Frontispiece: Sketch of a Turkish archer at full draw, ready to loose a flight arrow. [Based on a photograph by Dr. Stocklein published in Halil Ethem "Le Palais De Topkapou (Vieux Serail)", Editions de la Librarie Kanaat 1931 page 17. Information supplied by Society of Archer-Antiquaries member James R. Wiggins.]

TURKISH ARCHERY
AND THE COMPOSITE BOW

by

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NORTHWESTERN TECHNOLOGICAL INSTITUTE

A Review of an old Chapter in the Chronicles of Archery and a Modern Interpretation

Enlarged Third Edition

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TABLE OF CONTENTS

ILLUSTRATIONS

Within the text

INTRODUCTION

The Simon Archery Foundation was particularly pleased to receive Dr. Paul Klopsteg's kind permission to reprint Turkish Archery because not only does it add to the knowledge of the Turkish bows and arrows in the Simon Archery Collection but Ingo Simon, whose Archery Collection formed the nucleus of the present Simon Archery Collection, was particularly interested in flight shooting. Flight shooting is shooting to obtain the longest distance possible by taking the bow and its string to breaking point and this form of shooting was one of the disciplines of the Turkish archer. Ingo shot a distance of 462 yards in 1914 and this remained a world record until 1933.

I also as Hon. Keeper of the Collection, was specially interested in this reprint because I was the British National Ladies Flight Champion in 1961, 1962, 1964, 1967 and 1971. From the late 1960s my bows were between 38″ (96.5 cm) in length, and were centre shot (see also page 67) with a space (keyhole) in the centre for the arrow-rest and the bows each had a forward handle which was a $\frac{3}{4}$″ (2 cm) wide strip of mild-steel metal shaped into a 5″ (12.5 cm) long square bracket with a wooden handle piece attached parallel to the bow. This enabled a short arrow (mine with small plastic fletchings, were between 16″ (41.5 cm) and 17″ (43 cm) long and weighed 80–105 grains), to be shot with the drawn arrow resting in the centre of the bow when the archer was at full-draw instead of drawing the arrow inside the bow. The bows I used, were made of fibreglass and wood laminates, and I shot over 400 yards. My release was with a "flooker". This was a double "flipper"—see fig. 45 between pages 168 and 169 attached to a block (without the hook)—see fig. 50 between pages 168 and 169.

Dr. Paul Klopsteg's training as a physicist and a research engineer helped him to experiment and design the recurve composite bow. These studies continued from 1931 and extended over a period of more than 20 years. In 1976 he was inducted into the Archery Hall of Fame which was formed in the USA to honour Americans in all phases of archery, who had given outstanding services to the sport, or had excelled in the sport for a long time, or who had been responsible for advancing the quality of archery equipment. Archers of today should thank him for his contribution towards their high scores.

The book originally printed in May 1934, and revised in 1947 describes and illustrates the construction of the horn, wood, sinew and glue Turkish composite bow, the design of the Turkish arrows, the accoutrements of the Turkish archer, methods of practice and of shooting, and gives distance records. To this, Dr. Klopsteg adds interesting historical background information including writing about the Guilds.

The Simon Archery Library which has a comprehensive collection of books and periodicals dating from 1792 to the present date, is most fortunate in having the 1934 first edition of the book. This bears the handwritten inscription:

"To Ingo Simon
with the highest regard
for his contribution to the
knowledge of that wonderful
weapon, the Turkish composite
bow.

Paul E. Klopsteg"

Mrs. Ruth Klopsteg Reed states that she can well remember her father devoting many hours in pursuit of a better understanding of the composite bow and its contribution to increased distance in flight shooting. At the age of 97, she says he now must confine his interest in archery to gratification for efforts such as the reprint of his book *Turkish Archery*.

But this reprint with further additional material, is a tribute to the time, energy and patience Dr. Klopsteg spent for the benefit of modern archery.

A. Wendy Hodkinson
Hon. Keeper,
Simon Archery Collection

DR. PAUL E. KLOPSTEG
Excerpts about him from articles written by him

From "Roving reminiscences and random recollections" Archery, 26, Feb. 1954

"I have lived archery, I believe, more interestingly than most—if that is possible. My activities have not been confined to the usual target shooting: this is pleasant, to be sure, but archery offers much more. I have done bow-and-arrow hunting. If the war hadn't come when it did, putting an end to serious shooting, I should have gone in for field archery."

"Although the war took me out of competitive shooting, my interest in all aspects of the sport continued. It has been of the armchair and desk variety since, except on those rare occasions when I can get home for a few days and set up my target. In my yard I have room for an American easily, and a York if necessary."

"Of great interest to me from the beginning was the challenge to scientific studies and development (I don't use the word "research", for it is overworked by the hucksters) which bows and arrows elicit from one who is thus inclined. I have had many hours of diversion in the design and construction of experimental models for the studies, and in making equipment for regular use.

There is also the fascination of collecting archery implements out of the past and near-present, and of searching for old books and putting together a comprehensive library, and finding an occasional fine old print."

"Many times the question has been put to me, 'How did you ever get started in archery?' My interest started with an archery set bought from The Archers Company in Pinehurst, in 1929, for our eldest daughter who had just completed grade school. During the summer we used it for pastime at a summer home in southern Wisconsin. My interest was aroused through the problems in physics that are presented by the action of the bow and the flight of the arrow. Possibly my interest in projectiles came from my experience in ordnance work at Aberdeen Proving Ground during World War 1.

The dormant interest sprouted and grew quickly, and flourished in the numerous directions that have been mentioned; and it had remained sturdy throughout the quarter-century.

In late '29 or early '30 Phil Rounsevelle and Harold Rohm arrived from Pinehurst to start an archery business in Hazel Crest, Illinois, a few miles from where we lived. We had many visits back and forth, and much knowledge about the background of archery was acquired by the novice from the fellows with experience, experience both in tackle-making and in their many contacts with other archers."

From "Bows and arrows—A chapter in the evolution of archery in America" Smithsonian Institution Publication, Washington 1963

"For a person of my interests, the most interesting diversion, which attracted others of like tastes, is the research and development aimed at understanding the mechanics of propulsion of the arrow and of its flight characteristics."

"The appearance of some of Hickman's articles in this ('*Ye Sylvan Archer*') magazine led to a renewal of our acquaintance. A lively correspondence about the physics and engineering aspects of archery developed. My Aberdeen Chronograph and shop equipment became the nucleus of an attic laboratory for which I built a shooting machine and other specialized apparatus. The latter included high-speed flash equipment for obtaining instantaneous photographs of an arrow being accelerated by the bow, and measurement of force-draw characteristics of a bow by photography. I was thus launched, not to say propelled, into experimental studies which were all the more welcome for the diversion they afforded from the serious economic problems following the great depression of 1929. In many respects, my equipment was similar to Hickman's, so that we could easily compare and check measurements and keep our efforts cooperative and complementary."

"In the early 1930's I had begun to make a collection of books on archery, most of which are of English origin, published from the 15th century onward. Among the items in the collection is a complete run of an annual review volume called 'The Archer's Register', beginning in 1864 and continuing through 1915. Some of these contained seemingly authentic information as well as some conjecture about the practice of archery in Turkey in the 15th and later centuries. One assertion was the almost incredible one that the Turks had shot arrows a distance of a half mile—incredible, certainly, to those who knew the limited range of the longbow. My technical interest stirred me to discover whether this might be true, and if so, how it had been accomplished."

From "Archery reflections and observations" Archery, 40, May 1968

"When I became actively interested in archery in 1928, Hickman had already done some work on bow design, and had experimented with bows to determine the effect of 'backing' on arrow velocity. This was the subject of his first report, published in the 'Journal of the Franklin Institute' in 1929. This was followed by a series of articles in 'Ye Sylvan Archer', dealing with the geometry and the possibility of improving cast by adopting a limb of constant thickness, rectangular in cross section, having uniform taper in width to zero at the point of attachment of the string. This was an important concept to be studied, worked into practicable designs and tested. Hickman and I worked in close collaboration."

"If you experience great pleasure in using the bow just for the sake of using it, without striving for superscores, perhaps from seeing, as Maurice Thompson put it, 'a bent, beautiful bow,' and the graceful arched flight of the arrow, then you can still savor the delights of archery as a superb, social activity. In the past this was one of the fascinating aspects. Then you can fully appreciate how pleasant it is, with good companions, to obtain your recreation with a bow lovingly crafted by such a superb bowyer as Cassius Styles, or with one which you yourself made of a select stave of Ullrich yew, cut in winter in the high Cascades and seasoned for years. It was a bow light in the hand, unencumbered with disfiguring attachments, and simple of line. The high scores possible with the modern bow are paid for by the sacrifice of some of the charming aspects of recreationed archery with its social amenities. But, in saying this, I am aware of and approve the old French proverb: '*chacun à son gôut*'—each according to his own taste."

PREFACE TO THE SECOND EDITION

The first edition of this book has been out of print since May 1934, the date of its publication. The limited edition had been oversubscribed prior to publication. The number to be published had been decided upon after the best appraisal that could be made of the probable interest in the composite bow. That the estimate was low and the number inadequate to supply all who were interested became apparent too late to increase the size of the edition.

During all this time, and particularly during the past few years, inquiries have become insistent. A reprint was suggested, but reprinting without revision would have fallen short of supplying the informtaion now available, which has been collected from many sources, for the most part during the pre-war period. A revision was begun in 1939, but the work had to be abandoned because of the demands of government service during the war years. It now appears that this edition may see publication in 1947—exactly a century since the publication of the Turkish book on which this one is so largely based.

There is ground for belief that the first edition was in part responsible for the marked growth of interest in flight shooting in this country, through the information it gave about distance shooting by Turkish archers, the construction of Turkish bows, the processing and gluing of horn, and particularly about the manner of producing sinew fibers from tendon and applying them as bow backing. In distance shooting we have only begun to approach the Turkish records. In both design and construction of bows and arrows and in shooting techniques there is still opportunity for progress. I hope that the greater scope and availability of this edition may contribute to the gains still to be made.

Grateful acknowledgment is made to many friends and acquaintances who have contributed and assisted in the gathering of information that has clarified things

obscure or uncertain when the first edition was written. Among them are Ingo Simon, whose long practical experience with composite bows and whose fine collection, including many of the bows from the Payne-Gallwey collection, were the basis for authoritative comments and suggestions; Marion Eppley, who probably has the finest collection of composite bows in this country, and who made available a report of his personal observations in Constantinople and of the handiwork of Chinese and Korean bowyers whose work he witnessed and with whom he conversed; the late George Cameron Stone; Stephen V. Grancsay, Curator of Arms and Armor, and the Metropolitan Museum of Art, for photographs of items in the Stone collection, and data concerning them; Joachim Hein, author of the exhaustive study titled "Bowyery and the Sport of Archery among the Osmanli", forming the basis for much of the material in this book; and the late Sir Henry Balfour, Curator of the Pitt-Rivers Museum at Oxford, who kindly supplied informative reprints and comments by letter. Particular appreciation is expressed to my long-time friend Carey Orr for providing several sketches for illustrations, including the authentic depiction of a Turkish archer at full draw, reproduced as the frontispiece.

The last chapter of the first edition has been replaced by several new ones dealing with technical matters that have come out of some fifteen years of experiments, and even longer practical experience in archery. In these chapters an effort has been made to provide such basic material as may give substantial assistance in the further development of flight shooting equipment.

Flight shooting is a mature, interest-arousing sport. In publishing this revised edition, it is my hope that archers generally will find it interesting and that those who are particularly devoted to shooting for distance may find it helpful.

Evanston, Illinois,
August 1947. PAUL E. KLOPSTEG.

PREFACE TO THE FIRST EDITION

There is a high degree of probability, amounting almost to certainty, that Turkish archers of the fifteenth to early nineteenth centuries established records for distance shooting with bow and arrow which, in more recent times, have remained unbroken by humiliating margins. Modern archers have been disposed to dismiss those records as fantastic; but as our knowledge about Turkish shooting equipment and methods increases, they become more and more credible. There now remains little doubt that they are genuine.

Our wood bows are long because of the mechanical limitations of wood. With decreasing length of limb the speed of an arrow increases. Scientific analysis and experiments have shown how to design bows with the shortest straight limbs possible, but even with the best of bow wood, they are still long compared with the limbs of composite bows. We cannot hope for much improvement in cast of the wood bow beyond that achieved in the past few years through scientific analysis and mechanically correct design.

The most promising opportunity for the development of greater interest in archery appears to be in the doing of such things as will captivate popular fancy because they are spectacular. Could anything qualify better than to shoot a shaft a half mile, or to drive it through several inches of wood? These are not impossible accomplishments, and they can be achieved by the exploration and exploitation of the territory beyond the wood bow. Fortunately it is not necessary for us to proceed blindly, for we have available maps and charts in the form of Turkish, German and English treatises and articles that show us the best routes to travel. Our task is immensely simplified by the records that have come down to us through the centuries.

The Turkish composite bow of horn, wood, sinew and glue shows what is possible of accomplishment. Is it the final development? We cannot tell. The archer of today has the opportunity of discovering the answer to that question. I believe that improvement in the composite bow is possible, and hope that many archer-craftsmen will find fascinating pastime in helping to develop the ultimate bow—the bow that will represent the highest possible performance as an instrument for transforming the energy of human muscle into the energy of a flying arrow.

In this brief treatise it is intended to convey in simple language the results of a study of numerous sources. I have endeavored to abstract from them those things which are sure to interest every archer, and which will give him a substantial background of facts for the development which I hope he will undertake. The last chapter is written in the light of experiments which have recently been carried on in the design and construction of composite bows, with the Turkish pattern as a point of departure, and comments are made on the results.

Evanston, Illinois
February, 1934 PAUL E. KLOPSTEG

CHAPTER I

THE BACKGROUND OF TURKISH ARCHERY

The serious student of archery cannot but wonder whether the Turcophobia among the English of Elizabethan time, as expressed in Ascham's "Toxophilus", did not close the English mind against anything and everything Turkish, no matter what its merit. Only in that way can one find a satisfactory explanation for the fact that so little attention is given the Turkish composite bow in the literature of archery published in England before the nineteenth century.

Facts about the extraordinary flight distances of Turkish archers seem never to have become widely known among English-speaking peoples. The apparent neglect if not suppression of this information is all the more singular because Turkish archery flourished contemporaneously with the English long bow, and there must have been some commercial or political intercourse between the two countries by which authoritative information about the composite bow might be expected to have found its way to England. Only the most sketchy references appear in Moseley's "Essay on Archery" (1792). Hansard's "Book of Archery" (1840) makes brief mention of the Persian composite bow, but has nothing to say about the use, in its construction, of sinew. He mentions the long shots by Mahmud Efendi in London in 1794, but erroneously gives the date as 1792. Hansard may have known more about oriental bows than he was disposed to tell. The references in Longman and Walrond's "Archery" (The Badminton Library, 1894) are equally unsatisfactory. Among the significant passages in the older books is the following quotation from the footnote on pages 99, 100 and 101 in Roberts' "English Bowman" (1801):

"Of all the bows that have been invented, and with which we are now acquainted, no one (in point of force, certainty and effect) has come so near the English long-bow, as the Turkish bow. Although Knowles (in his

History of the Turks, p. 517) tells us 'that the *Persians* used both *greater* and *stronger* bows, and shot more deadly arrows than the Turks.' The very great elasticity of the *horn* bow gives it greatly the advantage of the wooden bow, in the *distance of its cast*: and had not Ascham, Sir John Smith and other writers, confidently and upon known experience, affirmed the superiority of the English bow in war; we might be inclined to esteem the Turkish bow as the *rival* of the English long-bow. However, in judging the *effect* of weapons when used in war, we must not forget the distinguishing *characters* of those who make use of them. For doubtless, with the same weapon, the coolness, courage, and discipline of the English, must have given them great advantage; opposed to the intemperate, and disorderly mode of warfare usually remarked among the Turks. The elasticity of the horn-bow is capable of communicating a surprising velocity to the arrow discharged from it; but, probably, it is not calculated to cast so *heavy* an arrow as the bow of wood; and its velocity diminishes its *certainty* of cast. Many very surprising long shots are attested to have been made, with the Turkish bow. Stuart (in his *Antiquities of Athens*, vol. i. p. 10) mentions a random shot made, in the year 1753, by Hassan Aga, the *waiwoode of Athens*, who delighted in archery, to have been *five hundred and eighty four yards and one foot* (English measure). Cantimir (in his *History of the Otman Empire*) speaking of the Emperor Murad IV, says, 'in the art of shooting with the bow, he had not his equal in the whole Turkish nation, except the famous champion Tozcoparan. There are now two marble pillars standing *fifteen hundred cubits* asunder, over which he is said to shoot an arrow.' Tozcoparan is said to have shot *seventeen hundred cubits*. In the year 1795, Mamhood Effendij, secretary to the Turkish ambassador, a man possessing great muscular power, shot an arrow with a Turkish bow *four hundred eighty two* *yards* in the presence of three gentlemen, members of the Toxophilite society, now living; who measured the distance, and to whom he observed, that the present emperor (Sultan Selim) could shoot further than any one of his subjects. In the year 1798, the sultan himself exhibited a proof of his great strength and skill in archery; by shooting (in the presence of Sir Robert Ainslie, late ambassador to the Ottoman Port) an arrow, which drove in the ground at the distance of fourteen hundred pikes (Turkish measure), or, *nine hundred and seventy two yards two inches and three quarters* (English measure): and which distance was measured in the presence of Sir Robert Ainslie. The arrows used by the Turks, for very long shots, do not exceed the length of twenty six inches, but they are drawn several inches within the bow, in a grooved horn used for the occasion: they are tapered from the nock to the pile, which is exceedingly small, and weight about three shillings and two-pence English arrow weight. It must occur to every one, that a bow, capable of carrying even a light arrow so great a distance, must be capable of casting an heavy one a less distance with a very great force. Accordingly, we read of arrows cast from Turkish bows, which penetrated the *best made armour*. Lord Bacon, indeed, goes so far as to say, that a Turkish arrow hath been known to pierce a *steel* target or a piece of *brass two inches thick*. (Nat. Hist. Expt. 704, vol. iii.) But this feat Mr. Moseley justly stiles *marvellous;* and observes, 'that to contradict such high authority might, perhaps, do greater violence to good manners, than truth'."

