.

13. A matched series of two or more golf clubs, each club having (i) a substantially similar spectral response curve, at least about the portion of the curve at about the natural frequency of each club, which spectral response curve is formed by plotting the frequency versus the excursion of the club head when each golf club oscillated over a range of frequencies, and (ii) an identical inherent shaft gradient, wherein the natural frequencies of successive clubs are shifted by an amount as generally determined from the following table:

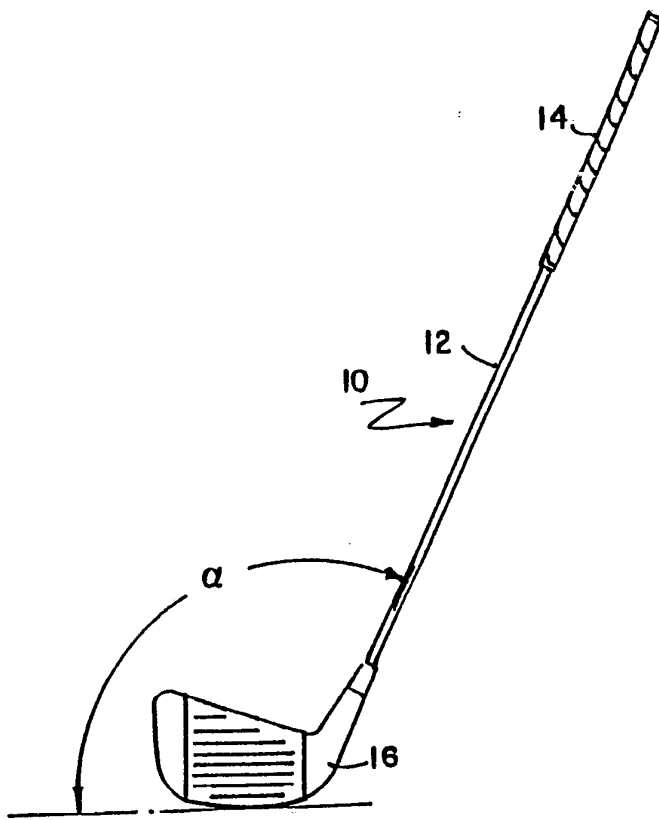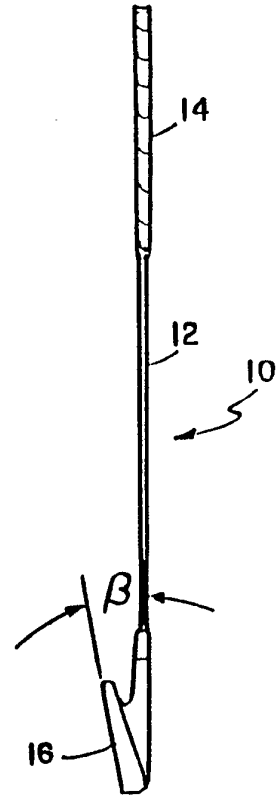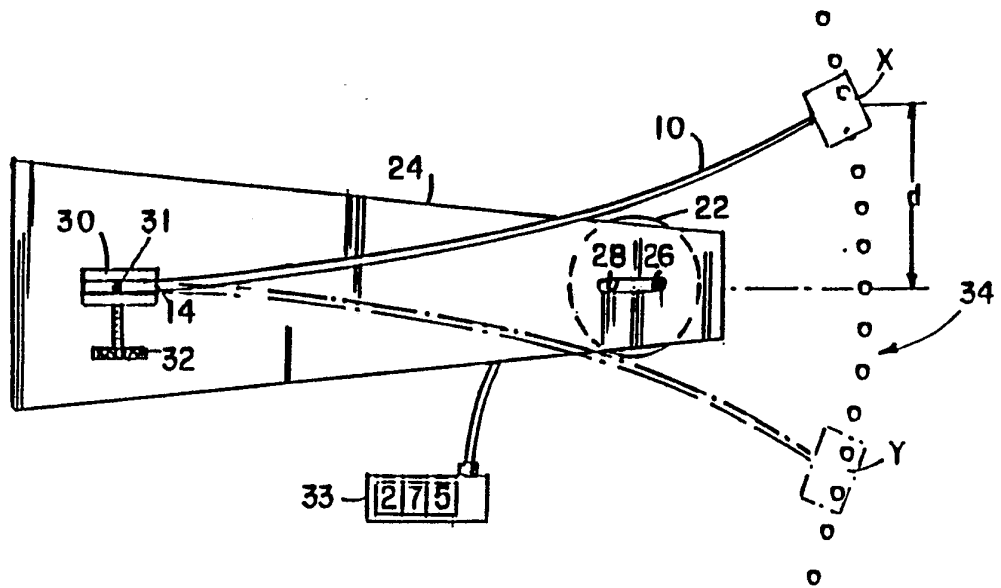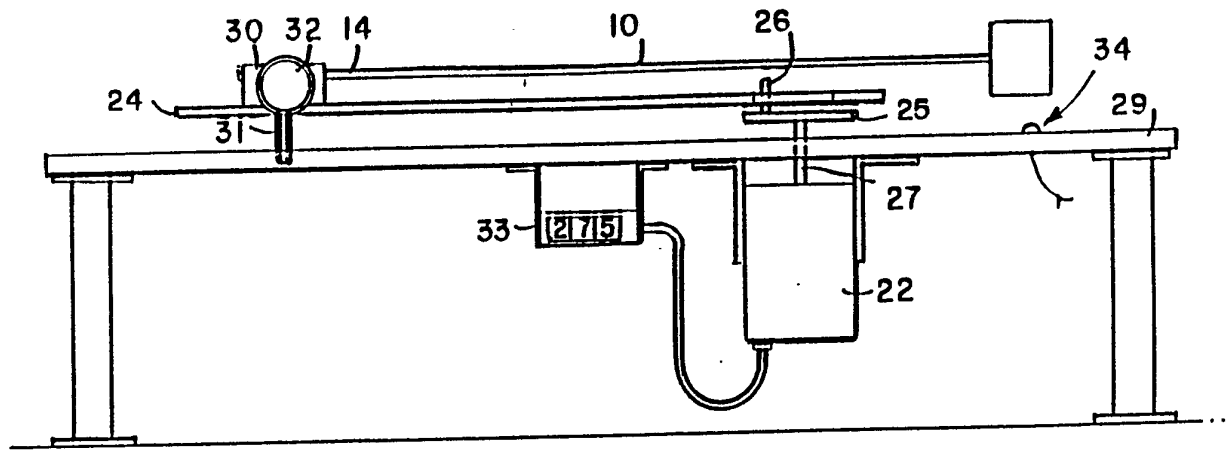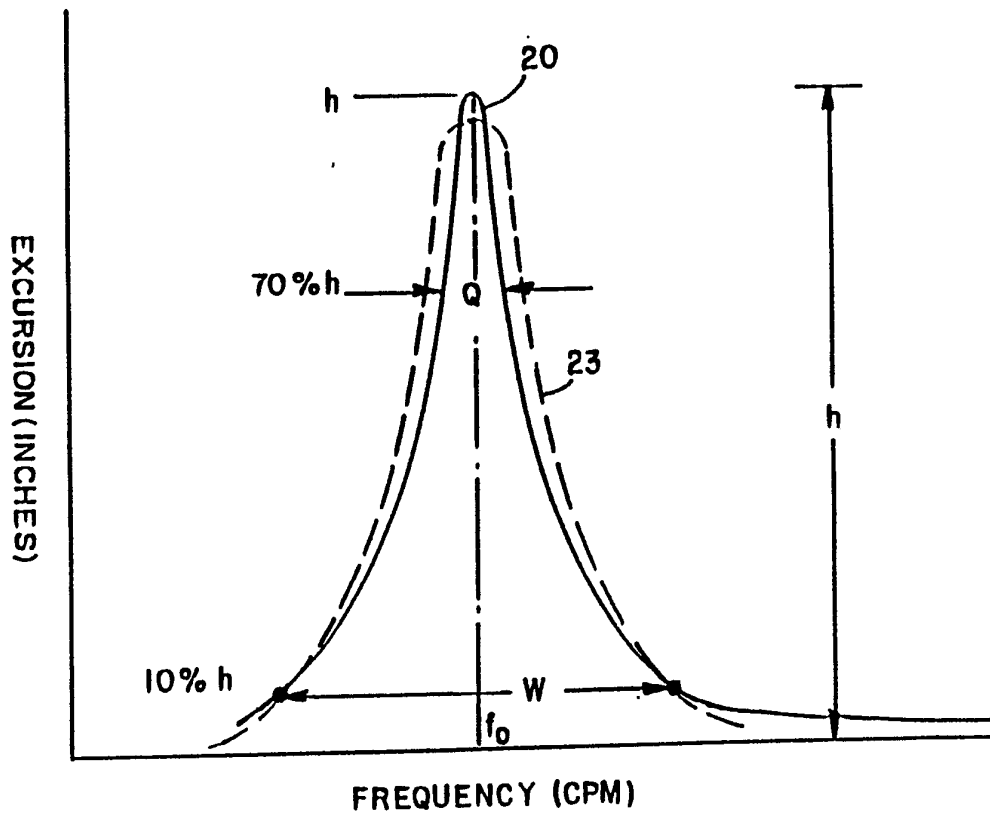| Club	Length of Standard Club	Frequency Increments Between Successive Clubs at Various Gradients (CPM)			
