Chapter Two

A NEED FOR COMPARABLE SHAFT INFORMATION

Key terms for understanding the information contained in Chapter 2:

Balance Point - The point at which a shaft achieves equilibrium; the point where a shaft has weight evenly distributed on both sides of a given point.

Bend point - The point of maximum bending on a shaft as measured by compressing both ends inward.

Cut Shaft - A shaft that has been trimmed according to manufacturer's directions and is ready for installation into the club.

Deflection - The deviation of the tip from the butt centerline after a known unit of force is applied to the tip to create a curve in the shaft.

Flex- The designation assigned to a shaft based on its stiffness or ability to resist bending - ladies (L), regular (R), stiff (S) and extra stiff (X). Also commonly referred to as shaft type.

Frequency - The number of oscillations of a shaft over a known period of time after the tip is pulled down and released while mounted in a frequency-measuring device. Measured in cycles per minute (cpm).

Kick Point - The point of maximum bending on a shaft as measured by deflecting the tip end of the shaft only.

Pattern - The design of a particular shaft, indicating the distribution of flexibility about the shaft. Pertaining to this shaft testing project, pattern is used to designate a particular model of shaft, e.g. Dynamic, Phoenix, Microtaper, Low Torque, etc., are all different shaft patterns.

Raw Shaft - A shaft in its manufactured form, before trimming and installation into a club.

Torque - The rotational twisting of a shaft during the golf swing. Measured in degrees.

Type - The respective flexes of a given shaft pattern, such as ladies (L), amateur or senior (A), regular (R), stiff (S) and extra staff (X).

Of all the different and varied types of sports equipment, a golf club is perhaps the most simple, yet at the same time, the most complicated. While made up of only a clubhead, a shaft and a grip, the evolution of these three components and the almost infinite variations of their assembly into a finished golf club had mystified golfers for centuries.

Of the three components, to both the users and the makers of golf clubs, there is no doubt the most perplexing is the shaft. The grip is but the handle, the means by which the golfer makes contact with the club. The clubhead, while complex in its own right with countless variations in composition and specifications, has been technically explained; virtually all of the dynamics of its role and performance have been discovered and are essentially accepted by the game's technical community.

But even in the year 2000, in a time of complex scientific advances which we all take for granted, the shaft, this component which connects the grip and the head remains cloaked in mystery. Years of study have not yet cracked the case; we still do not know exactly how this thin, tubular connection between the grip and the clubhead does what it does. We know it plays an important role in the execution of a golf shot, for its different variations do seem to create different shotmaking results when used by the world's golfers. We also know that despite the confusion, golfers do seem to express strong opinions on behalf of certain patterns, types and flexes of shafts.

Yet despite these fundamental realizations, we truly do not know what the real differences are between different shaft designs, nor do we truly know how to accurately predict what different designs will do in the hands of the different types of golfers. We have general ideas, which can help predict some of the expected occurrences, but never have we been as clear in our explanations of why a shaft does or doesn't perform for a particular golfer as we have with the clubhead or the grip. While a case can be made that many golfers select a shaft based either on an emotional or perceptual basis, often prompted by multi-million dollar advertising campaigns. It is a fact that when such types of promotional smokescreens fade away, golfers are left with some undefined, but still performance-driven reasons why they play the shafts they do.

As a leading company in the field of clubmaking, we too at Dynacraft Golf Products have wondered why. Having been engaged in clubmaking and clubfitting for years, despite our experience and our constant study of shafts, too often we have felt we were doing little more than conducting a formalized trial and error session when helping a golfer select a shaft. Throughout our tenure in the golf industry, whenever we have had the opportunity to teach the principles of shaft fitting to clubmakers as well as to fellow employees, it seemed as if we were doing nothing more than passing along the rites of a modern voodoo ritual. In short, like thousands of clubmakers around the world, we were frustrated by the fact that very few hard and fast rules existed for shaft fitting and comparison!

Over the last decade, the principles of so-called traditional shaft fitting that Dynacraft and others before helped to develop, have become accepted and have been put into practice by thousands of clubmakers and golf professionals. In many cases golfers who have been put through the paces of such shaft fitting principles have walked away with a better playing club. However, rare was the time after a shaft fitting session that we felt the advised shaft had been selected with an expectation of success and improvement with which we felt was even close to being considered guaranteed.