Roberts' quotation of Moseley is slightly inaccurate; Mosely is sufficiently penetrating and amusing to be quoted accurately: (p. 71)

"Lord Bacon says, 'The Turkish Bow giveth a very forcible shoot; insomuch as it hath been known, that the Arrow hath pierced a steel target, or a piece of brass of *two inches* thick!!!' These seem marvelous facts; but should one dare to contradict such high authorities, it might do greater violence, perhaps, to good manners, than truth."

It appears that Roberts spared no pains in seeking factual material, and in this respect he differed from his predecessors. He must have had some conviction about the authenticity of the records he cites, yet these achievements apparently aroused no further curiosity or interest as to the manner in which such extraordinary shots were made. The material quoted, inadequate though it is, lends strong support to the records obtained directly from Turkish sources, and provides a conversion factor between the Turkish pike and the yard, which has some importance in our later considerations.

Whatever the traditions in American archery, they have their roots in England; hence our knowledge of the composite bow, to the extent that it has come from England, is circumscribed indeed as compared with information about the long bow. This lack is deplorable, in view of the treasure of tradition and fact pertaining to one important branch of archery that could have been secured with relative ease had someone been sufficiently interested to do so. Had we been fortunate enough to get reliable information by way of an English observer, much might have been handed down to us about the science and craft and practice of Turkish archery that has been difficult to recapture from the Turkish sources.

One of the most important of these is a book published in Constantinople in November 1847. A copy of the book came in my possession through Dr. Paul Monroe, former president of Robert College, Istanbul, who kindly brought the book with him when he returned to this country. Through him I was also able to obtain a number of items of Turkish archery equipment, including a bow, a number of arrows, a quiver, an archer's belt, a shooting ring or thumb ring, a *siper* and a *mushamma,* all of which greatly assisted in an understanding of the descriptions in the Turkish book.

Needless to say, I am unable to read the book in the original. An attempt to learn the language, with the aid of grammars, dictionaries and guides to conversation soon convinced me that I had neither the time nor the patience to do more than learn the characters, which are for the most part Arabic. Fortunately it became unnecessary either to translate the book or have it translated, because there was at hand a scholarly work in German, published in 1925 by Joachim Hein, evidently a doctor's dissertation based principally on the Turkish book to which reference has been made. Hein's work, "Bowyery and the Sport of Archery among the Osmanli", appeared in three installments in the German journal "Der Islam", a magazine "concerning the history and the culture of the Islamic Orient". It encompassess 212 pages. It was my good fortune to be able to purchase the three issues of the journal in which Hein's work appeared. This made it possible to separate the dissertation from the other material in these numbers, and have it bound as a single volume. This constitutes one of the most valuable treatises available on the Turkish composite bow and its associated implements, as well as on the customs and practices pertaining to Turkish archery.*

Following the enumeration and discussion, in 24 pages, of many earlier works in Turkish and Arabic, Hein devotes most of his attention to the aforementioned Turkish book. This has the title, *Telchis resail er-rümat,* "Excerpts from the Writings of the Archers", and its author is

*Although Hein did notable work, his knowledge of the practical and technical aspects of archery was not profound. A new translation, rendered directly in English from the original Turkish, done cooperatively by a linguist and an archer, as exemplified in "Arab Archery" by Faris and Elmer, might disclose interesting and valuable information that eluded Hein.

Mustafa Kani. Fig. 1 reproduces page 224 of this book in exact facsimile. It conveys an excellent idea of the general appearance of the book. It is written in old Turkish, the language of the *yeni cheri*, the Janissaries. The characters are mostly Arabic. There are no paragraph indentations. Chapter headings, bracketed with ornamented parentheses, but not occupying a separate line, are difficult to find. The total of numbered pages is 278. At the back there is inserted a folding plate with 21 illustrations and captions, and these, together with other illustrations in the book, are for the most part reproduced in the text of this book. The paper is a good quality hand-laid rag. The page size is 6x8½ inches. The covers are marbled board, with a back of thin cloth.

A work earlier than Hein's, based on Kani, was published by Hammer-Purgstall in the Proceedings of the Royal Academy of Science in Vienna, where it had been presented at an Academy meeting on March 21, 1851. The Purgstall work bears the title, "Concerning Bow and Arrow, Their Use and Construction Among the Arabs and Turks". The title sounds promising, but unfortunately most of the work is concerned with Arab and Turkish glossaries relating to the bow and arrow, and to the mysticism and religious implications of archery as presented in Kani's book. Although Purgstall's whole article is based on Kani's book, his study appears to have been most superficial. Not once does he mention its author. The only value we find in it is his translations of the captions appearing with the 34 illustrations in Kani.

Sir Ralph Payne-Gallwey in his "Treatise on the Construction, Power and Management of Turkish and Other Oriental Bows of Mediaeval and Later Times" (1907) states, "In one of the Turkish manuals of archery, translated by Baron Purgstall, many illustrations are given of

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Fig. 1. Full size facsimile of page 224 of Mustafa Kani's "Excerpts from the writings of the archers".

آتمش منزل ایسه دخی حالا نصب سنك اولنمادی بو تجدید تدرا ایکداران میدانم دیمرك واقع اولان تیلز ینده مساعده اولنوب بیك ایکیوز یرکز منزله وضع نشان ایدوب بعده سنان مذکور سایس مذبورك سنك نشانندن اوتوز بر کز ایلرو اول آتدیغی موضعه بیك ایکیوز اوتوز ایکی کز منزله وضع نشان ایتمش حالا اوزون قره طاش دیو معروفدر بعده زمان سلطان بایزیدخانده هوان دلی نام صولاق بالی نام تیر انداز اناطاشنك یتمش درت کز شست طرفندن سنك سنانی یدی کز سبقت ایدوب بیك ایکیوز اوتوز طقوز کز منزله نصب نشانا یتمش (بنه ایلم سلطان بایزید خانده) شجاع نام تیرانداز انا طاشنك یوز قرق اوج کز شست جانبندن سنك صولاغی اوتوز ایکی بچوق کز بچوب بیك ایکیوز یتمش بر بچوق کز منزله سنك منزلن وضع ایتمش (بعدینه ایلم بایزید خانده) توزقوپراندیمکله معروف اسکندر نام تیرانداز انا طاشنك یوز اللی درت کز شست طرفندن سنك شجاعی اوچ کز کچمکله قناعت ایتمیوب تکرار یدی کز دخی سبقت ایله اون کزه واصل و بیك ایکیوز سکسان بر بچوق کز منزله نصب نشان (صاحب المنزل والمیدان هذا اسمه توزقوپران) تحریریله وضع ایتدی سنکی حالا موجوددر وسبب شهرت مخلص توزقوپران برکون میدانده توزاو تعبیر اولنان صندلوس روغنلی قوس جدیدك قبضه سی شوقلة صیقوب قبضه اوسنده بولنان روغن جدید پرمقلرینه یاپشوب قبضه یی قویو بردکده پرمقلریله برابر قالقدیغی موجودیندن بیلدیرم باباتام ربیر کهن سال کوروب بوکانکش توزقوپران دیو نطق ایتمکله شهرت بولوب اسمی دخی اونو دیلوب بو مخلص ایله یاد اولنور زمان قاصده قاضی قواو حسام نام تیراندازدن مشق وقبضه الوب شیخ المیدان حمدالله افندینك تعلیم ایتمش (دردکر منزل جعفر بك یاباد کون طوغریسی) بو منزلك جای قدمی طریق کاغدخانه اوزرنده امام منزلی ایاق طاشی طوغریلغی واکثی منزلی برابرنده کوجك برذراع قدر مرمردر باشرطنی یهودی مشاطلغی مانده واقع امازمه الشده اولان دوز

سایس محمود
۰۰٤۰
۱۲۰۱

سنان صوباشی
۰۰۳۱
۱۲۳۳

هوان دلی
۰۰۰۷
۱۲۳۹

شجاع
۰۰۳۲
۱۲۷۱

توزقوپران
۰۰۱۰
۱۲۸۱

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the construction of the Turkish composite bow, but, unfortunately, minor details are omitted, though doubtless they were common knowledge when the Ottoman author wrote. Without these details the correct formation of the bow cannot be ascertained. The chief omissions are (1) the composition of the very strong and elastic glue with which the parts of the bow were so securely joined, (2) the treatment of the flexible sinew which formed the back of the bow—whether, for instance, it was glued on in short, shredded lengths or was attached in one solid strip." Obviously Sir Ralph was in error in stating that Purgstall had translated "one of the Turkish manuals of archery". Through Hein we have been able to recover the "omissions" to which Gallwey refers.

Hein's interest was much broader, fortunately, than that of Hammer-Purgstall; he deals with the organization and activities of the archers' guild in Constantinople; the construction of their bows and arrows; the details of methods employed in such construction; and the technique of shooting the Turkish bow. Hein himself is not an archer, but he appears to have studied as much of the technical treatment of bows as was available to him in German publications, which at best was sparse. His lack of experience in archery leads him to some false deductions and erroneous statements. Some of the things with which the practical archer is concerned have escaped him. But where he was uncertain about translations or interpretation, he had the commendable foresight to give page and line references to Kani's 'Excerpts". This has made possible the reviewing of such passages, and with the help of persons conversant with Turkish, and the author's familiarity with archery, to clarify them.

It was hardly to be expected that any writer on the subject, prior to 1930, would deal with it scientifically or with emphasis on the technical aspects; for there had been but few technical studies of archery up to that time.

It is therefore expedient, in reading Hein, to interpret his translation and comments in the light of our newer knowledge, and try to determine how Turkish craftsmen made bows and arrows and how Turkish archers used them with such astonishing success in flight shooting. In this book we include only incidentally those portions of Hein which report the cultural and religious matters of which Kani treats in his work.

Before World War II, the author had managed to obtain Hein's address, engaged in correspondence with him, and endeavored to obtain specific technical information on matters not clearly treated in his dissertation. His letters confirmed the impression previously gained that he had no first-hand knowledge of archery, and that he depended for such information on other German writers to whom he makes reference, e.g., Mylius, "Die Theorie des Bogenschiessens", *Archiv für Anthropologie,* Vol. III (new series) 1905; Genthe, "Mit dem Pfeil und Bogen", *Schuss und Waffe,* Vol. I, 1907/08; Reimer, "Vom Pfeil und Bogen", *Schuss und Waffe,* Vol. II, 1908/09. A study of these references also helps in appraising Hein's comments on technical matters.

Hein in one of his letters characterizes Kani as a courtier with a practical knowledge of archery, himself an able archer, who was ordered by the sultan to write a book on the subject. The royal order* is reproduced in the introduction to Kani's "Excerpts". He conscientiously carries out the order without evident enthusiasm. He has not been told to differentiate clearly between the important and the unimportant. So he frequently slides off into ponderous, long-winded discussions that fail to touch the essentials of the matter in hand. On the other hand, the prolixity which characterizes his writing en-

*Designated, in Turkish, *ferman.* In modern bureaucratese it would be called a "directive". For its translation, see Appendix, page 167.

ables one, according to Hein, to discover much interesting and significant material by digging deeply enough.

During the years from 1451 to 1566, covering the reigns of the sultans from Mohammed II to Suleiman the Magnificent, Turkish archery attained the zenith of its development. How highly the Turks prized the bow and arrow is evidenced by the frequency with which Turkish names are compounded with the word for arrow, *ok*. Tradition and history combine to tell of the mastery of the bow by the sultans. The most noted of the archer-sultans was Murad IV, in whose festival parades the guilds of bowyers, arrowmakers, instructors in bow-shooting, archers and thumb-ring makers participated.

The conquest of Constantinople under Mohammed II in 1453 marks the introduction of firearms as weapons of warfare. In Mohammed's army there were sixty soldiers armed with muskets. Yet the development of the musket appears to have been exceedingly slow, for we read that nearly two centuries later the arrows of Murad IV were more effective than musket balls. Nonetheless, the use of bows and arrows as implements of war began to decline with the introduction of firearms; but with their decline as weapons began their rise as implements of sport. It was one of the objectives of the guild of archers to preserve the love of the sport among the people even after it had been completely abandoned by the army, about 1591.

Turkish archery as sport and pastime continued for about four centuries. Its last brief period of revival in Constantinople came about through the interest and efforts of Mahmud II, whose reign extended from 1808 to 1839. This enthusiast for the sport left nothing undone to revive the lustre of the old competitive matches. He permitted his enrollment as an apprentice in the archers' guild, and to qualify for membership, subjected himself to the usual period of six months of arduous training prescribed for the novice. He was duly initiated in 1818 and, in accordance with the by-laws, this event was made the occasion of a great feast for the guild. He rebuilt the time-ravished guild hall on the *ok meidan*, or shooting field, and provided for its maintenance. He participated in the regular tournament matches and established prizes as incentives to the archers to increase their skill. He issued the *ferman* that Mustafa Kani write a book which should relate the history of the guild and describe the making of bows and arrows, tournament rules, methods of shooting, and the distance records achieved by members of the guild over a period of several centuries. The sultan's order mentions that it would be impossible for all who desire to learn the art to consult the many articles of the many writers who had written exhaustive treatises on all phases of shooting; and although the learners might have access to the articles, to study them advantageously would be a difficult matter. The articles are described by the sultan as verbose, lacking in conciseness, and dealing with much extraneous matter. Hence Kani is commanded to organize and record what is known for the benefit of those who are fond of shooting in the bow.

Kani himself learned his archery from the sultan, as appears in the order. His official position gave him free access to the monarch. Kani was evidently quite accomplished in the sport, and understood the work of the craftsmen. He personally observed their methods, and tried to describe what he had seen.

After the reign of Mahmud II, the guilds of archers, bowyers, fletchers and all other related crafts dwindled in size and finally vanished. Turkish bowyery came to be regarded as a lost art. Traditions became current about the wood, horn, sinew and glue they used. Thanks to Mahmud II, Kani and Hein, we have a great amount of authentic information about these matters.

Thanks also to the fact that Kani knew archery, we have records of flight distances in tournament competition which would be almost incredible without competent supporting evidence. His own skill with the bow was worthy of regard, as was that of his sultan. The flight distances reported are so outstanding that Purgstall ascribes them to the flattery of sycophants. Distances exceeding 1200 *gez* were not unusual. Kani, sensing the incredible nature of these records, goes to great pains to emphasize that there was no fraud in the reporting of the distances; to guard against any truckling to the sultan by the reporting of fictitious distances, he personally placed reliable archers in the field to measure and report the shots. Kani witnessed and confirmed some of them. As we read these reports of distances expressed in *gez*, we have the problem of determining what they were in yards. Much research has gone into the question. The findings are applied to the appraisal of the distances reported by Kani.

Among the Mohammedans archery had religious implications. Because Mahmud I revived the sport, he was highly praised for having renewed and revivified an old, lost religious custom. To do so was "the greatest glory in the eyes of the believers, and those rulers are extolled and their piety is to be praised who have given renewed life to the practices of those who lived in earlier times". Such undertakings were regarded as meritorious in the highest degree.

In the fact that the revival of the sport was an act of merit from the religious point of view, there is exemplified that singular Islamic idea of the religious motivation of all human activity. Accordingly, the exercise of archery was carried on as a religious ceremony, requiring ablutions and prayers. Its origin was ascribed to a *pir*, a holy person or patron saint, and its various practices were codified in the terminology of the religious schools of law. According to one tradition, most of the prophets, beginning with Adam, were devotees of archery, and among the descendants of Abraham through Ishmael—who, according to Genesis xxi, 20, grew up to be an archer in the desert—the shooting of arrows never ceased up to the time of Mohammed. God Himself, according to the Koran, commanded Mohammed that bows and arrows were to be used. The Prophet, together with his associates, gave religious sanction in both word and deed to the art of bow shooting. Thus we may follow the uninterrupted sequence of persons, beginning with Adam, through whom the art and skill of archery were handed down to succeeding generations.

Mohammed the Prophet was clearly the most outstanding of the persons in the great succession of archers. Although he did not himself practice the art extensively, he repeatedly encouraged his associates to engage in it, as may be seen in the Forty Sayings (*hadiths*) of the Prophet. He owned six bows whose names are mentioned by Abdullah Efendi "for the sake of the blessing".

The arrangement of subject matter in Kani's "Excerpts" provides for an introduction consisting of the sultan's *ferman** that Kani undertake this work. Then follows a section (pages 4 to 36 inclusive) of writings by Abdullah Efendi, scribe of Ayub Anshari mosque, consisting of a dedication to the ruler, and of the *hadiths* about archery. This material and the remainder of Chapter 1, which extends to page 60, have the purpose of emphasizing the legends and traditions, and the history and religious implications of archery. These things Kani discusses, and presents the views of Turkish archers regarding them.

Chapter 2 (pp. 60 to 116) describes the course of the novice from his acceptance by the archers' guild through

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*See Appendix 1, Page 167.

his initiation as a member. It also describes the techniques of shooting in exhaustive detail, from the points of view of the several *imams* who originated and taught the various methods used.

Chapter 3 (pp. 116 to 128) deals at length with the flight distances achieved by Mahmud II and his associates on the *ok meidan*.

Chapter 4 (pp. 128 to 207) describes details of construction and includes a section on errors in shooting techniques.

The remainder of the book is the "conclusion" (pp. 207 to 272) which gives further details about the construction of accessories. It recites the tournament rules of the archers' guild, and devotes 46 pages to flight records made in the 48 ranges of the *ok meidan*. On page 269 it is stated that the *sheikh-ül-meidan* had read and approved the book, and that his son Bohdyet, archer and arrowmaker, had drawn the illustrations. The last few pages contain an appendix to Chapter 4, in which details of arrow making are given.