		8	10	12	14
Driver	43"				
		> 1.0	> 2.0	> 3.0	> 4.0
2 Wood	42½				
		> 2.0	> 2.5	> 3.7	> 4.5
3 Wood	42				
		> 2.3	> 3.5	> 4.3	> 5.6
4 Wood	41½				
		> 3.0	> 4.0	> 5.2	> 6.0
5 Wood	41				
		> 3.4	> 4.3	> 5.4	> 6.4
6 Wood	40½				
		> 3.5	> 4.4	> 5.5	> 6.5
1 iron	40				
		> 3.6	> 4.7	> 5.6	> 6.6
2 iron	39½				
		> 3.8	> 4.8	> 5.7	> 6.7
3 iron	39				
		> 3.9	> 4.9	> 5.9	> 6.8
4 iron	38½				
		> 3.8	> 5.0	> 5.7	> 7.0
5 iron	38				
		> 3.6	> 4.5	> 5.4	> 6.5
6 iron	37½				
		> 3.3	> 3.5	> 5.2	> 6.3
7 iron	37				
		> 3.1	> 2.0	> 4.5	> 6.0
8 iron	36½				
		> 1.0	> 0	> 2.0	> 4.0
9 iron	36				
		>-5.0	>-4.8	>-4.0	>-2.0
PW	35½				
		>-5.0	>-4.5	>-4.0	>-3.5
SW	35½				