Setting the Stage for A Shaft Testing Project

In 1987, a new operations team was selected to manage the Apollo Shaft Corp. in Birmingham, England. Chosen to head up the research and development division for Apollo was an engineer named Graeme Horwood. To best describe his area of expertise, Graeme was a tubing engineer; from his previous stint with Raleigh Bicycles he possessed a strong foundation in technical matters relating to the design and formation of tubing. Graeme wasn't a golf shaft designer, and on top of that, he wasn't a particularly good golfer. But he did bring what could best be called a fresh perspective to his position as Apollo's new head of golf shaft development and production. As an engineer plying his trade in a new application, Graeme first had to learn just what these tubes he was now charged with creating and producing were expected to do, and for whom they were supposed to do it.

Thanks to a good relationship, which had been established between Dynacraft and Apollo, we were afforded several opportunities to discuss shafts with Graeme and his fellow staff members. What we found was that Graeme shared quite a number of our questions and doubts about the golf industry's accepted shaft design and fitting standards. From these beginning conversations, we sensed on behalf of Graeme and his company an open attitude and a willingness to support any effort to develop better ways to match golfers with the proper shaft.

At about the same time, another part of the effort to unravel the knots of shaft fitting was falling into place within the Dynacraft operation in Newark, Ohio. Having learned clubmaking through a succession of promotions from the production line to clubmaking component sales in 1988, Jeff Summitt accepted a position change within Dynacraft to finally put some of his engineering training to work and become a full-time technical adviser in clubmaking. This promotion had the initial effect of putting Jeff in closer contact not only with the clubmaking customers of Dynacraft, but with the shaft manufacturers for whom we handled distribution. Immediately after his promotion, Jeff began to demonstrate an almost inexhaustible desire to learn everything possible about the technical side of golf clubs. In particular, he possessed a keen interest in shafts, an enthusiasm that was fueled daily by the fact that in his position as lead technical adviser, he talked more about shafts and shaft fitting to clubmakers than any other aspect of clubmaking.

During the course of our regular technical staff meetings, Jeff began to constantly question certain aspects of what have been the accepted principles of shaft fitting. Among the technical staff, it was agreed that part of the problem was the golf industry's growing inability to acquire accurate, comparable data on shafts, which would allow for reliable shaft-to-shaft comparison. Another problem was the fact that existing shaft-fitting principles did not take into account the possible relationships of individual shaft design parameters and how they might affect each other in the overall performance of a shaft.

From our technical staff discussions about shafts and shaft fitting, more questions seemed to come up than answers. For example, how much did changes in torque affect the flex of a shaft? Was bend point truly as important as previously thought in the performance of a shaft? Was flex a constant, not just between different shaft patterns possessing the same flex code, but between wood shafts and iron shafts of the same pattern? In short, it was obvious that due to the many different ways that shaft manufacturers recorded the specifications of their designs, shaft-to-shaft comparison, a fundamental background to shaft fitting, had become completely unreliable. This, combined with the fact shaft design and development was moving forward at almost breakneck speed, confirmed our belief that shaft fitting knowledge was just not keeping pace with advances in shaft design technology.

Throughout the last 70 years, shaft-manufacturing companies have been free to develop their own testing standards and procedures for measuring the individual specifications of their designs. While one manufacturer might hang a 7 lb. weight from the shaft to determine deflection (one means of noting flex or relative stiffness between shafts), another might use a 6 lb. weight and a third could use a 4 lb. weight.

Torque, a shaft specification that has recently assumed a more important role in the overall shaft-fitting picture, also has no standardization for its measurement. One manufacturer might record the resistance to torque by applying a 2 ft./lb. force on the shaft tip, while another could choose 1 ft./lb. to obtain a shaft's rotational resistance (torque). Inconsistencies even exist concerning how the shaft is clamped and fixtured during the torque testing.