Hein organized his material more systematically. Following the introductory bibliographical, legendary and religious matters, he makes his presentation in three sections: (1) Description of the construction of bows, arrows and accessories, with a digression about Arab and Persian bows; (2) the right and wrong methods of using bows and arrows; instructions in shooting, and theories about errors in shooting; (3) the organization and the tournaments of the archers' guild of Constantinople.

In this book we confine our attention principally to those matters that make potential contributions to our knowledge of design, construction and use of bows and arrows.

CHAPTER II

THE DISTANCE RECORDS OF THE TURKISH BOW

In this treatise on the Turkish bow we shall not engage in conjecture regarding its origin, its invention, or its development to that high degree of excellence which enabled the Turkish archer to distinguish himself in shooting great distances. The Turkish bow was composite, made of wood, horn and sinew, so assembled with a superior grade of glue that the physical properties of the materials thus united were best exploited to give that superb performance which is associated with it. We do not know whether the composite bows of other origins were better or inferior. We have seen very little technical or other information about them. The Scythians and Tartars had composite bows, as did the Mongols under Ghengis Khan, the Persians, the Arabs in the latter years of their use of bows, the Indians of the East, and, to this day, the Koreans and Chinese. From its design and construction it may be judged that the Persian bow may have approximated the Turkish in performance. We shall not endeavor to explore the matter, except to take note of the construction as shown in fig. 2, page 16, reproducing part of a plate from an article by Henry Balfour.* Beyond that we consider only the Turkish bow, for it is this weapon about which we have the comprehensive descriptions and records in Kani's "Excerpts".

It is interesting to note what English writers had to say about the performance of the Turkish bow. A quotation from Roberts (1801) was given in the first chapter of this book. We find a brief note on the subject in "The History of the Royal Company of Archers" by James Balfour Paul, published by William Blackwood & Sons (1875), Edinburgh and London, page 116:

*On the Structure and Affinities of the Composite Bow, Jour. Anthrop. Inst., XIX, 220, 1889.

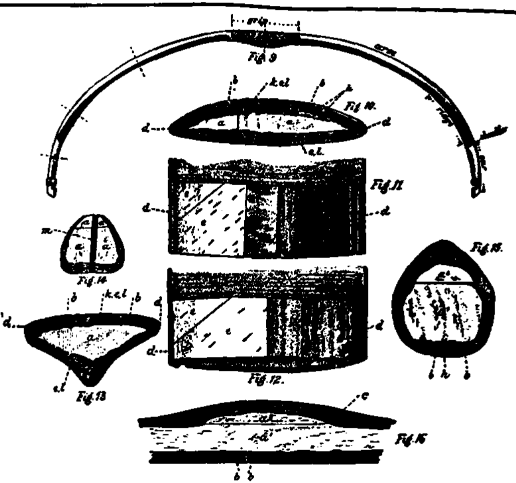

Fig. 9. Persian bow, dotted lines indicate where transverse sections have been taken.
Fig. 10. Transverse section through one of the arms.
Fig. 11. Dissection of the belly at the same part.
Fig. 12. Dissection of the back at the same part.
Fig. 13. Transverse section through the center of one of the ridges.
Fig. 14. Transverse section through one of the ears.
Fig. 15. Transverse section through the center of the grip.
Fig. 16. Longitudinal section through the grip.

a. Hardwood base.
a.² Plug of hardwood inserted in grip.
b. Strips of horn.
c. Sinew backing.
d. Side strips of horn.
e. Layer of very fine inner bark of birch.
h. Glue.
k. Transverse sinews over the horn on the belly.
l. Lacquer coat.
m. Piece of horn supporting the ears and nocks.

Fig. 2. Structure of a Persian composite bow. (Balfour).

"While on the subject of remarkable shots, we may mention that there is inserted in the minute book of the Royal Company a leaflet bearing to be an extract of a letter from Thomas Greene, Esq., of Gray's Inn and Bedford Square, London, to Mr. Charles Hope, Advocate (afterwards Lord President and Justice General). It is dated 11th July 1794, and is signed by Mr. Hope as a true copy. The following are its contents:

"Wednesday was a target day. The Secretary and suite of the Turkish Ambassador did us the honour to attend. The Secretary brought his bow and arrows with him. He did not shoot at a mark, but said if we had a mind to see how far he could shoot, he would go into the fields with us. Mr. Waring and I went with him accordingly, and to our utter astonishment he shot *against* the wind, by my stepping, 415 yards—and back again *with* the wind, 463 yards. He had a short Turkish bow, an arrow of 25 or 26 inches, very light, with small feathers."

Hansard, in his "Book of Archery" (1840), page 137, writes:

"One other curious contrivance connected with the Oriental bow remains to be described. When flight-shooting, to which they are particularly attached, a grooved horn, about six inches long, is fastened upon the back of the bow hand by straps of crimson morocco buckled round the wrist. The bow is then, and then only, held across the body, and, by drawing several inches within this horn, they can use very short arrows. By thus diminishing their length, superior lightness, the chief quality of a slight shaft, is proportionately attained. On the 9th July 1792, Mahmood Effendi, the secretary to the Turkish embassy, exhibited his great strength by shooting an arrow in this way 415 yards partly against the wind, and 482 yards with the wind, in a field behind Bedford

House, London. He used a Turkish bow, drawing 160 pounds; and this exploit was performed in the presence of three gentlemen, members of the Toxophilite Society. The arrow measured 25½ inches, which he pulled 3 inches within the bow, so as to make the draught 28 inches. He said, upon the ground, that Selim, the then Grand Segnior, often shot 500 yards, the greatest performance of the modern Turks. However, the Sultan afterwards, in 1798, drove an arrow in the ground 972 yards from the spot where he stood, the distance being measured in the presence of Sir Robert Ainslie, ambassador to the Porte. All these singular contrivances are, of course, common in the East to archers of both sexes; and their dissimilarity to everything we apply to the same use in England, has induced me to detain the reader by a minuteness of description otherwise unnecessary."

We note that Mr. Thomas Greene states that he and Mr. Waring were witnesses in 1794 to the shot of Mahmud Efendi, and that the distance with the wind, by his stepping was 463 yards. By the time Hansard wrote about it, the year had become 1792; and the distance had become, and in subsequent writings remains, 482 yards. We find next, in "The Archer's Register" for 1882-1883, on page 61, an article on "Turkish Archery in the Last Century." This gives another eyewitness account of the same shot, preceded by interesting descriptions of Turkish archery gear.

The distances achieved by Mahmud Efendi, though regarded as commonplace by him, astounded the English spectators, particularly those who had become convinced that a distance of 350 yards with the bow lay in the realm of the unattainable. The author of the account is anonymous, nevertheless his skill and interest in archery are implied in his having written for "The Archer's Register". The author had the foresight, for which we are duly grateful, to provide the conversion between "pikes" and yards, which gives 25 inches as the "pike". This agrees within a few percent with the results of extensive investigations which I have made to determine the distances in yards which Kani reports in *gez*, and suggests the identity of the latter unit with the "pike".

"Turkish Archery in the Last Century"

"The following *Notes* are collated from a manuscript copy of 'Anecdotes of Turkish Archery, procured from Constantinople by Sir Robert Ainslie, and translated by his interpreter, at the request of Sir Joseph Banks, Baronet, 1797'.

"As late as 1797 the Turks had detachments of archers in their armies, upon the purely conservative principle of avoiding a deviation from an ancient custom; for, in fact, Archery had for years past been looked upon in Turkey as entirely an exercise of amusement, and as such it was at that period practised by all ranks of people.

"The Ottoman Emperors, with their Courts, frequently indulged in public in the diversion of archery, and there was (if there is not now still in existence) an extensive piece of ground set apart for the purpose, upon an eminence, in the suburbs of Constantinople, commanding an extensive view of the city and harbour, called Ok Meydan, or 'the place of the arrow'. This place was full of marble pillars, erected by those archers who had excelled in shooting their arrows at any remarkable distance. These pillars were inscribed with the names of the archers, the extraordinary distance at which they had shot their arrows, and usually with some verses in praise of their dexterity.

"It was always understood that the Turkish Emperors lived by their manual work, and, in consequence, they were compelled to learn some art or profession, and most of them preferred the art of manufacturing bows and arrows. Selim, the reigning Emperor in 1797, was bound apprentice to this trade; and at the time he was made a master, he gave on several occasions very splendid public entertainments at the Ok Meydan, where tents were pitched for him and his court.

"It may not be uninteresting to give, as far as possible, a description of

The Turkish Bow

"The Tartar bows were preferred to those manufactured in Turkey, being larger and stronger; but there was, at the date of the 'Anecdotes', an important manufactory at Constantinople, called 'Okzilar', or 'the arrow makers'. The body of the bow was made chiefly of buffaloes' melted horns, smoothed with a file to the proper shape, joined in the centre or handle by a different material, and backed with some kind of elastic wood; the ends, with deep notches for the strings, were usually made of box-wood—the whole being painted, varnished, and richly gilt. The back of the bow was sometimes covered with a material resembling shagreen, slightly lapping over the inner side. The bow-string was usually made of numerous threads of silk, doubled from end to end, so as to form a loop at each end, and tightly bound or lapped at intervals with silk of a different colour. To each loop in the silken string were added loops of catgut, joined by a peculiar knot. These strings contained as many as fifty-eight threads of silk. The bow was bent only when required for use, and then it was done with great caution, the heat of the fire being employed to make it flexible. When unstrung the Turkish bow was reflex to an extraordinary extent, bending back as much as it was bent when strung. These bows were of great power, for at point blank range, at a distance of 100 yards, the arrow would fix itself nearly two inches deep through a plank of the thickness of half an inch.

The Turkish Arrows

"(if diagrams in the 'Anecodotes' are to be understood as giving exact measurements) were 26 inches in length, being thickest in the middle and tapering to each end. They were feathered close up to the nock, so that the ends of the feathers were contiguous to the bow-string. Such a mode of feathering would be useless in English Archery, but the Turks did not hold the arrows to the string by their fingers, in our fashion, as will shortly be explained. The feathers, in shape and size, were cut very much as is now the practice with our best English makers. The feathers of the lightest arrows, used only for flight, did not exceed two inches in length and three-sixteenths of an inch in depth. These flight arrows weighed 10 dwt. 21 grains, or a little over half an ounce, and measured in diameter at the end, close to the feathers, .268 inch, at the pile .27 inch, and at intermediate distances in the length, .321, .34, and .312 inch. . . . The nock, into which the wood shaft was let, consisted of horn, the nock for the bow-string being narrowest at the mouth, so that the arrow when slipped or adjusted on the string remained in its position without being held.

"The bow, instead of being drawn with three fingers on the string, according to our mode, was drawn by the right thumb, with the arrow placed on the string immediately above it. A thumb-piece, or guard of bone, answering the purpose of our 'tips', was worn. It covered the ball of the thumb, one end being made as a ring and passed over the joint. A projecting tongue in the inside prevented the string slipping off the guard into the angle of the thumb formed by the bent joint. The inside of the guard was lined with leather. A curious contrivance, consisting of a horn groove several inches in length, fixed on a foundation of wood attached to a leather strap and buckle, was fastened on to the bow hand. The groove projected inwards. The arrow was laid in this groove, which rested on the thumb, and was rather higher on the outside, as the arrow was shot on the right side of the bow, or the contrary side to which it is in England. . . .

"On the 9th July, 1794, in a field behind Bedford Square, London, near the Toxophilite ground, the Turkish Ambassador's Secretary, with a Turkish bow and arrow, shot 415 yards against the wind, and 482 yards partly with the wind. He said his bow weighed* 160 lbs., and the length of his arrow was 25½ inches, which he drew within the bow to make his draught 28 inches. The latter fact is explained by his using the groove described above. As regards the strength of the bow, Mr. Waring observed (Mem., June 3rd, 1797) 'the Turk's bow could not draw 160 pounds, for he made one for Sir Foster Cunliffe at 100 lbs., and was afterwards directed to reduce it to 70 lbs., also one for Lord Aylesford at 90 lbs., and was obliged to reduce it'.

"According to a memorandum made by Mr. Waring July 17th, 1794, the Turkish Ambassador's Secretary said that the Grand Sultan 'shoots' 500 yards† which was the greatest performance of the modern Turks; but that pillars stood on a plain near Constantinople commemorating ancient distances of about 800 yards.

"Sir Robert Ainslie said (Mem., Mr. Jones at Mr. Waring's, April 5th, 1796) that the Turks would sometimes shoot with a bow and arrow three-quarters of a mile with the wind—1320 yards, or 66 score yards!

"Translation of extracts from inscriptions on the marble columns existing at the Ok Meydan, and erected by those who had excelled in Archery:—

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*On this point, Ingo Simon comments, in a letter: "Mahmud Efendi's bow was nowhere near 160 pounds pull. I knew the bow well. I estimate its pull at not more than 80 pounds. This bow and the arrows were lost after being for years at the old Tox in Regents Park. I have studied it so much in times past that I could give a pretty accurate account of it, its arrow groove and thumb-ring."

†Mr. Waring says, more likely 700, as his Secretary shot 482 yards.

(Editorial comment concerning the following records of distances: The feet and inches have no significance whatever. They are reproduced because they appear in the article being quoted. The distances in pikes may have been paced, or measured with a tape, or even a cord. The probable inaccuracy may be great. The feet and inches as tabulated come from converting pikes to inches by multiplying by 25, then changing the inches to yards by dividing by 36, and changing the remainders to feet and inches.)

	Pikes	*Yds.*	*Ft.*	*Ins.*
"Ak Siraby Mustapha Aga shot two arrows, both of which went the distance of	900	625	0	0
Omer Aga shot an arrow which pierced two crystal mugs at	900	625	0	0
Said Mahammad Effendy, son-in-law to Sherbetzy Tade	902	626	1	0
Sultan Murad	987	685	0	0
Hagy Muhammed Aga shot four arrows, all of which were fixed into a wooden block at	1050	729	0	7
An arrow shot by Sahib Assis Muhammed Ashur Effendy was fixed in the ground at	1093	759	0	0
Ahmed Aga, a gentleman of the Seraglio, under the reign of Sultan Sulaman, the legislator, shot also	1093	759	0	0
Pashaw Oglee Mahmed	1097	761	2	4
The present Grand Admiral Hassan Pashaw shot an arrow which drove into the ground at	1100	763	2	8
Bilad Aga, Treasurer to Hallil Pashaw shot an arrow which drove into the ground at	1202	804	2	2

	Pikes	*Yds.*	*Ft.*	*Ins.*
Hallil Aga	1210	810	0	10
The reigning Emperor Sultan Selim drove into the ground at	1400	972	0	8
Also a second arrow with the same effect	1400	972	0	8"

In 1907 Sir Ralph Payne-Gallwey published a book on "Projectile-Throwing Engines of the Ancients", in which was tucked away a section on "Turkish and Other Oriental Bows". From this book the following quotation is interesting, since it includes an account of the shot by Mahmud Efendi, from still another point of view.

"In 1795 (Error: it was 1794.—Author) Mahmoud Effendi, Secretary to the Turkish Ambassador in London, shot a 25½-in. flight arrow 480 yards. The bow he used is now preserved in the Hall of the Royal Toxophilite Society, Regents Park.

"Mahmoud Effendi accomplished this feat—which was carefully verified at the time—in the presence of a number of well-known members of the Toxophilite Society of the day, including Mr. T. Waring, the author of a work on archery.

"Joseph Strutt, the historian, was also a spectator, and describes the incident in his book* entitled 'The Sports and Pastimes of the people of England'.

"It is beyond question that in the seventeenth and eighteenth centuries, with bows precisely similar to the one shown in fig. 1, but of much greater power, flight arrows were shot from 600 to 800 yards by certain famous Turkish archers.

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*Author's note: Strutt's account adds nothing whatever to the information from the sources quoted. If he was a spectator, as stated by Gallwey, he was hardly a reliable witness. His comments are not worth quoting; to do so would propagate several errors, such as the identity of the archer, and the kind of arrows he was shooting.

"The achievements of these celebrated bowmen were engraved on marble columns erected at the ancient archery ground near Constantinople, and these records are still in existence.

* * * * * *

"I have obtained with much difficulty during the last few years about a score of composite bows of Turkish manufacture from various parts of the Ottoman Empire. Not more than three or four of these have, however, proved serviceable, owing to their age, as no bows of this kind have been made for over a hundred years, the art of their construction being long since neglected and lost.

"With one of these bows I shot six arrows in succession to ranges exceeding 350 yards, the longest flights being 360, 365 and 367 yards. This public record was established July 7th, 1905, at an archery meeting held at Le Toquet, near Etaples in France. The ground selected for the trial was perfectly level; there was no wind, and the distances were accurately measured by several well-known members of the Royal Toxophilite Society who were present.

"With the same bow I have, in private practice, thrice exceeded 415 yards, and on one occasion reached 421 yards.

"Though this bow is a powerful one for a modern archer to draw, it is a mere plaything compared with other Turkish bows of the same length, but of far greater strength, which I possess.

"Some of the latter are so curved in their unstrung state that their ends nearly meet, and are so stiff, when strung, that I cannot draw them more than half the length of a 25½-in. arrow. . . .

"Such bows as these require a pull of 150 to 160 lbs. to bend them to their full extent, which quite accounts for the marvellous, but well authenticated distances attained in flight-shooting by the muscular Turkish bowmen of bygone days.

"Though 367 yards is a short range in comparison with that which the best Turkish archers were formerly capable of obtaining, it is, so far as known, much in excess of the distance any arrow has been shot from a bow since the oft-quoted feat of Mahmoud Effendi in 1795.

"Full corroboration of the wonderful flight-shooting of the Turks may be found in some treatises on Ottoman archery which have been translated into German by Baron Hammer-Purgstall* (Vienna, 1851).

* * * * * *

"The orthodox length of a pace is thirty inches, and thus even 1000 paces . . . would exceed 800 English yards. . . .

"In further connection with long-distance shooting with the Turkish bow, I append a letter written by one of my ancestors to another. They were both skilled and enthusiastic archers in their day. This letter, and the notes and translations which follow it, describe the extraordinary feats said to have been achieved by the Turks with their bows when shooting to attain a long range with a flight arrow:—

London, 1795.