FIG.1(a)

FIG.1(b)

FIG.2

FIG.3

FIG.4
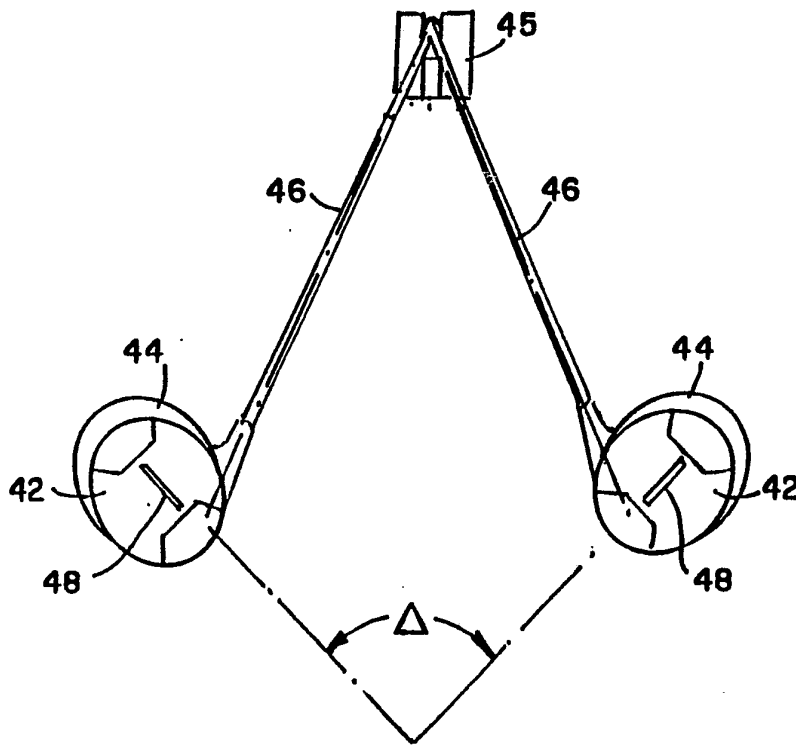
FIG. 5