Bend point, a specification describing the primary location of maximum bending on the shaft, has never had a quantitative description for its measurement. Generic designations of "low," "mid" and "high" are all that clubmakers have had to go on when comparing the bend point of one shaft to another. On top of that, two totally different methods for determining a shaft's maximum position of bending have been used among shaft companies.

As a result, for virtually every shaft design parameter except weight, tip diameter and butt diameter, discrepancies in the description and measurement of shaft specifications exist. Perhaps due in part to the intense competition that exists between the industry's growing number of shaft makers, the fact that there is no standardization in shaft specification testing has made comparing the shafts of one company to that of another all but impossible.

To depart slightly for a moment, this lack of standardization in shaft specification measurement should not be construed as a negative statement about the shaft manufacturing industry or the quality of its designs. Just as clubhead designers are free to create better playing heads by choosing to make changes in specifications, so too are the shaft makers free to express their beliefs in what could make a better playing shaft through the designs they conceive. The difference is while clubhead designers all agree on the ways that ironhead, woodhead and putter head specifications are measured, and the shaft makers do not. As a result, truly accurate shaft fitting has simply not been possible.

A Shaft Testing Project Is Conceived

Motivated by this absence of comparative shaft information standards, in the fall of 1988 Dynacraft contacted Graeme Horwood to inquire if he and Apollo would be willing to participate in a shaft testing and information gathering project. Initially the project was to consist of measuring a number of design specifications for as many shafts as possible, with all of the specifications to be recorded on one common set of test equipment. From such a test, it was hoped that for the first time uniform measurements could be obtained from a single source on such confusing shaft specifications as flex, torque and bend point. With measurements obtained from a common set of test standards, it was our belief that accurate comparisons between shafts could then be made to pave the way to more accurate shaft fitting.

One very fortunate key to the accuracy of our proposed uniform shaft specification testing was the fact that Apollo was in the process of installing all-new, state-of-the-art, shaft-testing equipment. In 1987-88, with the assistance of the mechanical engineering department of Birmingham Polytechnic University in Birmingham, England, Horwood had designed and built a new bank of shaft testing equipment. The primary apparatus within Apollo's testing machinery was designed to record deflection and torque in opposite directions, and to measure kick point, all while the shaft was secured in the single unit. Completely computer driven, with all data retained and assimilated by the computer, Apollo's new test machinery represented the most meaningful equipment that could possibly be used to measure shaft specifications.

In addition to kick point, flex and torque, a number of other shaft test parameters were called for in the test program, which we at Dynacraft took the responsibility to record. The shaft butt and tip diameters, weight, balance point, length and frequency of all the shafts were to be measured by Dynacraft in our own R&D workshop. In addition, assorted other specifications relating to assembly and clubmaking were recorded by Dynacraft for use in other reports not related to shafts. Details of that research will be released at a later date.

Jeff Summitt began the shaft testing project in early 1989 by tackling the job of compiling two each of some 400 different standard weight steel, lightweight steel, specialty metal and graphite (composite) shafts, all in parallel tip form. This proved to be no easy task. To assure consistency in the testing, each sample shaft had to exhibit the exact design specifications of length, weight, and tip diameter and butt diameter as ordained by its manufacturer. Understanding that manufacturing a shaft within its plus/minus tolerances is not the same thing as producing one to its exact design specifications, Jeff had to measure and sort through more than 10,000 shafts to find two of each design which were produced exactly to each manufacturers' intended specifications.

Summitt was able to draw from the tens of thousands of shafts in Dynacraft's operating inventory in the attempt to find the perfectly made, zero tolerance "test subjects". Even despite the size of Dynacraft's in-house stock, in many cases Jeff just was not able to find a zero tolerance shaft for a company's particular pattern and flex. As a result, he often had to call upon the manufacturers to obtain the remaining zero tolerance samples. In all, compiling the initial group of more than 800 acceptable test samples for the 400 or so different shaft patterns required some six weeks of searching and measuring and was, quite literally, somewhat like trying to find more than 800 "needles" within a very large "haystack!"