" 'Dear Brother,—I have just been to see the secretary of the Turkish Ambassador shooting with Waring and other famous English bowmen. There was a great crowd, as you may suppose, to see them. The Turk, regardless of the many persons standing round him, and to the amazement and terror of the Toxophilites, suddenly began firing his arrows up in all directions, but the astonishment of the company was increased by finding the arrows

*Author's note: For comments about Purgstall's translation, see page 6. Payne-Gallwey evidently was as casual in appraising Purgstall as the latter was in appraising Kani's "Excerpts from the Writings of the Archers."

were not made to fly, but fell harmlessly within a few yards. These arrows* the Turk called his 'exercising arrows'. This was an idea that was quite new to the bowmen present and they began to have more respect for the Turk and his bow. The Turk's bow was made of antelopes' horns and is short, and purposely made short for the convenience of being used in all directions on horseback.

" 'The Toxophilites wished to see the powers of the Turkish bow, and the Turk was asked to shoot one of his flight arrows. He shot four or five, and the best flight was very carefully measured at the time. It was 482 yards. The Toxophilites were astonished, I can tell you.

" 'Waring said the furthest distance attained with an English flight arrow, of which he had ever heard, was 335 yards, and that Lord Aylesford had once shot one, with a slight wind in his favor, 330 yards. Waring told me that he himself, in all his life, had never been able to send a flight arrow above 283 yards.

" 'The Turk was not satisfied with his performance, but declared that he and his bow were stiff and out of condition, and that with some practice he could shoot very much further than he had just done.

" 'He said, however, that he never was a first-class bowman, even when in his best practice, but that the present Grand Seigneur was very fond of the exercise and a very strong man, there being only two men in the whole Turkish army who could shoot an arrow as far as he could.

" 'The Turk said he had seen the Grand Seigneur send a flight arrow 800 yards.

" 'I asked Waring to what he attributed the Turk's great superiority over our English bowmen; whether to his bow or not. Waring replied he did not consider it was so

*Called by Kani *abrikh*; see page 76.

much the result of the Turk's bow, but rather of his strength and skill, combined with the short, light arrows he used, and his method of shooting them along the grooved horn attached to his hand.

" 'Neither Waring nor any of the Toxophilites present (and many tried) could bend the bow as the Turk did when he used it.

" 'So much for the triumph of the Infidels and the humiliation of Christendom.

" 'Yours aff.,
" 'W. Frankland.

" 'To Sir Thos. Frankland, Bt., M.P.
" 'Thirkleby Park.' "

In the Payne-Gallwey book there follows a quotation from the identical source cited in the article quoted from "The Archer's Register", but with certain inexplicable deviations. In the table of distances, Payne-Gallwey does not give the values in "pikes", but only in yards; the figures in yards agree in each case but the last. Here, instead of the 972 yards attributed to Sultan Selim, the Sultan is allowed only 838 yards. The greater distance, on the other hand, is corroborated by the quotation from Hansard. Thereupon Payne-Gallwey continues:

"In the translation of the above from the Turkish language the feet and inches were also given for each shot, but these I have omitted as unnecessary.

"In the manuscript, the interpreter remarks that the measurements of the distances on the marble columns at Ok Meydan are in pikes, the pike being a Turkish measure of a little over two feet, easily convertible into English yards, feet and inches. (Author's query: Why did not Payne-Gallwey say 25 inches? Does 'a little over two feet' mean less than an inch in excess of two feet? The records in 'The Archer's Register', as translated from the inscriptions on the marble columns, clearly indicate—as pointed out, page 23,—that the pike was taken as 25 inches.)

"It will be observed that the longest flight recorded on the columns selected for quotation is 838 yards, (Author's query: Why not the 972 quoted in 'The Archer's Register'?) and the shortest, 625 yards. Though these distances are almost too extraordinary to be true, they corroborate the statement made in 1795 by the secretary of the Turkish Ambassador. If they are correct, they can only be accounted for by the use of a light, short arrow, a very powerful bow, great strength and skill, and above all else by the horn appendage which the Turkish archer attached to his left hand, and without which he could not shoot so short an arrow from his bow.

"Even if we accept the shortest range recorded on the columns as correct—i.e., 625 yards—it is an extraordinary distance for any arrow to be propelled, and is 285 yards beyond what has ever been achieved, as far as we know, by an English bowman with a longbow.

"It is, however, beyond question that the secretary to the Turkish Ambassador did shoot an arrow 482 yards, though he declared at the time of the occurrence that he was not proficient in the art of sending a flight arrow to what he considered a great distance. We may from this safely assume that a range of 143 yards further than the Turkish secretary attained with his bow, or a total flight of 625 yards, was quite possible in the case of a more powerful and skilled Turkish archer than he was."

Hein has supplied a direct translation from Kani (pp. 223 and 224) of the records of distances shot by Turkish archers on the *ok meidan*. Among the longest are those shot on the range of the East Wind, in westerly direction. Some of the marble markers on which record shots were commemorated still existed in Kani's time. From Hein, we abstract the following list:

During the time of Fatih Mehemmed Khan:

Hazzaz Achmed	1037 *gez*
Sinan the arrow-maker	1109
Benli Kara Göz	1161
Police Captain Sinan	1232

In the reign of the Sultan Bayezid Khan:

Solak Baly	1239
Shudja	1271½
Toz Koparan	1281½

The record shot of Toz Koparan—depending on the conversion factor used to express the distance in yards—is somewhere between 850 and 890 yards. This corresponds to a value of the *gez* between 23.9 and 25 inches. Evidence for the lower value is found in the quotation from Roberts* where it is stated that "Toz Koparan is said to have shot seventeen hundred cubits." An 18-inch "common" cubit (Hering's Tables of Conversion Factors, 1904) gives 850 yards for this distance. Using 18.24 inches from Nicholson's "Men and Measures" (1917), the value is 861 yards. If the "pike" in the quotation in "The Archer's Register" is the same as the *gez*, the latter would be 25 inches, and the distance 890 yards.

Interestingly, and perhaps significantly, the average length of several dozen Turkish flight arrows, accurately measured, is 24.45 inches. Is this mere coincidence, or did the Turkish flight archers choose the length of the arrow as the unit for measuring distances? This surmise seems indeed plausible. It is strengthened by a translation of the inscription on one of the commemorative stones on the *ok meidan*, erected for Mahmud II in 1832: "The center of world renown, the Sultan Mahmud Khan, opened the tournament, shot his arrow a distance of 1215 arrow lengths, and hit the mark. May his throne ex-

*Page 3.

tend to this place. But whatever my tongue may say, it is insufficient." The inscription is quoted to present evidence that the unit for measuring flight distances was the length of the flight arrow. If we choose this length, say 24.5 inches, as the value of the *gez*, the shot of Toz Koparan was 874 yards, and that of Sultan Selim of 1400 "pikes" was 953 yards—if pike and *gez* were the same.

The fact that all Turkish flight arrows that I have measured, or that have been measured for me, regardless of their source, are of the same length within a fraction of an inch, seems singular, and is evidence of standardization of length. That the length could be standardized, for archers of different stature, was possible because they all used the *siper* or horn groove for getting increased length of draw. All evidence considered, I lean strongly towards acceptance of 24.5 inches as the probable length of the *gez*. The "pike" to which repeated reference has been made may have been the same as the Turkish *pic*, a length of 24.84 inches. It may be something more than coincidence, moreover, that the Arab unit called *guz* was the same as the *pic*. It may therefore be asserted with some assurance that the *gez* and the *guz*, the pike and the *pic*, all stood for the same unit, and that its length was about 24.5 inches. It was certainly not—as Hein supposes*—107 cm. or 42 inches; for this would render the distance records incredible, indeed impossible.

Kani describes the measurement of distances of shots as being done by means of a cord, or by pacing. The stretch of a cord under tension, and the inevitable nonuniformity of the pace, introduced inaccuracies of some magnitude into such measurements. It is practically certain, therefore, that whether we use 24.5, 24.8 or 25 inches as the equivalent of the *gez*, we shall be expressing the distances given by Kani with an accuracy greater than

*Hein appears inconsistent in taking 107 cm. as the *gez*, for he states that, among other meanings of the word, it signifies the length of an arrow.

that with which the original measurements were made. It thus becomes an academic pastime to try to determine the value of the *gez* more accurately than 1%, or even 2%.

This minor uncertainty throws no shadow of doubt upon the records Kani cites. The measurements were made and recorded routinely, and recorded on the memorial stones honestly. That such distances were actually attained is confirmed by the fact that American flight archers have exceeded 650 yards or 956 *gez*.

It is not unreasonable at all to expect such further improvement in tackle and technique that within a few years American flight archers will equal or exceed the Turkish records. This prediction takes into account the consistent improvement in our flight records, with bows of diminishing weights, in regional and national competition. It assumes that with continuing improvement in bows and arrows as in shooting techniques, it will become possible to shoot a flight arrow with an initial speed of about 320 feet per second, using a bow of not over 90 pounds. If such initial speed is attained, distances of 900 yards and up may be expected.

CHAPTER III

THE GUILD OF BOW MAKERS, AND FAMOUS MASTERS

In Constantinople the bow makers, like all other skilled artisans, were organized in a guild. The bowyers' guild was one of those reported to have participated in a grand review before Murad IV (1634-40). The guild comprised 500 members in 200 shops, near the Sultan Bayezid mosque, in Galata, Skutari and at the Adrianople gate. Their *pir* should have been Abraham, for according to tradition he was the first bowyer; but as a result of the endeavor to choose their patrons from those close to the Prophet, they regarded Muhammed ben abi Bekr, who was custodian of the Prophet's bows, as their *pir*.

Before the conquest of Constantinople, and for a period thereafter, at the time of Mehemmed II (1431-81), the bowyers of Adrianople enjoyed the best reputation. In this period Usta Sinan was especially noted. He had many pupils who became famous through their association with his name. Ibn Bahtiyar says, "If in Arabia or Persia a bow from Adrianople is bent, it is one of Usta Sinan's". One of his famous pupils was Usta Ali, *dyebedyi basby* of Daud Pasha, the vizier of Bayezid II, with whose (Usta Ali's) bows many archers achieved victory. A famous archer, Achmed Agha, arranged to have him come to Constantinople for the purpose of obtaining one of his bows. This indicates that during the period mentioned the bowyers of Constantinople had not achieved top rank in reputation.

However, during the reign of Mehemmed II there were two master bowyers in Constantinople, namely, Usta Ibrahim and Hadyi Sinan, the predecessors of the later masters. It is not improbable that this Ibrahim is the one who became chief of the bowyers' guild, and who died at Brussa at the time Selim I (1512-26) ascended the throne.

A masterpiece of art and skill, such as a composite bow, can be created only by a skilled artisan. To be sure, there were many bowyers; but only a few succeeded in becoming famous. The vocation required more than mere technical skill. According to Ibn Bahtiyar, it is self-evident that a good bowyer must also be a good archer. He must know the laws of ballistics and must therefore know both the theory and practice of the art of shooting in order to be able to construct bows accordingly. Among the holders of distance records there is many a bowyer; numbers of them are mentioned in Kani's "Excerpts".

A competent bowyer must be able to do more than make a good bow. He must be able to select the proper bow for an archer, and fit it to him. To bring all parts of a completed bow into full harmony was an art through which Hadyi Suleiman, the master bowyer of Murad IV, achieved renown. A bow that was finally adjusted by him was said to have surpassed others by 150 *gez*. He also was famous for his skill in the proper tying of the loops of the bowstring. Twice he was chief of the royal courtiers, and eventually became minister of justice. In competition he made a record of 1122 *gez*.

A well-known bowyer of the time of Bayezid II was Muhyiddin, who is said to have surpassed all others in his art. His bows were 9-12 fists (a unit of about 3¾ inches) long—probably the length of the braced bow. The grips of his bows were made longer and flatter than were those of later bows, for at that time they were used without the *mushamma*. The heads of his bows were made smaller than those made by his famous contemporary Suleiman. The latter made the limbs of his bows wide and flat near the grip, and tapered them towards the ends, with the ears about four fingerbreadths in length. A third famous bowyer was Usta Bayezid, bowmaker to Sultan Bayezid II. The similarity in names created confusion, causing occasional reports that the Sultan had followed the profession of bow maker.

The bows of these and several other of the old masters were so well made that some of them were still in use at the time of Kani, some 200 years later. Such durability must have greatly enhanced the reputations of their makers; for the life of a bow was said to be comparable to the life-span of a man, with 120 years maximum. The reasons given for such exceptional durability were that the artisans used only the best wood, cut at the proper time and seasoned naturally; that they used only the best grade of *chigha* glue, the preparation of which, from selected tendons, they entrusted to no one but themselves; and that they were most painstaking in weighing out the correct quantities of the components of which they made the bows, and in processing them into the finished weapons. Moreover, they allowed many months to elapse after applying the horn, and each layer of sinew, and after finishing the bow, before final tillering. Besides, they knew many of the secrets of the bow maker's art which have never been recorded, because they are almost impossible to describe.

CHAPTER IV

HOW THE TURKISH BOW WAS MADE

The distance records cited in Chapter II are undoubtedly representative of the best performance of Turkish archers. The bow with which they attained these extraordinary distances achieved its high level of mechanical excellence through centuries of experiential development. Being composite in structure, strongly reflexed and short-limbed, it is far more complex in point of construction and action than the English longbow. Its superior ability to impart high initial speed to a flight arrow, in contrast with bows made solely of wood, is warrant enough for studying its structure and the manner in which the Turkish bowyer went about making it.

With the possible exception of early Arab bows, most oriental bows were composite. Of these, the Turkish bow seems to represent the most successful development of bows of this kind. If there were others that could outshoot the Turkish bow, we lack records of the fact. Pictures illustrating various kinds of reflex composite bows provide some evidence that the Persian composite bow may have differed little from the Turkish. An excellent plate showing the shape of a Persian bow when relaxed, with views of sections taken at various points along the limb, accompanies the article by Henry Balfour in Jour. Anthrop. Inst., XIX, opp. 245, 1889. The plate is reproduced as fig. 2, page 16, including the accompanying captions for the several illustrations.

The composite bow is made of a supporting skeleton or core of wood, to which, on the belly or compression side, strips of horn are glued; whereas the back, which experiences great tension, is provided with one or several layers of sinew fibers laid in glue. The function of the thin strip of wood in the limb is primarily that of supporting the materials that are so superbly suited to withstand the great forces of compression and tension which accompany the bending of the limb. Although straightness or reflex shape is not the criterion for composite construction of limbs, practically all such bows used in oriental lands were more or less strongly reflexed. By this is meant that the limbs of the relaxed bow are curved backward, i.e., they are opposite in curvature to that in which the limbs are bent when the bow is drawn. The great amount of bending which the short limb of the Turkish bow has to undergo gives rise not only to great stresses of tension and compression, but also to large longitudinal shearing forces which are highest within the wood strip, or in the region closely contiguous to the latter. Thus the wood and the glued joints had to be especially strong with respect to shearing stresses. The durability of the Turkish bow testifies to the excellence not only of the materials, including the glue which holds them united, but also of the skill of the artisan who combined them into the worthy implement that emerged from his craftsmanship.

The Turkish word for the bow is *yai*, for the arrow *ok*. The upper end of the bow is called *bash*, head; the lower end *ayak*, foot. The ends of the bow are rigid ears, with deep nocks for the string. Adjoining the ear is a section of the limb called in Turkish *kassan*,* in Arabic

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*The *kassan* in the Turkish bow seems unquestionably to be identical with the *siyah* of the Arab bow; in any event, it is a portion of the limb just beyond the bending portion, towards the tip. In "Arab Archery" by Faris and Elmer the authors describe the *siyah* as the stiff, unbending extremity of the limb. In the Turkish bow it does not include the ear. That the Arab bow may have had no ears is implied in Hein's observation that, according to the designations of the Prophet's bows, namely, "the yellow one," "the white one," "the straight one," "the crooked one," the early Arab bows were not reflex and therefore probably not composite. However the studied effort by the Muslims to show that all archery implements in later use derived from Mohammed resulted in ascribing the composite reflex bow to him also. This created much confusion. It may be surmised that the designation *siyah* for the unbending ends of straight bow was later transferred to the reflex composite bow, where it means the section designated "ridge" in the Balfour plate (p. 16), or the *kassan* in the Turkish bow. Hein's translation of *kassan* into German is "Grat" which means "ridge". In my estimation "shoulder" is more descriptive, if it is applied to the belly side of the portion which Balfour calls the ridge, not merely to the juncture between ridge and ear. It is the shoulder on which the string "rides" on the belly side of the limb.

siyah. It is the shoulder, the portion of the outwardly curving belly on which the string rests when the bow is braced. Each *kassan* is about a span in length. The section of limb between the *kassan* and the grip is called *ssal*. The juncture between the *kassan* and the *ssal* in the upper limb is *kassan basby* and in the lower, *kassan gezi*. The grip is called *kabza*. The juncture between the upper *ssal* and the grip is *tir getchimi* or arrow pass; the corresponding lower juncture is *kabza boghazy*. The nock is called *gertik* or *gez*. The outermost tip of the upper limb is *yai basby*; the back of the bow is *zahr*, the belly, *baghyr*.

There are two general classes of Turkish bows: those which must be conditioned or treated to dry them before shooting, designated *timarli*, and those usable at any time, without special treatment, called *timarsyz*. That there are bows which must be dried out before shooting, to develop their highest efficiency, validates Saxton Pope's opinion that a composite bow would quickly lose its utility in a damp climate, for the conditioning consists of driving out moisture by heating. It was the *timarli* class of bows with which flight shooting was invariably done. These contained relatively larger amounts of horn and sinew than the bows usable without conditioning; the latter accordingly contained the relatively larger amount of wood. Horn, sinew and glue being adversely affected by atmospheric moisture, the *timarli* bow could not deliver maximum cast without preliminary drying.