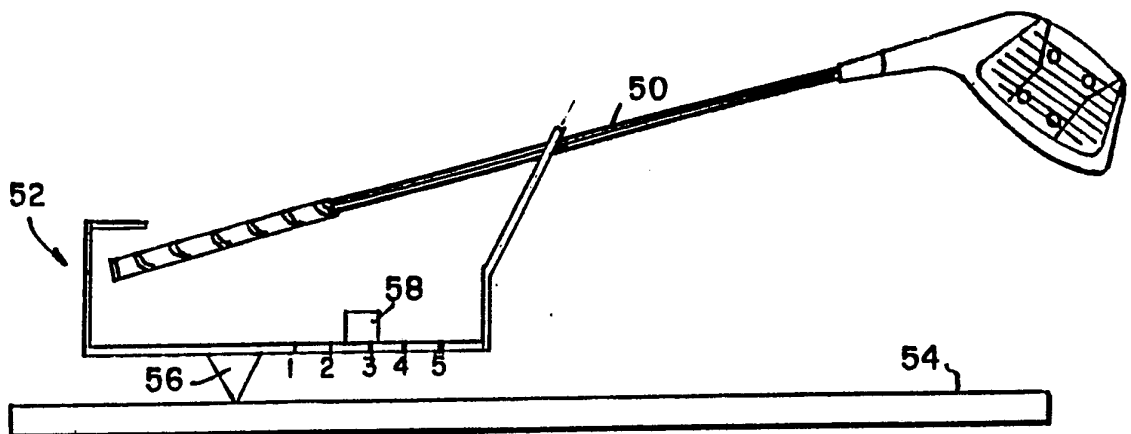
FIG. 6
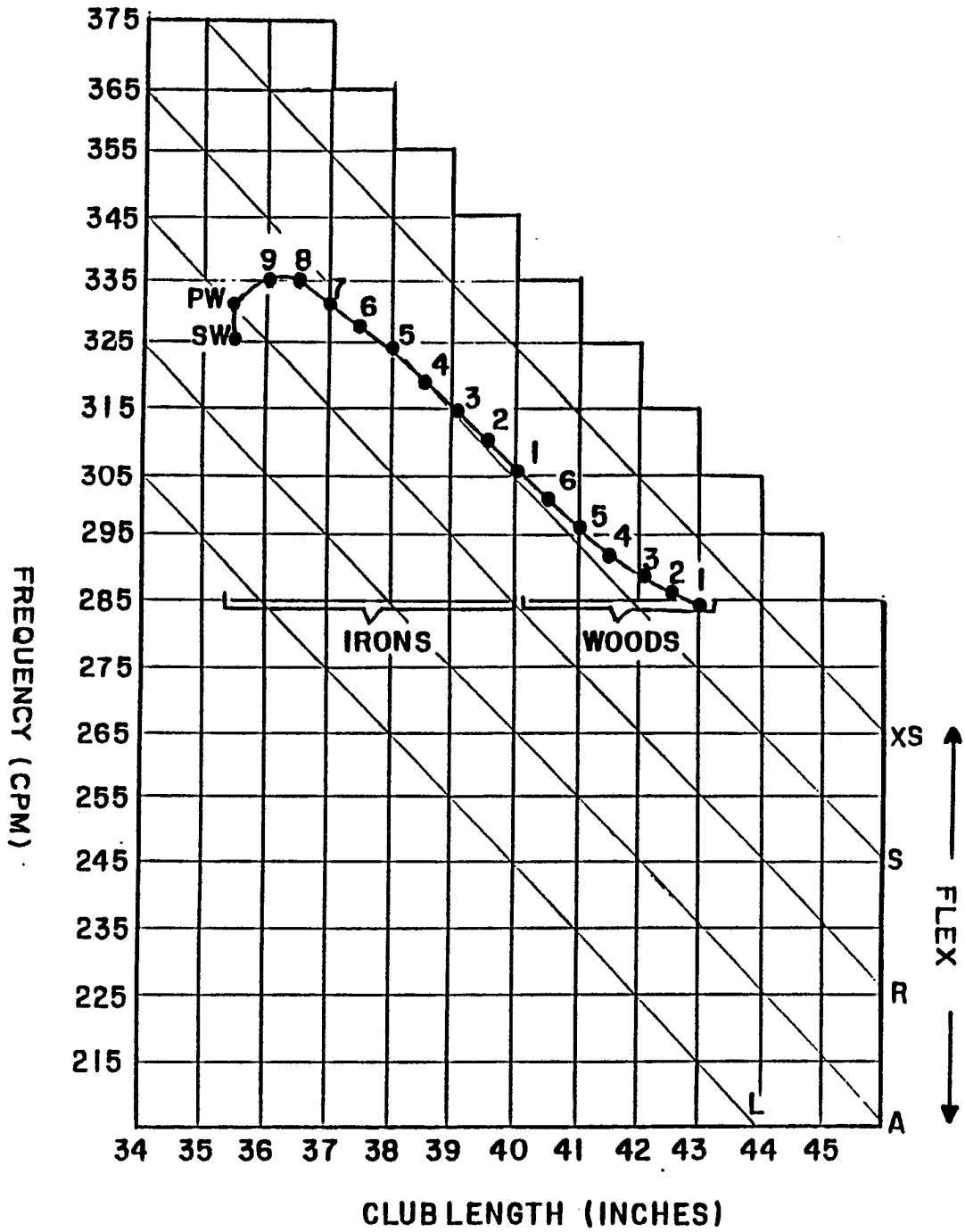
FIG.8