Since Apollo was to provide a significant portion of the data in this shaft-testing project, for industry credibility, we felt every effort had to be made to keep the project and the test results free of any potential industry "commercial implications". Therefore, all of the sample shafts were sent to Apollo devoid of identification. Every effort was made to render the shafts unrecognizable to Apollo's testing personnel. To keep track of and organize the shafts, after each identification label or name was removed; a numerical code was applied. Apollo agreed to perform their portion of the tests "blind" and further agreed to not accept a key list of the codes until its work was completed. While our trust of the Apollo personnel was implicit, we felt this type of confidential approach was necessary to eliminate any chance of accusations by members of the golf industry that the test results were polarized or skewed for the sake of commercial gain.

The Parameters of the Shaft Testing Project

The initial 800+ shafts comprising more than 400 different shaft patterns and flexes were first separated into two groups. One shaft of each pattern and flex was set aside to be tested for each of the different selected parameters in its raw, uncut, unassembled form. The other identical shaft of each pattern/flex was trimmed as per the manufacturer's intended installation instructions for a metal wood Driver and #5-iron, thus creating the opportunity to test each shaft in its cut, assembled form. In addition, the cut shafts underwent a number of additional tests after being assembled with a clubhead and a grip.

While test were conducted on both the raw and cut versions of each shaft, we felt the measurements obtained from the cut shafts would prove to be more important for use in making actual fitting comparisons. After all, this is the form all shafts assume when they are assembled in a finished golf club. There was also another very important reason for setting up the shaft-testing project in this raw vs. cut manner. From pre-test research, it was completely unclear whether the shaft manufacturers' published specifications were taken from the shafts in their raw or cut form. Because trimming and installation can drastically change a raw shaft's specifications, to use the data for making fitting comparisons, it was vital to know the shafts' specifications in the cut form. Additionally, having the raw shaft test data would make it possible to compare this information against each manufacturer's raw shaft measurements to see if and where discrepancies exist in the industry's published shaft information.

The raw and cut shafts were tested for the following design specifications:

1. Deflection
2. Frequency
3. Torque
4. Kick Point
5. Balance Point
6. Weight
7. Tip Diameter
8. Butt Diameter
9. Length

In addition, the shafts were subjected to a number of other tests while installed into finished golf clubs. A specially prepared metal wood Driver head and #5-iron head were made to attach to the cut shafts. Each clubhead was fit with a hosel-mounted set screw for temporarily, but tightly, securing the shaft to the head. A series of identical weight-sorted, slip-on rubber grips were prepared for temporary installation to complete the simulated assembly of the golf clubs. Grips were selected with core sizes to match the butt diameter of each shaft. A single layer of grip tape was attached to the outside of each grip to simulate the true grip weight as closely as possible.

Each of the grips was slit lengthwise to allow for quick installation and removal from the shafts. The clubs built with the A, R, S and X-flex shafts were assembled to the men's standard playing length of a 43" Driver and 37.5" #5-iron. All of the men's specification Drivers and #5-irons were set to a swingweight of D-1, achieved through the addition of lead tape applied to the clubhead.

The clubs bearing all of the L-flex shafts were set up to conform to the ladies standard playing length of a 42" Driver and 36.5" #5-iron. In turn, each of the ladies specification Drivers and #5-irons were built to a C-6 swingweight, with any necessary weight addition again achieved through the addition of lead tape applied to the clubhead.

The tests on the assembled Drivers and #5-irons were as follows:

- Assembled Club Balance Point
- Assembled Club Total Weight
- Grip Weight
- Headweight Required To Achieve D1 or C6 Swingweight (at the standard lengths)
- Shaft Frequency

The most important reason for assembling the cut shafts into Drivers and #5-irons was to obtain the vibrational frequency for each shaft. However, since Dynacraft as a company is interested in all aspects of clubmaking, the need for the shaft frequency measurements afforded the opportunity to conduct the other clubmaking information tests which could be used later in other non-shaft related reports. Very little will be said in this publication about these other non-shaft-related tests. However, the information obtained (assembled club balance point, assembled club total weight, headweight required to achieve D1 or C6 swingweight and grip weight) is included in the raw data measurement charts found in the shaft fitting addendum.