The general name for tournament flight bows was *pishrev*, from the name of the best flight arrow. In them the wood could be regarded primarily as the means for holding the other materials in their proper relative positions. The bow not requiring conditioning was ordinarily covered with leather, to exclude moisture. The target bow, *puta yayi*, was never used in flight shooting. Another kind of bow, usually carried by the seniors of the archers' guild was the *azmayish*, with which practice arrows of that name were shot. A light, slightly reflex bow, used only for practice in drawing, was called *kepade*. Other bows were named after celebrated bowyers and archers.

"The bow", says Kani, "must be so designed that when it is fully drawn, its full power is being utilized". This is a good maxim, whether the bow be composite or self, if one is to realize its potential cast. "If the arrow does not fit the bow, nor the bow fit the body, the arrow cannot be correctly shot. When the bow is very slightly larger than 'exactly right' it can be easily and safely braced, and gives a good flight. Target bows are longer than flight bows. The relatively short flight bow develops its full power at the cost of accuracy".

The force at full draw of target bows was determined by supporting the bow at the grip and loading the string at the nocking point until the displacement of the string reached the length of the arrow. No actual figures are given for weights of either target or flight bows. The latter, which required conditioning, were not tested in this manner. Instead, their weight was specified as the self-weight or mass of the bow. This method, in which the correlation between the mass of the bow and its force at full draw could hardly have been high, must have achieved whatever validity it had from the fact that such bows contained the same relative quantities of component materials, and had standard length. The range of masses as determined by weighing, was between 80 and 130 *dirhem*, which, in English measure, was between 9 and 14.6 ounces. Three such bows that I have weighed are remarkably alike; they weigh 88, 90 and 90 *dirhem*, or about 10 ounces. On the question of drawing force of Turkish bows, Ingo Simon says, in a letter: "There seems to be an idea that the Turkish bow was incredibly strong. This is not so. I have owned and handled at least fifty of these bows and amongst them fine ones; not including bows that had been weakened, they average about 65 pounds".

Since glue was the medium for holding the component materials together despite great stresses, its quality was of supreme importance to the bowyer. The best glue was made from the end pieces of tendons, suitable portions of which had been made into sinew fibers for backing. Obviously the whole tendon could and was used when the bowyer had a surplus. The tendon was immersed and

Fig. 6. Glue-cooking pot in which the bowyer prepared his glue from pieces of tendon, hide etc.

cleansed in hot water in which it was permitted to simmer for a short time. The greasy, dirty water was then poured off and replaced with clean rain water. The tendons were then slowly cooked over a charcoal fire, and clean, warm rain water was added from time to time to replenish loss by evaporation. After several days of slow cooking, the pieces had become "like leeches". The liquid was then strained off, evaporated to a viscous solution, and poured into shallow containers. When the mass had cooled and jelled, it was cut in pieces which were strung up on threads and allowed to dry in the shade. This constituted the bowyer's stock of glue.*

Glue may also be made from the ears and hides of cattle in the same manner. The resulting product is clear and white, like fish glue, and is next in quality to that made from tendons.

*For a discussion of modern glues, see page 131.

Of almost equal quality is fish glue, the raw material for which is the skin from the roof of the mouth of the Danube sturgeon. Depending on the size of the fish, the pieces of skin may be up to the size of two hands. It is translucent and sugar-colored, and has the strength of leather. A circular incision is made and the skin pulled out. The pieces are then dried, and are sent to the market in this form. To prepare glue from the pieces of dried skin, the bowyer soaks them in water for 24 hours, whereupon he stacks several pieces on a marble slab or block and pounds them vigorously with a wooden club or mallet. The latter is frequently moistened with saliva, for it is said that moistening with water adversely affects the quality of the glue. Pounding is continued until the mass has become quite thin, whereupon circular pieces are cut from it. Cutting waste is restacked and again pounded thin, and circular pieces cut from the sheet. These pieces when dried are the stock from which the bowyer makes his glue. To prepare the glue, the bowyer breakes these pieces into bits and dissolves them in clean water over a charcoal fire.

Frequently a mixture of tendon glue and fish glue is used. It may be supposed that fish glue was added to delay setting time, thus reducing the need for hurried work. It is said that a bow made solely with glue from tendons is unsuited to the use of long arrows and has inferior cast. Such a bow is well adapted to practice, however.

The wood that was preferred for the foundation of the bow was a fine-grained maple. This, when thoroughly soaked in glue, was said to acquire great elasticity. A comment on this report is that penetration by glue of such close-grained wood as maple cannot be great, hence the elastic properties cannot be much influenced by the glue. It is well known, however, from laboratory tests, that maple accepts glue exceedingly well, and is one of the best-gluing of all cabinet woods.

Out of their long experience the Turkish bowyers preferred wood from the vicinity of Kastamuni, but used maple from other parts of Anatolia also. That from Roumelia was considered inferior. They preferred wood from trees grown in the shade, in moist meadow soil. For the best bow wood, the tree should be cut during the brief period in which growth is dormant, at a height of one-half ell from the ground. Wood that was cut at the proper time was termed *kurd yemez*, "the worm does not gnaw it". From the entire trunk only a single billet was used which, when split, provides material for two bows. In one of the Turkish writings yew is also mentioned as bow wood.

The horn must be flawless. If it has a scale-like surface, or projections "like birds' tongues", it is not suitable for bows. The pure black horn of the carabao or water buffalo is used, as is also the horn of young longhorn cattle from the vicinity of Aidin, some 200 miles south of Constantinople. The bowyer saws the horn in strips, pairing the outer sides and the inner sides, respectively. The outer sides are harder than the inner. For superior sport bows, only the inner horn is used because it is not brittle, and does not deteriorate in the process of conditioning the bow.

For the sinew backing, Achilles tendons of cattle are used, cow tendons for the best flight bows, steer tendons for war bows. The best sinew is derived from tendons

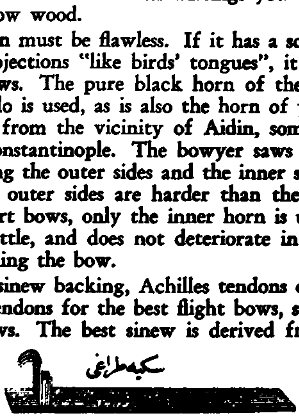

Fig. 7. Hatchel or comb, *sinir taraghi*, for reducing pounded, dried tendon to sinew fibers.

obtained near Constantinople. The tendons are dried in the sun, or in conditioning boxes for bows. After drying they are scraped, then reduced to fibers by pounding with a boxwood mallet on a smooth stone slab. The fibers are separated by means of a coarse-toothed hatchel or comb, through which they are repeatedly drawn until they resemble fibers from flax. They are then assorted according to length and stored for later use.*

It is self-evident, according to Hein, that in the construction of a bow definite quantities of the several component materials are used, and that the strength of the bow depends on the quantities. Apparently the wood foundation is not included in the weighed quantities; for, says Hein, if 30 *dirhem* of each, horn, sinew and glue are taken, a bow weighing 70 *dirhem* when finished results. The shrinkage in weight is accounted for by the removal of surplus materials in the finishing process. According to another source that is quoted, the wood is also weighed; for according to this report, a bow in which the quantity of wood weighs less than the quantities of the other materials becomes more strongly reflexed because of the preponderance of sinew, but its cast is impaired. The remarks are neither clear nor precise; whether the original text or the translation is at fault is not known.

Kani's illustration (fig. 8) indicates that the limbs are spliced to the mid-portion, and that the ears along with part of the shoulder are spliced to the arms, all with single

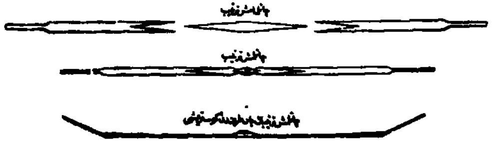

Fig. 8. The wood foundation of the composite bow, showing the parts before and after they are glued together.

fishtail joints. The ridge has a reenforcement of wood. A diagram in Payne-Gallwey's treatise, on the other hand,

*For this technique in American practice see pages 126 to 128.

shows arm, shoulder and ear as a single unit, spliced to the grip. Examination of a number of old Turkish bows shows the ears to have been spliced to the limbs, but the portion of the limbs near the grip could not be seen because of being covered with horn and sinew. The matter is hardly important. It seems somewhat easier to make the entire foundation as a unit without splices.

Measurement of the old bows gives results in close agreement with those of Payne-Gallwey, but they are reflexed much more strongly than the ones he shows in his illustrations. The length between nocks is 44 inches, measured along the side of the relaxed bow. The grip section is 6 inches long, and the arms, including the shoulders, to the point where the ear comes off the shoulder at an angle, are 16 inches each. The active portion of the limb is about 10 inches long, the shoulder being rigid. The widest part of the limb, at about 6 inches from the grip, is 1⅛ inches, and its greatest thickness, ½ inch. It is almost beyond belief that the short 10-inch section can safely bend the amount required by a 28-inch draw. It eloquently testifies to the elastic and mechanical excellence of the horn-wood-sinew-glue combination.

In the preparation of the maple foundation for the

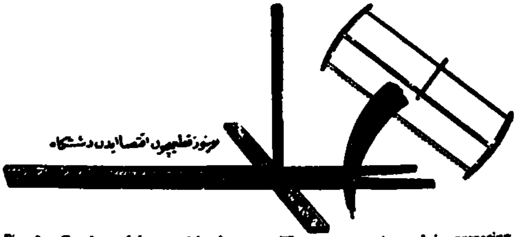

Fig. 9. Cutting of horn with the saw. The same saw is used in preparing the wood parts.

bow, the craftsman uses a primitive saw (fig. 9) and an adze, called *keser*, the universal tool of the Orient (fig. 10) with which he roughly brings the parts to shape. The arms are soaked in water for three days, then boiled until the wood is pliable. After heating them over a fire of chips, he bends them with the aid of a device called

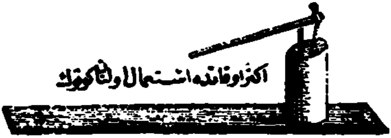

Fig. 10. The bowyer's basswood block, *kötük*, with the cutting edge of the adze, *keser*, imbedded in it.

destgah (fig. 22). To hold the parts until dry, they are firmly tied with cord. Before the wood is worked further, it is kept in dry storage at least a year.

The horn is also roughly cut out, and after it has been kept in boiling water to the point of pliability, it is further heated over fire and pressed to the desired shape in special molds of wood. The paired strips are stored together until needed.

To begin the construction of a bow, the bowyer selects a set of the wood parts from his store and dresses them down to the desired finish until the symmetrical parts are exactly alike and flawless. In the abutting sur-

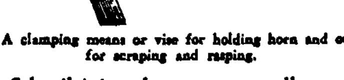

Fig. 11. A clamping means or vise for holding horn and other parts for scraping and rasping.

faces of the fishtail joints he scrapes small parallel grooves with a tool called *tasbin*, after which these surfaces are sized, and later covered with hot glue. A clear tendon glue is used, to which has been added some fish glue. Having spread the glue, he reheats the surfaces over a fire, probably to assure liquidity of the glue, then presses and binds the parts together. When dry, this constitutes the finished foundation, from which he scrapes the dried glue that was squeezed out of the joints. The foundation is then ready for application of the horn belly and sinew back.

The paired strips of horn, extending from the middle of the grip to a point well over the shoulder—approxi-

Fig. 12. Scraper for horn.

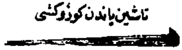

Fig. 13. The *tashin*, a toothed scraper, for finely grooving surfaces to be glued.

mately 18 to 20 inches—are now carefully fitted to the wood frame. The convex surface of the wood and the concave surface of the horn are scored with the *tashin,* and both surfaces sized with the glue mixture. The purpose of the scoring is to give greater holding surface and prevent sidewise slipping. For a good joint, the surfaces must fit accurately. A tight binding is next put on the

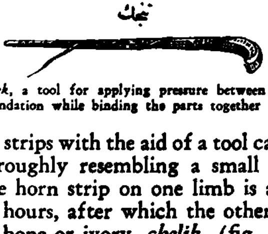

Fig. 14. The *tendyek*, a tool for applying pressure between the horn strips and wood foundation while binding the parts together in gluing.

wood and horn strips with the aid of a tool called a *tendyek,* of boxwood, roughly resembling a small wrecking bar. (fig. 14). The horn strip on one limb is allowed to dry for five or six hours, after which the other is applied. A small piece of bone or ivory, *chelik,* (fig. 3) may be inserted between the ends of the horn strips. This has the thickness of a knife blade, and is invested with religious mysticism. The partly finished bow is then hung up an ell or two above a charcoal fire until it is thoroughly dry. Because of the pre-shaping of the wood and horn, the bow is now partially reflexed.

Before applying the sinew back, the ears, which remain uncovered, are worked approximately to their final shape. The entire length of the back is then scored with the *tashin*. After heating the bow it is bent backward for greater reflex, and held thus with a cord. Several applications of hot glue for sizing are then made, after which the bow is ready for the sinew.

There are five different lengths of sinew fibers, the relative amounts of which constitute one of the secrets

Fig. 15. The glue-pot used in applying sinew backing.

of the bowyer. To discover the secret Kani recommends analysis of a bow of an acknowledged master by soaking the fibers apart in hot water.

In applying the sinew back, a fairly fluid mixture of tendon and fish glue is used. The bowyer's helper puts half the fibers in the hot glue, the other half being reserved for the second layer, to be applied later. He works them with his fingers to saturate and soften them, and to consolidate them into leather-like bundles. Short fibers are removed. When the glue-soaked bundles have the proper consistency, the helper hands the master a bundle of sufficient size to cover the grip. The bowyer, with the bow across his knees on a leather apron, molds the bundle in place. To apply the sinew properly he uses a tool called *sinir kalemi* (fig. 16). Made of brass, it has a rectangular blade, with a toothed edge on one side and a

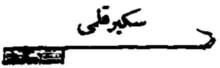

Fig. 16. The *sinir kalemi*, a bowyer's tool used in applying sinew backing.

smooth edge on the other. Its handle is a stout brass wire bent into a sharpened hook. This tool he keeps in a jug of water. At times he uses its teeth, at times the smooth edge, occasionally the hook; all the while he uses the fingers of both hands. In the meantime the helper is preparing the next bundle of fibers, of appropriate length, which the master applies in a similar manner. The tapering end of one bundle of fibers is placed in overlapping

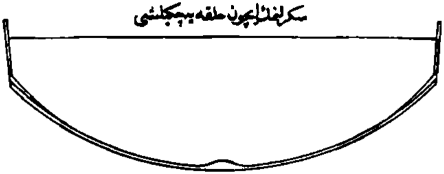

Fig. 17. The wood foundation after the horn strips have been glued on, ready for application of the first layer of sinew.

relation with that of the adjacent bundle, and care is taken to stagger the junctures along the back. Thus the bowyer proceeds until he arrives at the point on the ridge opposite which, on the shoulder, the string rests. Beyond this point, where the horn ends, the sinew completely surrounds the wood. The ears are not covered. The first course of sinew is now allowed to dry by suspending the bow a carpenter's ell above the ground. Experience shows that if it is suspended higher, the sinew cracks off.

After drying, the first course of sinew is given a coating of glue, which must be uniform and smooth. After

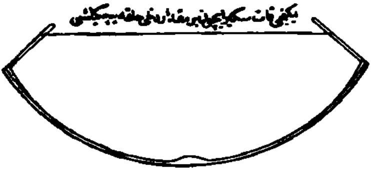

Fig. 18. After the first layer of sinew has dried, the bow is bent to a sharper curve and dried, and a second layer added.

this has dried, the bow is again heated, and reflexed further*, almost to its final shape, and the ends bound together as before. The surface is now slightly roughened with a rasp, the second course of sinew applied in the same manner as the first, and after drying, given a finish coat of

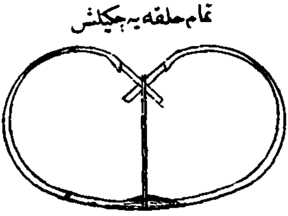

Fig. 19. The bow bent and tied in final shape.

glue. If, upon drying, the glue shows fine cracks, it should be rubbed with a moist sponge. Finally the bowyer again heats the bow and bends it to pretzel shape by drawing the ends inwardly and down, and binding them to the grip. The bow is left in this form for about a year,

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*The further reflexing is mechanically wrong, for it puts the outer layers of fibers under excessive tension compared with the inner. For more nearly uniform tension in the fibers, the first course of sinew should be applied with the reflex curve sharpest. The curvature should be diminished for each succeeding course.

"to become fully accustomed to the strong reflex". It improves with the length of time it is thus kept.

In applying the sinew, distinction is made between the bows to be conditioned and the bows to be covered with leather which do not require conditioning treatment. In the former the sinew is stacked, in the latter it is left flat. A bow with stacked sinew shoots farther, and does not lose its cast like one with a flat sinew back.

In all the gluing processes it is imperative to avoid even the slightest contamination with grease. For this

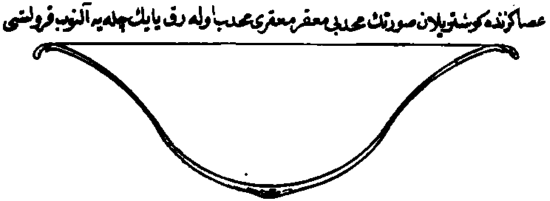

Fig. 20. The bow after its first bracing and before the limbs have been adjusted to proper curvature by means of the curved boxwood form called *tepelik.*

reason workmen in bowyers' shops are not permitted to eat greasy foods. Even the vapors from such foods contaminate the surfaces and prevent the glue from adhering.