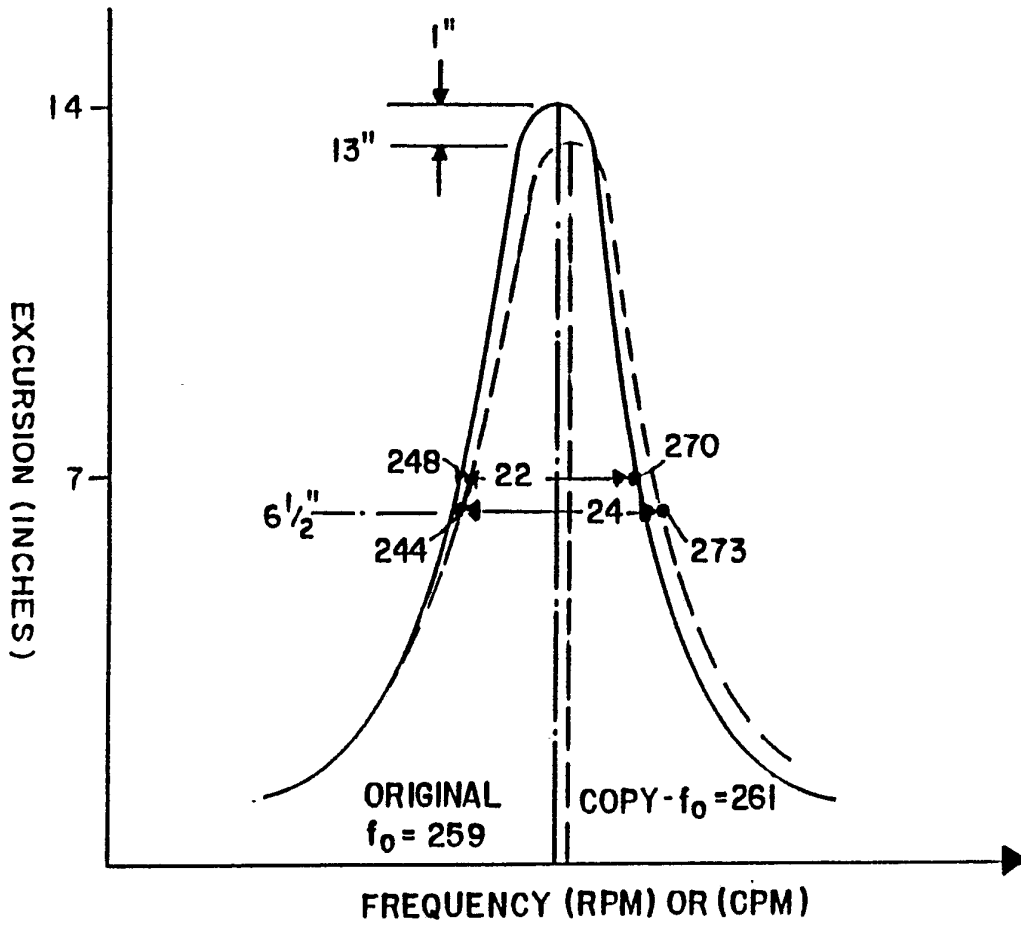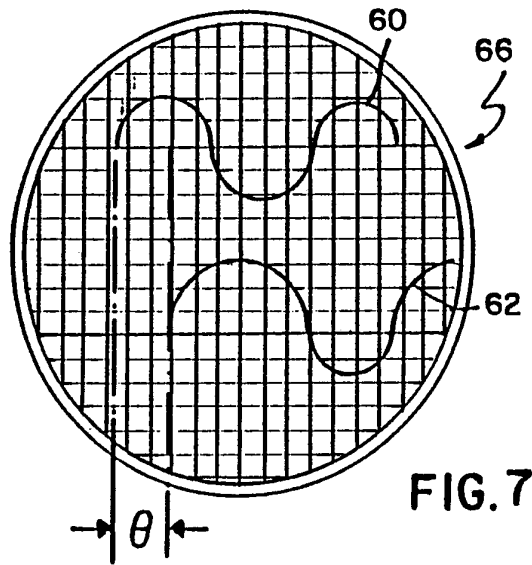
FIG.7