THE METHODS AND CONDITIONS OF THE TESTING

Weight, Length, Tip Diameter and Butt Diameter

For consistency and the ability to obtain measurements from each shaft which would be representative of the manufacturers' intended design, all of the samples selected had to conform within +/-0.02 oz. of the manufacturers' designed weight, and +/- 0.001" of the manufacturers' designed tip and butt diameter specifications for each shaft. As a guide in the selection of the test samples, the intended dimensional and weight specifications for each shaft were obtained from its respective manufacturer. Measurement of the weight was recorded to 0.01 oz. on a scale, which had an accuracy tolerance of +/-0.005 oz. Again, for accuracy the scale was zeroed out and recalibrated after every 100 shaft weight measurements. Weight measurements were recorded on the raw shafts as a part of their initial selection. Weight for the cut shafts was recorded after each shaft was trimmed for installation into the Driver and #5-iron heads, respectively.

Each shaft was tested for straightness by rolling it across a level surface, after which the length was measured with a 48" aluminum ruler, noted along a line representing the center axis of the shaft from tip to butt. Each raw shaft selected was allowed a length tolerance of ±1/16", a tolerance that is tighter than the average shaft industry production tolerance of ±1/8". The shafts, which were cut for installation into the Driver and #5-iron heads, were trimmed as per each manufacturer's published instructions. An additional 1/8" trimmed from the butt to allow for the thickness of the grip cap and thus make the clubs conform to the ordained standard playing lengths.

Balance Points

During the shaft-testing project, three different balance points were recorded. Balance Point #1 was the measurement of the center of gravity of the raw shafts. Balance Point #2 noted the center of gravity of the cut shafts and the Balance Point #3 was the point of equal weight distribution for the assembled Drivers and #5-irons.

Balance Points #1 and #2 were first measured at Dynacraft by balancing each shaft horizontally on a 1/16" wide steel strip, which was positioned on a level bench top. Each shaft was shifted back and forth until it settled in a straight horizontal position. The point of balance was marked with a felt tip marker and measured in inches from the butt of the shaft.

Balance Point #3 was measured at Dynacraft by balancing each assembled Driver and #5-iron horizontally on the same 1/16" wide steel strip. Each assembled golf club was shifted back and forth until it settled in a straight horizontal position on top of the indicator. The point of balance was measured in inches up from the tip of the shaft and marked with a felt tip marker. Later, BP3 was checked and verified by mathematical calculations.

In all cases of measuring balance point, as much care as possible was taken in both balancing the shafts and assembled clubs and in applying the mark on the shaft. While there could be a slight chance for error in our somewhat crude method of measurement, it was estimated that the care taken in balancing and marking kept the tolerance for error within ±1/16".

Torque, Deflection and Kick Point

Apollo personnel, using the company's computer-driven testing machine, performed the measurements for torque, deflection and kick point. For all tests, 2" of the butt and 1" of the tip of each shaft were clamped into the holding fixtures of the machine. Uniform clamping pressure was achieved by tightening the butt and tip with a specially designed torque wrench. After each shaft was clamped, the computer was used to zero out and calibrate the unit to ensure as much accuracy as possible.

The Apollo testing machine was designed to record torque, deflection and kick point consecutively without removing or repositioning the shaft. Torque was the first measurement recorded because the shaft was required to be held straight in the machine during the application of the twisting force. After calibration, the computer generated an electronic command, which activated a small motor attached to the clamp on the tip of the shaft. First in one direction, then in the opposite, the motor rotated the tip until a load cell attached to the unit recorded 1 ft./lb. of force. As the force increased on its way to the desired level, the computer constantly outputted the degrees of tip rotation on the CRT screen. When the 1 ft./lb. force was achieved, the computer automatically locked on to the torque reading and stored it in its memory. After recording the torque in one direction, the computer drove the shaft back to a zero position and proceeded to measure torque in the opposite direction. The final torque value for each shaft was calculated as an average of the two oppositely rotated readings. Apollo's R&D personnel confirmed that the mechanical engineering department of Birmingham Polytechnic University had assured the torque testing apparatus to accuracy within ±-0.05º.