After the bow has seasoned for a year it is ready for final adjustment in the tiller. This device requires little description, for every craftsman is familiar with it. It has four notches to hold the string, at 22½ inches, 26¾ inches, 28¼ inches and 29¾ inches, respectively. Any departure from perfect symmetry which the bowyer's practiced eye discerns in the bow when drawn in the tiller is corrected with the rasp or file. Tillering is done only after every trace of moisture has been driven off by hanging the bow in the sun at least two days, then warming it before drawing. No rasping or scraping is done until the bow has remained drawn in the tiller for several hours. After the first adjustment it is warmed again,

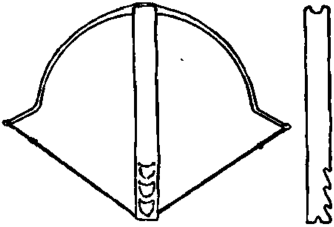

Fig. 21. A bow drawn in the tiller, and side view of the latter.

drawn to the next notch, and again adjusted. This is repeated until the last notch is reached. The Turkish bowyer acts upon the principle that the bow acquires its elasticity by drawing, and its flexibility by warming.

Upon having made final adjustment of the bow in the tiller, the bowyer removes it. In its braced condition, the bow is now symmetrical and its limbs are balanced; but it bends too much in the arms. To secure the proper sigmoidal shape of each limb, the bowyer uses a special form called *tepelik*. This is properly shaped of boxwood, curved and grooved to fit the bow arms. The latter are heated, while the bow is braced, and one *tepelik* is firmly bound against each arm. The bow is again drawn in the tiller and allowed to cool there. This evidently sets the limbs in their desired curves. After removal of the *tepeliks* the tillering process is repeated and uneven places equalized by heating and pressing, or by rasping if necessary. Thereupon the bow is unstrung, again heated, and bent into its reflex shape. If a flight bow, it is now ready for the conditioning box; if a target bow, it is hung up. After a day or two it is again braced, but without the *tepeliks*, and again adjusted by heating, bending and rasping, as needed. This may be repeated four or five times until the bow is flawless. When it is correct in every detail, it is finally smoothed. A target bow at this point is

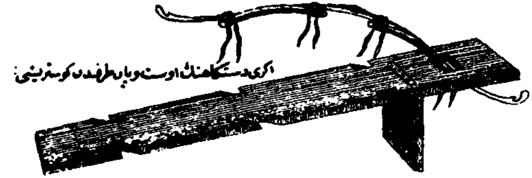

Fig. 22. A fixture, *destgah*, used in bending and shaping the limbs of the bow, so that the curved boxwood piece, called *tepelik*, may be bound to the limb to give it the proper curve.

covered with leather, decorated with paint and lacquer, rubbed with sandalwood oil, its nocks lined with leather, and hung up to dry. The bow is then ready to use.

The processing of a Turkish bow is seen to require unlimited patience, a high degree of skill, and thorough familiarity with all details. Luschan has estimated that the time required in production, including the intervals of drying and seasoning between operations, was from five to ten years. We can only conjecture that if a bowyer, working continuously, could perform the operations needed to produce only 100 bows in one year, he had to carry a stock of 500 bows in process before he could begin to sell those that were finished. It must have taken considerable capital, and the cost of the bows was therefore probably high. It is difficult to imagine an American producer of bows working for five years before he could realize income through sales. In the golden age of archery in Turkey, bow making must have enjoyed a high degree of stability as an industry.

The conditioning box is made of wood, suited to the dimensions of the bow, and provided with a tightly fitting lid. It is completely lined with horse-blanket felt. Supports are provided for the bow so that its ends do not rest on the bottom of the box. With the bow in place, the lid is fastened down, and the box placed in a depression, three digits in depth, in the baking oven. In 24 hours the bow is removed and braced. If it manifests improper bending, it is again heated and corrected, after which it is replaced in the box. A new bow, too heavy for its user, is drawn in the tiller and left a suitable number of hours after which it is adjusted for proper bending, then removed from the tiller and replaced in the box. In three days it is taken out and several arrows are shot with it. Thus the conditioning process includes adapting the bow to the strength of its owner, which is done by a repetition, as appears necessary, of keeping the bow fully drawn in the tiller for a period, and adjusting the limbs.

Heat treatment in the conditioning box may be extended several days, but need never exceed four. Proper and complete treatment may increase the cast of the bow by 100 *gez*. A bow which has been conditioned may also be improved by hanging in the sun; but before use, it must be suspended in a shady, airy place to cool it.

Untreated bows easily become damp and flabby in winter and in rainy weather. For this reason such bows are kept in a warm room, and before use, are hung in the sun. A braced bow must never be exposed directly to the sun for any length of time, or it will warp. On hot days, sun treatment is beneficial for any kind of bow.

From the foregoing it is seen that the purpose of heat treatment is the elimination of moisture from the bow. With so much material of animal origin, more or less hygroscopic, a bow quickly loses its elasticity upon exposure to dampness; and an excess of moisture promotes decay and disintegration.

CHAPTER V

BOW STRING, ARROW GUIDE, THUMB RING AND *MUSHAMMA*

The makers of bowstrings in Constantinople comprised a guild of five hundred members in eighty shops, as reported by Evliya. He terms it "a bad-smelling handicraft", which implies that gut and hide were the principal materials used in his day. The fact that they had affiliation with the guilds of cooks and of glue-makers provides support for the supposition. Hein asserts that in remote times rawhide strings, particularly those made from camels' hides, were generally used. These were said to remain constant in length, regardless of atmospheric conditions. He surmises, however, that the gut string, well known to the Arabs and probably quite serviceable in a dry climate, was not used by the Turks because of its variations in length induced by changes in weather. Such variations would not be conducive to the shooting of maximum distances, for this requires a precise and unchanging length of string.

In early times, the Turkish string appears to have been made of horse hair, from which it derived its name *kirish*, from *kir*, meaning horse. In later times they were made of unspun silk, finished at the ends with two loops called *tundj*, which were tied into the "skein" of silk with a special knot. The loops fitted the nocks of the bow. The raw silk was undyed, to preserve its strength.

"To secure maximum distance with a given bow, the length of the string must be exactly right. A string that is either too short or too long reduces the cast". The master bowyer used to determine the proper length of the string by measuring from nock to nock along the side of the unbraced bow, using a cord for this purpose. From its length he deducted 1/12, and from the remainder again 1/12. For a flight bow, the second cut was 1/6. The resulting length was correct for that particular bow.

Some masters accepted this method of determining the proper length of string only for practice bows, and held the view that for bows used in competition the length thus found would be excessive. In such bows, not only is the length of string critical, but the bow must in all respects be as nearly perfect as possible; otherwise a string, no matter how well fitted, might easily slip off the shoulders, since a bow so strongly reflexed is quite unstable. If this happens, and the bow violently springs back into its relaxed, reflex form, it is almost sure to break. To prevent such an accident, bowmakers—either because they were not particularly interested in having the bow shoot its greatest potential distance, or because of ignorance of these extreme refinements—became accustomed to the use of a rather "tight" string. Such a string, too short for maximum cast, makes for uncertainty of flight, although it increases the stability of the bow. A string that is too long also diminishes cast as well as stability. When the bow is correctly strung, the string should be about 8½ inches from the grip, but the exact distance depends somewhat on the bow and the archer. No inflexible rule can be written. Practice must guide theory. Some bows require a longer, some a shorter string. Most archers measure the bracing height by the span of the hand from the middle of the grip, thus eliminating the need of other measuring devices.*

A thick string is better for the target bow because it increases accuracy. A thin string is better for the flight bow because it increases cast. From the sound of the plucked string one can tell whether the string is suited to the bow. A thin string requires mastery of shooting technique, for unless the loose is clean, the arrow will flirt and lose range. With a heavy string the difficulty is not encountered.

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*This statement is interesting because of the resemblance of this practice to that of using the fistmele to check the bracing height of the longbow. The fistmele for the author's hand is just over 6 inches; the span, nearly 9.

The weight of the string is important. With *tirkesh* or combat type bows having a length of 12 fists (*ca.* 45 inches) the weight of a suitable string including its loops is 5 *dirhem*, and for a bow 10 fists in length, 3 *dirhem*. With larger bows of about 14 fists the weight is correspondingly greater, and may be between 5 and 6 *dirhem*. For flight bows, the weight is about 2½ *dirhem*. (The *dirhem* was about 49.3 grains.) An Arab saying affirms that the weight of the string should be 1/300 of the drawing weight of the bow. This could refer only to a relatively weak bow of the early Arab, longbow type. Hein believes that Kani was not aware of this type of bow, so that, to make the verse fit the strong reflex composite bow, interprets it to say that the string should be 1/30 of the mass of the bow as found by weighing. Kani rated bows by their own weight (mass), not their drawing force. Thus a bow that weighed 90 *dirhem* would require a string of 3 *dirhem*.

Abdallah computes the weight of the string according to the drawing weight of the bow: for a weight between 70 and 80 *rotl*,* 3-4 *dirhem*; for 100 *rotl*, 4½-5 *dirhem*; beyond this, up to 8 *dirhem*. This is in general agreement with the weights of strings used by the Khorasanians, who chose a string of 3-3½ *dirhem* for a bow of 70 *rotl*, 2-2½ *dirhem* for one of 60, and 1-1½ for one of 30 *rotl*. Abdallah further says of the Persians that they use a string of 4 *dirhem* for a bow of 150 *rotl*, and one of 3 *dirhem* for bow of 70 to 80 *rotl*.

The string from which the loops, *tundj*, are made consists of many strands of raw silk, saturated with a mixture of 5 parts beeswax, 10 parts rosin and 20 parts of fish glue. One must suppose that the dry fish glue is

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*According to "Commercial Dictionary of all the Coins, Weights and Measures in the World," by Joseph Palethorpe (Henry Mozley & Son, Derby, 1829), the *roll* or *rololo* was a weight used in Turkey and generally throughout the Levant, containing 176 drams English. This would be 11 oz. avoirdupois, or 4815 grains. "Arab Archery" by Faris & Elmer states that the "Ancient Arabic *rotl*" was 5760 grains, hence identical with the Troy pound.

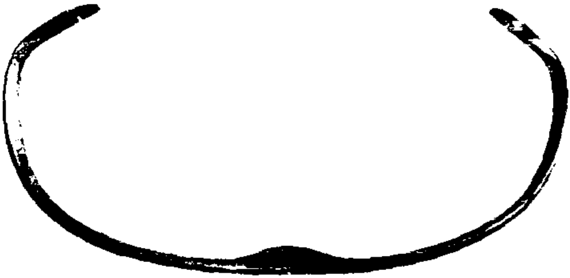

Fig. 3. Turkish *pishrev* bow from the author's collection, probably more than two centuries old. Note the ivory piece, *chelik*, separating the two strips of horn at the grip.

Fig. 4. Turkish bow in the Stone collection latter 18th century. (Courtesy Metropolitan Museum of Art).

Fig. 5. Detail of end of Turkish bow (1783), with leather-covered back, ornamented. (Author's collection, presented by Ingo Simon.)

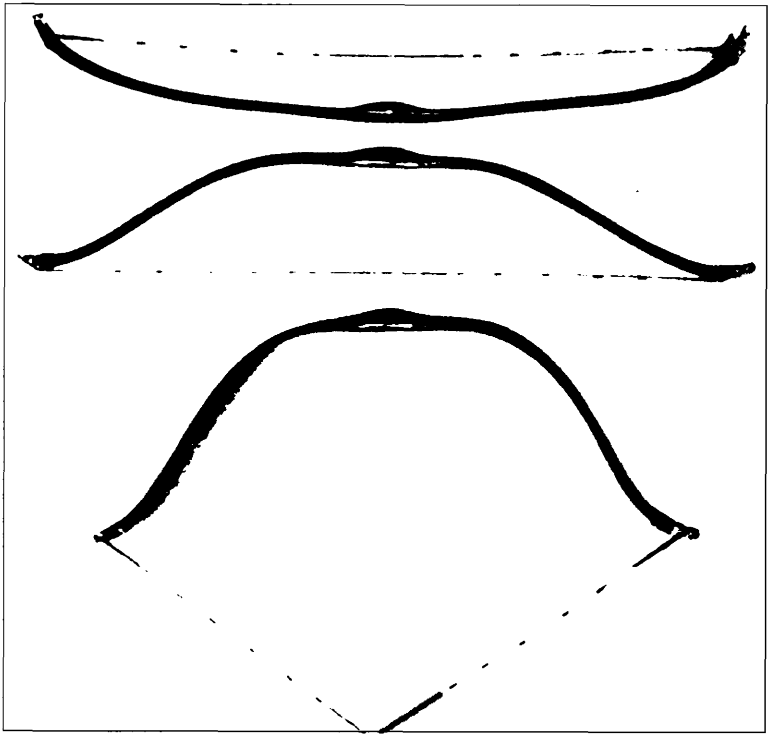

Fig. 23. A modern Turkish type bow a) relaxed, b) braced and c) at full draw. The bow, made by Mebert of Hamburg, is leather-covered, and draws 52 pounds at 26 inches.

Fig. 24. Old Turkish bowstring. (Stone collection, Metropolitan Museum of Art.)

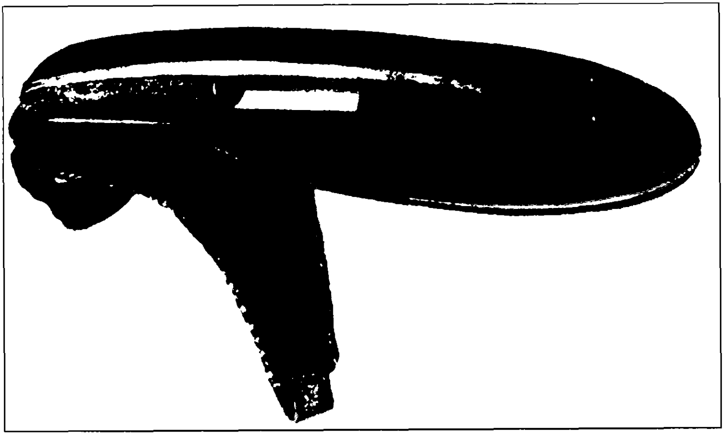

Fig. 28. *Siper,* with groove of ivory lined with morocco leather, with the *tabla* withdrawn about 1½" from its groove in the *esbik.*

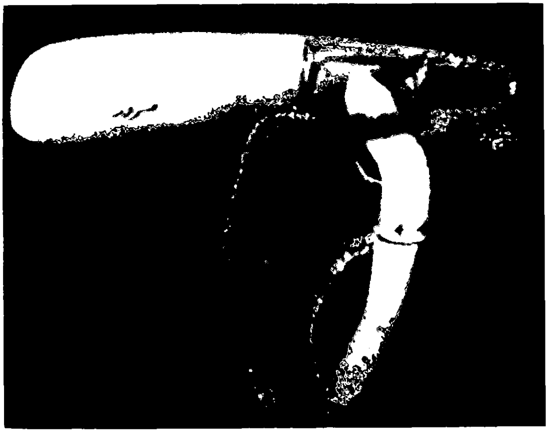

Fig. 29. Bottom view of the ivory groove of the *siper,* glued at its anterior end to the *esbik.* The strap fastenings are glued to the latter.

Fig. 30. The *siper* secured to the left hand.

soluble in the melted wax-rosin mixture. The bundle of strands is then twisted and allowed to dry, after which suitable lengths may be cut from it to make the *tundj*. Glue of the right characteristics may be used alone. Payne-Gallwey says that the loops were made of hard, closely twisted sinew. The skein of silk for the string is wound on two boxwood pegs placed the correct distance apart to give the desired length of string. A colored tracer thread is laid in with the undyed ones, as an indicator for absence of twist in the strand. As high as sixty threads might be used.

The knots of the *tundj* appear to command great respect on the part of Kani, and of his commentator as well. They must be perfectly symmetrical, and the loops must be of equal length, to avoid having the string slip off the shoulders during a shot. A verbatim translation from Hein, of the method of tying the knot as described by Kani, is the following:

"Lay the two ends of the *tundj* down, scissors-fashion, the right end crossing over the end of the skein of silk, the left end crossing the opposite way under the end of the skein. Each end is now carried around the skein and inserted through the end of the skein from opposite sides, and the *tundj* pulled up to the end of the skein. At the same time the skein is drawn firmly downward against the ends of the *tundj*, thus forming a tight, symmetrical knot. It is difficult to describe this knot; one must see it being tied. If one cannot see a professional tie it, it is best to loosen and analyze one already tied." This description seems to me to be clear, and its directions can be easily followed. Hein evidently failed to grasp it, for he presents a picture to show the knot which is not tied as Kani described it. However both knots, shown in figs. 25 and 26, appear to be suitable for the purpose intended. Experiments in tying them, using linen thread for the skein, and heavier twists for the *tundj*, including tennis-racquet

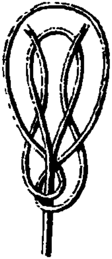

Fig. 25. Hein's conception of the manner of forming the *tundj*.

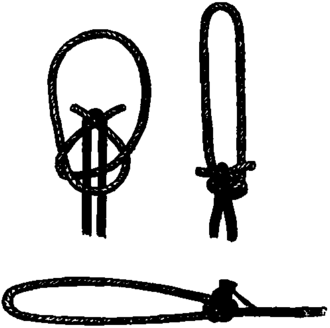

Fig. 26. Representation of Kani's description of the manner in which the loop, *tundj*, is tied. (From Payne-Gallwey's "Treatise on Turkish Bows".)

catgut, prove them satisfactory, both as to simplicity and utility. I know of no more simple method of making a bowstring.

When the loops have been completed, the string, now half finished, is put on a weak bow, and rubbed with clean wax. The knots are wrapped with silk, some glue applied, and the ends of the twist from which the *tundj* was formed heated with a glowing ember to keep them consolidated.