ORIGINAL
$f_0 = 259$

COPY - $f_0 = 261$

EXCURSION (INCHES)

FREQUENCY (RPM) OR (CPM)

FIG.9

I. CLASSIFICATION OF SUBJECT MATTER   (if several classification symbols apply, indicate all)⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

Int.Cl. 5 A63B53/00;   G01H13/00

II. FIELDS SEARCHED

Minimum Documentation Searched⁷

Classification System	Classification Symbols
Int.Cl. 5	A63B ; G01H

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched⁸

III. DOCUMENTS CONSIDERED TO BE RELEVANT⁹

Category°	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No.¹³
Y	EP,A,0 141 976 (W BEER) 22 May 1985 see page 1, line 4-6 see page 3, line 21 - page 5, line 15 see figures ---	1-13
Y	GB,A,2 223 951 (BRUNSWICK CORP.) 25 April 1990 cited in the application see the whole document ---	1-13
A	US,A,4 622 836 (D LONG) 18 November 1986 ---	5
A	US,A,4 200 286 (R BENNETT) 29 April 1980 ---	4

° Special categories of cited documents :¹⁰

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
24 AUGUST 1992	16. 09. 92

International Searching Authority	Signature of Authorized Officer
EUROPEAN PATENT OFFICE	VEREECKE A.

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT
ON INTERNATIONAL PATENT APPLICATION NO.

US 9203562
SA   60258

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 24/08/92

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
EP-A-0141976	22-05-85	CH-A- DE-A- JP-A- US-A-	662886 3469223 60098330 4599898	30-10-87 10-03-88 01-06-85 15-07-86
GB-A-2223951	25-04-90	US-A- JP-A-	5040279 2232075	20-08-91 14-09-90
US-A-4622836	18-11-86	None		
US-A-4200286	29-04-80	None		