After the torque test was completed, the shaft was driven back to a zero torque, straight position in the machine. Next the computer began to apply force to bend the shaft in its test for deflection. A separate motor on the unit activated a drive screw, which pushed the entire tip clamp unit along a track. The tip clamp unit was engineered to rotate freely during the deflection test to allow the shaft to be bent without applying rotational strain to the tip. Again, a load cell hooked directly to the computer monitored the amount of force as the shaft was pushed into a curve. Displaying data throughout the time the bending force was increased, again the computer locked on to the tip deflection measurement when the designed test load of 6 lbs. of force was achieved. At this point the computer measured the deflection as the distance between the center of the shaft tip and the straight axis line of the shaft, to 0.01”. Just like the torque test, the deflection test was conducted by averaging the readings taken from bending the shaft in two opposite directions under the force of 6 lbs.

The final Apollo test, the determination of kick point, was recorded at the same moment the shaft was bent into a curve under the 6 lbs. of deflection bending force. When 6 lbs. of deflection bending force was achieved, immediately after recording the deflection the computer “drew a straight line” from the center of the tip to the center of the butt. The point of greatest deviation on the bend of the shaft as compared to the straight line drawn from tip to butt was defined as the kick point. The computer measured kick point to 0.01” up from the tip end of the shaft. Kick point was plotted from both of the deflection positions, with the final measurement taken from an average of the two readings.

Within the shaft industry, bend point and kick point, are two shaft specification terms that are mistakenly thought of as being interchangeable. While assumed to be very similar, kick point is a measurement of the position of the shaft’s greatest point of bending deviation when the shaft is deflected, while bend point is an expression of the shaft’s greatest point of bending when one end of the shaft is compressed toward the other.

While the pure bend point compression test is used by a majority of shaft manufacturers, after discussions among the technical staff at Dynacraft and with Horwood at Apollo, it was felt if a static measurement had to be used to express the shafts’ greatest point of bending, kick point would be preferable. This decision was made because of the two static tests; the kick point measuring procedure most closely simulates the forces placed upon the shaft when in use.

Frequency

Vibrational frequency was the most important test performed on the cut shafts as they were installed into assembled Driver and #5-iron form. While the majority of all the industry’s shaft tests are static in nature, it was felt that frequency had to be included as an indicator of flex because it takes headweight and shaft length into account in an effort to offer a better expression of flex. While deflection tests are used by all shaft manufacturers as an indication of relative stiffness, obtaining accurate flex data for use in fitting was viewed as being extremely important. Since golfers play with finished golf clubs and not the raw or cut shafts only, to a certain extent, frequency can become a viable means of relating the relative stiffness of one shaft to another. Therefore, from a fitting standpoint, the decision was made to use the frequency measurements of the assembled Drivers and #5-irons as a primary description of shaft flex.

To test for vibrational frequency, each shaft was trimmed as per the manufacturer’s guidelines and assembled into the Driver and #5-iron heads. The clubs were secured in a frequency-measuring machine, which was designed to clamp 5 1/4” down from the end of the grip. The club was steadied and the frequency machine was zeroed out before each trial.

Each club was vibrated three separate times and the average of the three trials was recorded as the frequency measurement, expressed in cycles per minute (cpm). The frequency machine used in the testing was similar to the machine invented by the Brunswick Shaft Corp. (now Royal Precision). The reason this machine was chosen for the test is because more units of this type are in existence and used for fitting within the clubmaking industry. Therefore, the data we obtained could be better correlated with individual clubmakers’ independent testing. In addition, using this type of frequency testing machine afforded us the opportunity to compare the frequencies of other manufacturers’ shafts with known frequencies that had been published by Brunswick on behalf of certain patterns of their manufacture. In addition, by comparing our own measurements of zero tolerance selected Brunswick Precision FM shafts with the frequencies obtained by Brunswick for the same shafts, there was not only a form of check and control, but comparable data that was obtained from one accepted industry norm.

Headweight, Grip Weight, Finished Club Total Weight, Finished Club Balance Point

The rest of the tests that were performed on the Drivers and #5-irons were compiled simply because of the opportunity presented through this shaft testing project. While these tests have little bearing on the shaft project conclusions, they will be helpful to clubmakers who are interested in the answers to such questions as “How much headweight is required with (a specific shaft) to achieve a D1 swingweight?" or "How much lighter is the total weight of a finished club if (a specific shaft) is used?" As an offering of "extra data" clubmakers are invited to scan the data tables included in the companion publication to this book and use this information as they see fit.