To protect the string against abrasion by the arrow, its middle is strengthened by a wrapping of silk for a distance of about a span. This wrapping or serving is called *meidanlyk*. The best kind of thread for serving is undyed raw silk. Wrapping of the string is begun at a point about two fingerbreadths above the nocking point, and carried downward a span. To apply the serving, take a sufficient length of three-ply silk and after having drawn it through wax three or four times, wind it smoothly about a piece of wood a digit in length. Assume a squatting position, and thrust the knees between the string and the ends of the braced bow. The section of string to be served then lies between the knees. The waxed thread is smoothly wrapped around the string without crossing turns, each turn fitting snugly against the next. In starting the serving, the loose end is laid along the string a short distance so that the turns are wrapped around it, thereby firmly securing it. Having arrived in the winding at a point eight or ten turns from the intended end of the serving, these turns are loosely wound and the end of the thread drawn back through each of these turns in sequence. Thereupon each turn is drawn up taut, proceeding outwardly to the end. The end of the thread is then pulled up snug, thereby securing it firmly under the last turns, and the excess is trimmed off. Between the serving and the loops, several short sections of serving are applied to hold the threads forming the string together.

THE ARROW GUIDE, *siper*. To Hein is due much credit and appreciation for having given us, in an occidental tongue, the information that Kani set down in Turkish; but, laboring under the handicap of lacking practical knowledge of the bow and its associated gear, he is in great perplexity over things that were commonplace to Kani, the accomplished archer, and described by him as by an archer for archers. Kani took for granted that his readers were not completely innocent of knowledge of things that were so familiar to him. He considers a description of the *siper* superfluous, "since it is generally familiar". Hein finds himself in a dilemma to describe accurately either the construction or use of the *siper*, that indispensable accessory in the Turkish archer's kit. Hein interprets Kani as best he can; he refers to the *siper* as "this peculiar, almost unknown device of the Turkish archers", and states that it is a trough fastened to a support that was strapped to the archer's left hand to receive (*aufzunehmen*) the arrow.

He cites other writers, such as Luschan and Essenwein, neither of whom knew the techniques of archery. Luschan, he says, describes the *siper*, "a Persian protective plate", about as follows: An oval brass plate with diameters about 9.3 x 12 cm (3.62 x 4.75 inches) which carries a parchment, adorned with Persian verses, with a protective cover sheet of thin, transparent horn, is provided at its middle with a trough of wood protruding through the plate. The trough is slightly curved below, and has a strap arrangement for fastening. The edge of the plate is finished with a braiding of silk and silver wire.

This is a confused, inadequate word picture, which bears evidence of Luschan's ignorance of the purpose of

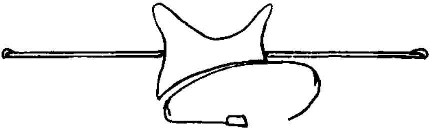

Fig. 27. Luschan's conception of the *siper*. This view approximates a vertical section through the middle, perpendicular to the arrow.

the *siper*, since his attention is largely fixed on the oval plate, an accessory not essential to the function of the device. The word picture remains confused and inadequate despite the illustration (fig. 27) stated by Hein to be a sectional view. Luschan is reported as having been originally correct in assuming the *siper* to be "a trough for arrows" but that he later abandoned this view, on the fallacious reasoning that the trough was quite unsuited to arrows, but highly useful to catch the rebound of the string. Hein properly observes that this would have required the trough to be worn in a vertical rather than horizontal position, which was untenable, and that, moreover, the Turks did not wear an armguard. But positive enlightenment about the *siper* is slow in developing under Hein's pen. He adheres closely to such descriptions as Kani gives, and frequently indicates his uncertainty by the use of the parenthesized question mark.

Fortunately we have an actual *siper*, as well as photographs of several other, excellent examples of the device, with a fair illustration of the manner in which it was used. These provide the needed clarification for Hein's lengthy and labored translation and commentary.

Briefly, the *siper* is an accessory which the Turkish archer used for making a long draw with a short arrow. It was secured to the bow hand, and enabled him to draw the arrow several inches inside the bow. He evidently had full appreciation of the value of the long draw for increasing substantially the energy in the drawn bow, and of the short arrow with its greater spine, its diminished tendency to buckle under great thrust, and the lessened drag or air resistance. The *siper* gave him both advantages. Its construction was adapted to his manner of shooting. The arrow, drawn as much as three inches within the bow, had to be guided past the grip safely. That was the function of the *siper*. (See figs. 28, 29, 30.)

The principal tool of the craftsman in constructing the *siper* was a special form of adze with a semicircular, hardened cutting edge that was sharpened by grinding on both sides. Another tool was the Islambul file, two spans in length, of constant width, rounded on one side and flat on the other. Also required was a pressing or forming die, made of cornel cherry or boxwood, about three spans in length. The four sides of a piece of such wood are planed smooth, and in one side a rounded groove is carved with the special adze. One end is rounded for a handle. Another similar piece of wood is turned to fit the groove, and hinged at the end with the grooved piece. This nutcracker-like tool was used for pressing a strip of horn or tortoise shell, after suitable heating of the piece, to the approximate shape of the arrow trough of the *siper*. The trough was then worked to exact shape by rasping and filing. This method of forming the trough was not used when the material was walrus or elephant ivory, or when a massive piece of buffalo horn was used. In such cases both the trough and underpiece were made in a unit. Finishing was done with files and scrapers, of such form and contour as were required by the curved surfaces of the groove and the contours of the associated parts. Final polishing was done with chalk and olive oil, applied with the flesh side of a piece of soft leather. Black buffalo horn was polished with powdered charcoal instead of chalk.

Heating of the strip of horn or shell for pressing was done by first boiling in water, then heating further by exposure to the flame of resinous wood. The heated strip was then placed in the grooved surface of the press, the handles slowly squeezed together and firmly bound, and the strip allowed to cool under pressure.

Ivory was frequently dyed. Kani gives recipes and instructions for coloring bone or ivory green, red, blue or yellow, all based on soaking the piece in yoghurt, sour milk or buttermilk, with certain addition agents, for many days to several weeks. Evidently lactic acid was essential to the process.

The form of the trough is described in some detail. Longitudinally the trough should have slight upward convexity, which may be tested by laying a straight, cylindrical test-piece in the trough. This should rock slightly in the fore-and-aft direction, over the highest part in the middle of the trough. The groove should be neither too deep, nor too wide, nor too narrow, so that the arrow when loosed will not strike it; neither should the arrow drag in the rear end of the trough, in what is called the "tail" of the *siper.* This posterior portion as well as the anterior, called the "head", must have the same width, nor may the middle be narrower. In short, it must be uniform in width. But Kani carefully avoids stating what the width should be. The *siper* that I have has the following dimensions: Length, 4¾ inches; width, 1 inch at the ends, 1-1/16 inch in the middle; depth, ¼ inch. The middle of the groove is about 5/32 inch higher than the ends, curving in an approximately circular arc of about 18 inches radius.

The underpiece called the *esbik* is usually made of linden or maple wood, unless it be carved out of the same block with the trough. Its length depends on the length of the latter. It is shaped by rasping and scraping to fit the hand of the intended user. The trough is glued to the *esbik* with slight inclination towards the left.

The inner surface of the trough is smoothed carefully after which a piece of thin morocco leather is glued over it. With practice arrows the *siper* may be used without the leather. When so used it may cause the arrows, *hava gezi,* which have no points and ordinarily of short range, to fly greater distances. On the other hand, it is not to be used without the leather when arrows with bone or metal tips are used, for this would cause a deflection detrimental to flight. The leather is thinned by skiving away the flesh side. It is sized with fish glue, then coated with more glue and allowed to dry. Upon moistening, it may be stuck to a surface, and used whenever desirable. It also serves as an emergency plaster for protecting a finger nail, or to cover bruises that occur in shooting. Such leather is known as *maska,* a name which also designates the gluing process by which it is applied.

For the *pishrev* or flight arrow, the groove is short.

For the arrow called *ssala koshusu*, tipped with iron and used in shooting for prizes, the groove must "fall away" towards the wrist so that when the arrow is drawn far back, it will not press down on the tail of the *siper*.

The description of the straps for fastening the *siper* to the hand is somewhat obscure. Hein says that this chapter in Kani is handled somewhat shabbily ("stepmotherly"). Kani considered a detailed description superfluous "because it is so generally and well known". Hein therefore translates as nearly verbatim as possible. What follows is a direct translation of Hein, in which it is attempted to convey, as closely as possible, the sense—or lack of it—of Hein's rendition.

"This strap, *tasma*, with which the *siper* is fastened, is cut accurately to fit the form (pattern?). When it is secured to the hand, it must fit snugly everywhere, like the skin of the hand. It is made from the best, firm morocco or other suitable leather, cut in the well-known shape. That part which corresponds to (or is located beneath) the head of the *siper* should be long, and the place where the ribbon is fastened should be cut away so that the section of ribbon between the hand and the bow grip may not cause abrasions and blisters. One avoids gluing flannel or velvet beneath the strap; rather one uses water silk or tafetta, to avoid adding thickness that would raise the *siper*. For the same reason one must use fish glue, and not the paste used by saddlers.

"At the left side beneath the head of the *siper*, where the water silk is glued under the leather, a narrow, thin ribbon is glued and sewn with thread. The strap, glued to the *siper* by the *maska* process, should be neither too tight nor too loose on the hand. The ribbon is carried between the thumb and index finger to the wrist and tied to the buckle, or to the strap near it. Then, with the proper grasp of the bow hand on the grip of the bow, the ribbon is so glued that the head of the *siper* rests close to the bow, and the tail, as it should, points towards that place on the arm which is selected by surgeons for bleeding or cupping. Thereupon the strap is carefully removed from the hand and, after partial drying of the glue, the *siper* is tested by using it in the shooting of an arrow. If this reveals improper fitting of the parts, they are separated and reglued to correct errors.

"If the tail of the *siper* is excessively elevated, it gives rise to the error known as *tir siperde boilama*, in which the entire length of the *siper* is occupied by the arrow. This requires a lowering of the rear end of the support. If the arrow 'erects itself' the rear end of the supporting member must be elevated.

"Should the ribbon be drawn insufficiently tight and the arrow is drawn back so that its tip rests in the tail of the *siper*, it causes a tilting upward of the head as suggested in the expression 'the first rears up' ('die Faust bäumt sich'). One must carefully do the fitting and trying in such a way that the head of the *siper* is not drawn excessively towards the bow-grip but that, at the same time, it does not present too great an opening towards the thumb ring side (auch nicht nach der Daumenringseite zu sich öffne). The left rim of the groove should be virtually united with the grip.

"When the shooting test takes place, a master archer should be present. The grasp of the bow-hand, either right or left, should be free from any errors that would be counter to the expressed rules and regulations. A trial is made with a light bow, to determine whether the arrow moves forward in the *siper* with precision, without dragging, and without a rising up of its tip in the middle of the groove. Once the *siper* has been cleanly fitted, and an error later manifests itself in shooting, the error arises not from faulty construction of the *siper*, but obviously from carelessness in its use; and effort must be made to overcome the error."

The *tabla,* though not an essential part of the *siper,* since the latter is usable without it, was nearly always provided as a safety device. Though existing in numerous modifications as to material, finish and embellishment, in structure it is an elliptical plate, interposed between the arrow and the bow-hand, of such size that the latter is protected against injury from an overdrawn or broken shaft. The *eshik,* on which the trough is mounted, as has been described, is provided with a rectangular groove on each side and across the posterior end. A longitudinal slot, parallel to the major axis, at one end of the elliptical plate, snugly fits the grooved *eshik,* thus holding the *tabla* securely, providing a reliable shield for the hand, and interposing no obstacle to the travel of the arrow or the string (fig. 30). One *tabla* which I have measured is five inches long and three and three-quarters wide. The slot in the anterior end is an inch and six tenths long and eight tenths wide.

Kani states that the *tabla* is made of tortoise shell, horn or sheet metal—silver, copper or brass—and that it is covered with polished lizard skin, from Franconia, of the kind used in carrying cases for timepieces and telescopes. It is usually dyed green, but the undyed and unpolished leather may also be used. He gives directions for coloring the leather green with sulphuric acid, spirits of ammonia and copper shavings. The leather thus prepared is glued to the roughened surface of the *tabla,* and the edge bound with cord, braid or silver wire.

Hein becomes hopelessly involved in attempting an explanation of the function and use of the *siper.* He states, for example, that the arrow passes the grip on the left side. He evidently saw one German writer's erroneous explanation of the archer's paradox with the Mediterranean loose (Buchner, "Globus" XC, 1906, 75), based on the earlier writings of Horace Ford, and of Longman and Walrond, and endeavors to apply the concept of Buchner to the release of an arrow from a Turkish bow, with a thumb ring and *siper*. Even if Buchner's explanation were correct it would fail to fit Turkish shooting, a fact which Hein did not appreciate.

Kani is quoted as saying that the arrow which is deflected towards the right, in passing the bow, usually hits the mark, hence this kind of shot is regarded with favor; but if the deviation is too great, it reduces the distance. However, it is undesirable to have the arrow drag on the bow. On the contrary, it should pass the grip closely but without contact. For this reason it has been suggested, as an exaggeration, that one should, if this were possible, bore a hole through the middle of the grip and shoot the arrow through it. This suggestion seems to be one of the earliest of record of a so-called center-shot bow.

Hammer-Purgstall confuses the *siper* with the bracer, as described by Hansard, "The bracer is a well known contrivance for protecting the archer's wrist from being bruised by his bowstring". Evidently Purgstall did not read Hansard as attentively as his footnotes might indicate, for, a small number of pages further, Hansard says, "One other curious contrivance connected with the oriental bow remains to be described. When flight shooting, to which they are particularly attached, a grooved horn, about six inches long, is fastened upon the back of the bow hand by straps of crimson morocco buckled around the wrist."

THE DRAWING RING OR THUMB RING (*zyghyr* or *shest*). The makers of thumb rings comprised a guild whose *pir* was Ali b. abi Talib, who, in accordance with the admonition of the *hadith*, taught his sons Hasan and Husein the art of archery. In earliest youth he was desirous of having means for protecting the fingers against the pressure of the bow string; hence, on the command of the

Prophet, he invented the thumb ring. According to tradition, it was made of ram's horn.

The thumb ring is the most important accessory required by the Turkish archer, for without it he is unable to shoot. It is made of gold, silver, jasper, ivory, and horn of many kinds, and is worn on the thumb of the drawing hand to distribute the pressure of the string over the inner area of the end of the thumb, and to guard the thumb against injury at the loose. The best rings are made of walrus tusk, because this material takes a good polish and does not turn yellow. Ivory is a permissible material and does not interdict the saying of prayers when carried in the pocket; but it turns yellow quickly. Deer horn is suitable for practice rings, but the main stem below the branch must be used on account of its hardness. Better still is a ring of rhinoceros horn, a material midway between sinew and bone which takes a good polish. The most widely used and cheapest material is buffalo horn.

According to Hein, many curious conjectures and false notions have arisen regarding the use of the thumb ring. He cites authors of several articles to illustrate "these most peculiar hypotheses", but in so doing commits the blunder of asserting—a second time, incidentally—that the arrow was shot from the *left* side of the bow. He mentions Boeheim, who places the thumb ring on the archer's left thumb, to be used as an arrow rest; Hein's comment is that this would require that the arrow pass the grip on the right. "To be sure", says he, "this manner of drawing is ascribed by Jacoby to the Japanese; indeed, Mylius identifies this draw with practically all Asiatics. Be that as it may, the thumb ring was not used to protect the left *thumb*. Moreover the Turks, by virtue of using the *siper* which was buckled to the left hand, shot the arrow off the left side of the bow. Essenwein thinks of the ring as being 'seated' at the root of the left thumb, to serve as protection against possible impact of the string. All these hypotheses are pure fantasy." To them we must add Hein's.

From the detailed manner in which Kani describes the thumb ring, how it is worn, and how the bow is drawn and loosed, it is obvious that Payne-Gallwey is in error in showing the ring reversed* on the second segment of the thumb, with the string engaged behind the acute angular edge, and held in place by closing the first finger against the ring. Having made several rings and tried them as described both by Kani and Gallwey, I am certain that Gallwey's method would result in severe contusion of the thumb, were it employed in drawing a bow as heavy as the Turkish flight bows. The thick-walled, almost cylindrical rings of the Chinese were thus used, but not the Turkish. This is corroborated by Morse's classical monograph on methods of arrow release.

To construct the thumb ring, one side of the block of horn is left straight. The opposite side is cut at an angle, and the shape is worked out with *keser* and rasp. A hole large enough for the thumb is drilled. It is then further worked, both externally and inside, so that the protective surface *dimagh* on which the string rests during the draw and over which it slides at the loose may exactly fit the contour of the thumb. A model of the thumb may be made of sealing wax softened in hot water, to serve as a convenient aid for fitting the ring. The *dimagh* requires special attention, so that it may be neither too short nor too long. If it is too short, the string may injure the tip of the thumb, and the distance of the arrow be reduced. If it is too long, it interferes with the proper hold of the middle finger in forming the "lock" for

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*A Treatise on the Construction, Power and Management of . . . Turkish . . . Bows" p. 14. Professor Henry Balfour wrote me that he had reviewed this book in the anthropological journal "Man" in 1907, and had criticized the manner in which the use of the thumb ring is portrayed.

drawing the string. The outer surface of the *dimagh* is rounded, as if turned on a lathe. The inner rim of the *dimagh* should be wide enough to prevent bulging of the flesh of the thumb over its edges. At the point where the ring lies in the inner angle of the bent thumb, it is slightly relieved by tapering, to permit sufficient bending. The opening is made slightly larger than the thumb because a piece of leather called *kulak* is glued by the *maska* process inside the ring. The leather has a protruding flap called *kash*. This leather insert serves as added protection to the thumb during the draw. The *dimagh* should be so finished that the string does not slide back to the *kash*, for if it does, it interferes with a clean loose and cause blisters, from excessive pressure on the joint of the thumb. Such an injury may be troublesome for several months. The ring, with the *kulak* glued in place, must fit perfectly. To achieve a perfect fit, repeated trial and alteration are necessary. It must, in fact, be a masterpiece. If it is too large, it may be wrenched off the thumb at the loose; if too small, it may stop circulation and cause the thumb to turn blue. Kani says that there is something peculiar about achieving a proper fit. The thumb can feel when it is correct, though the maker of the ring cannot be certain about it. Certainty must be proved by actual trial. Every master artisan has his own views on this subject, and an accurate description or directions cannot be written. It is a matter of experience. The greater the experience of the master, the more frequently does he succeed.