The test for finished club Balance Point (Balance Point #3) was described in the overall information provided previously about balance point testing. Again, this information may be interesting to clubmakers who are curious about the relative differences in finished golf club weight distribution.

Accumulating the Shaft Information

As previously noted, the first step in the Dynacraft/Apollo shaft testing project was to select two zero tolerance samples of all the shafts. During the selection of the shafts, the weight, tip diameter and butt diameter of each shaft was recorded. Since all of the shafts were selected in raw form, the most accurate shaft of each design was set aside to be used for the cut shaft testing. As mentioned before, golfers do not use shafts in their raw uncut form. When a club is assembled and played, the shaft in the club is in what is called its cut form. Hence, for the testing of the cut shafts, we chose the most accurate of the two shaft samples that could be obtained for each design.

Those shafts that were to be left and tested in their raw, uncut form were code labeled and set aside for shipment to Apollo's testing center. The shafts that were to be cut and assembled into finished Drivers and #5-irons then became the focus of the initial testing at Dynacraft's facility. As mentioned before, a metal wood Driver head and an investment cast #5-iron head had been specially prepared to allow each shaft to be tested in finished club form. Because a permanent epoxying of the shaft to the head was not time efficient, the heads were secured to the shafts through the use of a set screw that was installed through the hosel of the clubhead.

A series of slip-on grips were prepared for use to complete the temporary assembly of the clubs. Because the shafts being tested were manufactured to a variety of different butt diameters, grips of each of the core sizes from .560" to .620" were selected to be appropriately matched the butt diameters of the shafts. To allow for the quick installation and removal of the grip from each shaft, the grips were slit lengthwise.

Following the manufacturers' recommended trimming instructions for the respective shafts, while adjusting for the bottom of bore to groundline measurement distance of each club, each club was tip and butt trimmed for the Driver and #5-iron heads. The tip end of each shaft was abraded in the same manner as would be done in a routine golf club assembly and inserted to the bottom of the hosel bore. The hosel set screw was tightened so that no vibration could occur during testing.

A grip of a core size as close as possible to the butt diameter of the shaft was installed so that the butt end of the shaft was snug against the inside of the grip cap. In all cases, ladies grips were selected for ladies shafts, and men's grips were chosen for all men's flex shafts. For example, if a ladies flex shaft was designed with a .560" butt diameter, a .560" core size ladies grip was used in the testing. For consistency, the grip was rotated on the shaft so the clamp of the frequency analyzer would not press down on the slit in the grip. Failure to observe and react to the position of the grip on the butt end of the club could result in varying clamping pressure, which would yield inconsistent frequency readings.

As a final step in the temporary club assembly, a swingweight of D1 was established for each men's flex (A, R, S and X) shafted club, while a swingweight of C6 was prescribed for the ladies length and flex clubs. Lead tape was applied on the sole of the Driver and the back of the iron head until the desired swingweight was achieved. One at a time, one shaft of each pattern and flex was properly trimmed assembled with the Driver and #5-iron head to be tested for complete club balance point, total weight and cut shaft frequency. After frequency analysis, the clubs were carefully disassemble, the head and grip weights were noted.

Once all the tests were performed on each of the cut shafts, all of the shafts were shipped to Apollo's testing center in Birmingham, England. Upon arrival in England, Apollo's personnel cataloged each shaft by its code number and proceeded to measure each shaft for torque, kick point and deflection. Individually calibrating the equipment and performing the tests for these three specifications required a total of some 30 - 40 minutes for each shaft. Therefore, because of the number of shafts included in the test project, an incredible amount of time was required to complete the testing. The entire complement of shafts in the project was tested in three batches over the course of the year, from August 1989 through August 1990. Once the data on torque, kick point and deflection was tested, the information was entered on a master document at Dynacraft's facility for evaluation.

Editor's Note: After 1992, all shafts were tested solely at Dynacraft's testing facility in Newark, Ohio.