The Turk used no bracer or armguard, for his bow was braced very high, which obviated impact of the string on the arm; nor could there be a rebound of the string after the shot because of the great tension in the string. Turkish sleeves, close-fitting, could not interfere with the string.

The old Arabs, on the other hand, used long, low-strung bows, with low initial tension in the string, and wore flowing, loose sleeves. Kani says that they used means for confining the sleeves either by a tight wrapping of bandage-like cloth or a guard of gazelle leather.

THE MUSHAMMA. The Turkish sport bow had but a small grip—barely a normal handful—which made a firm grasp difficult. To remedy the deficiency the archers used a strip of wax-impregnated cloth which they wrapped around the grip before using the bow. This made possible a firm grasp and prevented a turning of the bow in the hand. The *mushamma* was a recent invention. It cannot be traced back to a *pir*, for in earlier times the grip was larger and required no padding.

Purgstall quotes Schlechta-Wssehrd's description of this accessory as being "a two-foot long strip of waxed linen, which is wrapped about the bow handle, to fill out the hand which grasps the handle, to enable it to hold the bow with greater firmness and certainty."

The archer prepares his *mushamma* with pure yellow beeswax or camphor wax. This is melted and poured into cold water, which separates out all dirt and leaves the wax clean. The wax is scraped into flakes and remelted; and in this liquid a thin material like batiste or water silk is allowed to "cook" for a time until it is thoroughly saturated. The cloth is then removed with tongs and the surplus wax allowed to drain off. Before the material has completely cooled it is properly folded for sewing. For winter use, it is advisable to add 10% turpentine to the wax, to make it more plastic. Before applying the strip in cold weather, it must be thoroughly warmed.

Hein states that the shape and dimensions of the bandage-like contrivance cannot be clearly deduced from the Kani text, and remarks that this particular chapter is very difficult to understand. The length is stated to be an ell, and the width to taper from ½ ell at one end to ¼ ell at the other. (The ell might have been anything from 25 to 45 inches). The relative dimensions given are hardly credible. A specimen of *mushamma* in my possession has a length of 35 inches. Its edges are folded inwardly, and sewn together approximately along a mid-line. (Fig. 35). The finished strip measures 13/16 inch at one end, and tapers to ⅝ at the other.

Kani, who assumes that the people for whom he is writing his "Excerpts" will have access to the various devices that he describes, gives the good advice to obtain a used specimen, rip open the seam and use it as a pattern for a new one. The strip of fabric thus cut out is folded inwardly along both edges and the folds creased. The creased edges are then brought into abutment and sewn together, leaving the folds on the inside of the tube thus formed, which is then flattened out with the seam in the middle. The seam must not be at an edge, for this would interfere with the proper grasp of the bow, particularly while the *mushamma* is new. When the strip has been properly made the width at the narrow end should be one-third less than that of the other, for when it is wrapped around the grip each turn should be narrower than the preceding one. This requires that the wrapping begin with the wide end.

The width and length of the *mushamma* depend on the size of the archer's hand. For people with long, thin fingers and a wide hand it should be both long and wide. For those with short fingers and a small plump hand it should be small and short.

The process of wrapping the grip of the bow is difficult to understand from Hein's description. According to this, one begins with the wide end at the left side of the bow, winds the bandage about the grip so that the left end remains low whereas the right end comes fairly high (presumably on the bow grip). The lower layers should be of equal heights whereas the upper ones should appear as steps. There is another method of winding in which the two ends (of the winding?) are symmetrical.

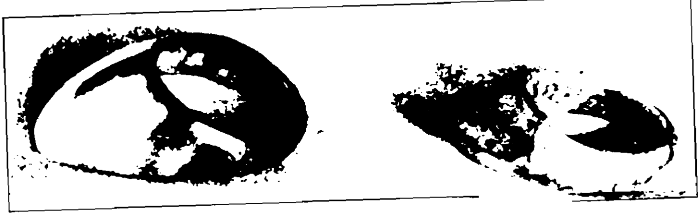

Fig. 31. Left: A thumb ring made by the author from cow's horn. Right: A Turkish thumb ring of silver, with its leather insert, *kulak*. The outer flap is called *kash*. (Author's collection.)

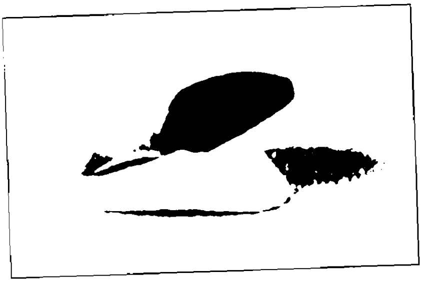

Fig. 32. Turkish thumb ring of ivory with *kulak*. (Eppley collection. Photograph from Marion Eppley.)

Fig. 33. Thumb rings in the Stone Collection. (Courtesy Metropolitan Museum of Art.)

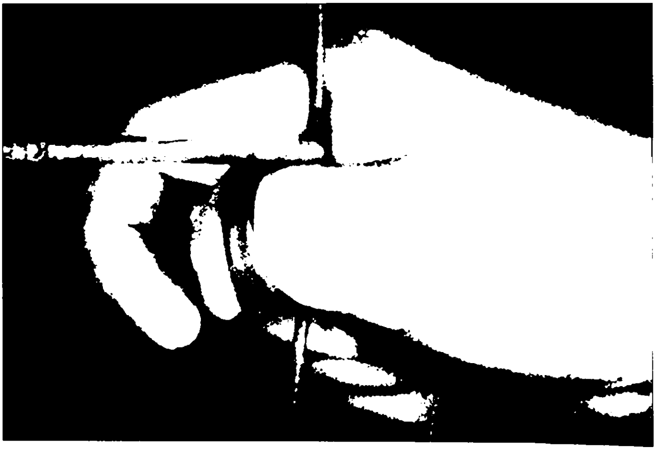

Fig. 34. The draw, *mandal* with the thumb ring. The thumb should be flexed more than the photograph shows, and its tip should press firmly against the side of the third finger. The third, fourth and fifth fingers are tightly clenched.

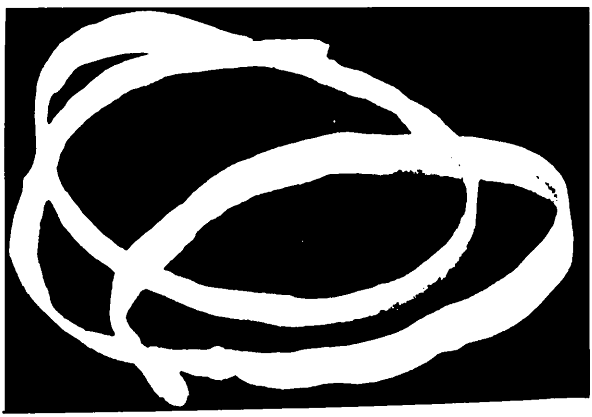

Fig. 35. The *mushamma*, a strip of waxed linen to be wrapped about the bow-grip.

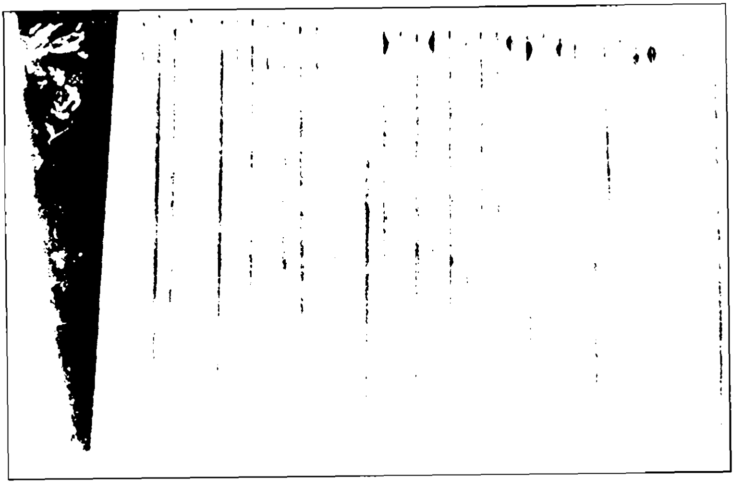

Fig. 36. Quiver with *pisbrev* arrows, Stone collection. (Courtesy Metropolitan Museum of Art.)

Fig. 37. Turkish arrows from author's collection. Reading downward: *hava gezi*, *torba gezi*, *pishrev* shaftment, *pishrev* foot (note repair with diagonal glue line), *puta*.

Fig. 38. Arrow for flight practice, *abrish*. (Courtesy Metropolitan Museum of Art.)

It is said that one must determine carefully which of these two kinds are best adapted to the archer's hand; for this assures far-flying arrows.

The lower left end of the winding must be made flat to prevent bulging at this point, which would interfere with a comfortable grasp, and cause the fist to be inclined towards the right and the arrow to fly in the same direction.

There follow several paragraphs that are quite unintelligible, but their purport seems to be that the principal consideration in the use of the *mushamma* is its providing bulk for the hand that holds the bow, and that the wrapping must be correctly applied to the grip in order that the bow may be properly held and the *siper* properly aligned for good shooting.

A partial picture of the *mushamma* may be gained from the following passage, which deals with the disadvantage of a bandage that is too wide:

"The little finger and the one next to it must grasp the bow handle below the *mushamma*, while the middle and fourth fingers must come between (?) the *mushamma*. If then the *mushamma* is too wide, one cannot correctly grasp the bow; aside from the fact that a waxed cloth between the fingers causes trouble, it also spoils the shot. If, on the contrary, the *mushamma* is too small, the grip, in the palm of the hand, does not correctly find its place on the root of the thumb, and the fist shows a tendency to bend upwards. This causes the error called *shalanmak*, in which the fist inclines upwards instead of downwards, as it should."

CHAPTER VI

TURKISH ARROWS

The construction of arrows was the domain of the guild of arrow makers who at the time of Murad IV had 300 members in 200 shops. Their *pir* was Omar ibn al-Hattab, the second khalif, who during the time of the Prophet is supposed to have disclosed methods of producing straight arrows and applying the tips. Evliya mentions Abu Muhammed who was the bearer of the bows and arrows belonging to the Prophet, and who in times of peace was an arrow maker. The making of arrows was highly regarded. We find among makers of arrows many high officials who were also good archers. Kani mentions, among others, the *imam* of the old palace, Mehmed Efendi, who was custodian of the seal of the grand vezir Siyavush Pasha. The requirement cited by Ibn Bahtiyar that a good arrow maker must also be a capable archer is met among those mentioned as well as in Kani himself, who not only made arrows but also made several record-breaking shots.

English arrows are classified by Horace Ford* as bob-tailed, chested, barreled and straight. The Turks had similar kinds, but classified them not only according to the shape of the shaft, but also according to the kind of fletching and their use. The diameter of the shaft just forward of the nock, called the "neck", is invariably smaller than that of the middle portion, called the "belly". In the "special form" the middle third is thickest, and the end thirds are somewhat tapered. The "cord form" is cylindrical. The "candle form" tapers somewhat towards the neck and much more towards the tip; the latter resembles a rat tail. The practice arrow, *hava gezi*, is bob-tailed. In his discussion of the types of shaft, Kani makes interesting remarks about air resistance. "Just as the fishes which swim with greatest speed are largest at the forward end, so it is also with land creatures which run

*Ford, "Archery, its Theory and Practice, 1856, p. 34.

swiftly, like lion and greyhound: they are most fully developed in their anterior parts. Likewise, an arrow which is constructed along these lines, namely with large foreshaft, and tapering towards the nock, encounters the least air resistance; its speed is less reduced by air friction than is that of the candle form." Hein brings the comparison up-to-date by reference to the tear-drop form of streamlined automobile.

The *sheikh-ül-meidan*, Hafiz, has said that the secret of shooting is not disclosed by descriptions, but that it depends on many factors—possibly even upon such insignificant matters as the wrapping on the string. The act of shooting is a secret which admits of no exact description or comparison. Consequently no opportunity should be neglected of determining by trial what kinds of arrows are best suited to the use and requirements of the archer.

In Kani's time there were ten kinds of arrows in use, classified according to fletching. The vanes of Turkish arrows show characteristic differences, depending on the purpose for which the arrow was intended. Feathers of the swan, the eagle, the white and spotted pigeon, and of the cormorant were used. Both pinion and tail feathers were employed. Only the narrow or inner vane of the former was suitable for flight arrows. The shape of the feather on the arrow was "like a cudgel, or butterfly wing". All three feathers must be from the same side of the bird, either right or left. "Those from the left wing are better for flight arrows, because they give the arrow higher velocity; those from the right wing give a flat trajectory, hence are better suited for target arrows. These cause the arrows to fly towards the right, while the left wing feathers cause deflection towards the left. Allowance must be made for these deflections in aiming". Lacking feathers, the fletcher sometimes used taffeta or batiste stiffened with thin glue. These artificial vanes were not so durable as feathers, but otherwise probably suitable. The vanes of the feathers are stripped from the rib, and applied to the shaft immediately in front of the nock. One of the three is placed on the lip of the nock, the other two at 120° with reference to the first.

The flight arrow called *pisbrev* was the most important from our point of view. It was a self arrow of pine, with a bone tip. Its nock was brazil wood, but occasionally wild goat's horn was substituted. The average length is reported to have been 20 digits* (62.2 cm or 24.5 inches). The length of the feather was 1 digit, and its greatest height 1/3 digit. Most of the Turkish flight arrows in the Stone collection, and others that I have had opportunity of examining, are evidently *pisbrev*. Two other flight arrows were used, *baki* and *kara batak*. These are of lesser quality and somewhat heavier than *pisbrev*. All were shot with a conditioned flight bow, but the *pisbrev* alone was used in tournament competition.

The *azmayish* arrow, light and thin, with an iron point, was used by the seniors of the guild. It weighs 2½ to 3½ *dirhem*, is 66 cm (26 in.) long and has swan's feathers. It was used in shooting for prizes. A heavier *azmayish* is used for practice.

A target arrow *puta*, of about the same length as the *azmayish*, has feathers 2 digits long and quite high. A modification of the *puta* arrow is called *abrish*, which has strongly spiralled, high feather tufts that "stick out like bristles", curl around the shaft, and cause large air resistance (fig. 38). Its flight is slow. It is intended only for practice. Because of slow flight and short range, it may be closely observed, and thus reveals errors in the loose. Any kind of shaft may be provided with *abrish* fletching. Repaired shafts are often used, which do not

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*Digit is probably the incorrect term; Hein calls it "Finger der Baumeisterelle," literally "finger of the builder's ell," to which a value of about 1.23 inch is ascribed. Despite much searching, we have failed to find mention of this unit elsewhere.

fly well. To apply such fletching, a vane, stripped from the rib, is wound about the shaft like a screw thread, and glued in place. The trajectory of such an arrow is peculiar. It begins its flight like an ordinary arrow, then rapidly or suddenly drops. Its short range makes it usable in small areas. It is highly probable that the practice shooting by the secretary of the Turkish Ambassador in London, as described by W. Frankland in 1795 (page 27) was done with *abrish* arrows.

Two kinds of practice arrows without feathers had the generic name *gez*. The *hava gezi*, without a point, is otherwise like the *puta*. Thirty of these are called a bundle. They must all be alike, so that the learner may judge whether he is doing everything correctly. If the arrows are unlike, he cannot tell whether a fault lies in himself or in the arrow. The *torba gezi*, with an iron tip, is shot into the "practice sack" only. Both *gez* arrows are shot with the practice bow.

The bone or ivory tips were made from small pieces square in section, drilled to fit the tip of the shaft, and glued in place. The tips were then placed in hot ashes, not glowing, but hot enough to scorch the wood. After the pieces had been thus fastened to the shaft, they were trimmed down to proper size and shape with rasp and file. Iron tips had a tang that was inserted in a hole drilled in the shaft. Glue was applied to the tang before insertion. The shaft was then put in hot ashes to dry and set the glue. Unless so treated, the tips failed to hold. Iron tips were coated with beeswax to prevent rusting.

The broadhead point is a digit long, and half as wide. Its weight should be between 1/7 and ⅛ that of the shaft. If the point is too light, the arrow gads; if too heavy, the trajectory is short. Many years ago four and even six vanes were used, but experience showed that the larger number had no advantage over three.

Pine alone was used for arrows in Kani's time. There are four suitable species that grow in the Orient. Of these four, the first has thin and closely-spaced layers of grain, with very small "figuring", and the color may be yellow or white. Second, there is coarse-grained wood with large figuring, used exclusively for the *pishrev* arrow. This kind of wood was valued so highly that occasionally an old target arrow made from it, possibly an heirloom, was reworked into a superior flight arrow. Third, there was a kind of wood which, although supposedly of the first kind, turned out to be much lighter than expected when the arrow was finished. For example, an arrow expected to weigh 5 *dirhem* might be only 4 to 4½ in weight. With a clean loose, this kind would fly farther than the same kind of greater weight. A fourth kind of wood is of brownish hue, after polishing, and manifests thin, narrow grain and scale-like figuring, somewhat like the pattern in water silk. This kind of arrow was called *pelenk*, meaning tiger, possibly because of the figuring, although it was said that its high speed gave origin to the name. Good arrow wood must be dense, hard and straight-grained.

The tree intended for arrow wood should be more than 10 years old, and should be cut during its period of dormancy. From the butt a length of 1½ ells is sawed, and this is split into billets about 2 digits square. After air drying for two months, the billets are further artificially seasoned, to make the wood as light as possible. They are stacked in a baking oven, held at exactly that temperature which the craftsman from long experience has found to be right. Here they remain until they turn yellowish and the pitch and rosin have oozed out of them. If the wood is left too long, it "becomes lifeless, like charcoal"; if too short, the wood remains heavy and the arrows made from it cannot fly with maximum speed. After the oven treatment the billets are stacked for about ten days in a well-ventilated, dry place, and are then kept in dry storage for three to five years. The longer they are thus stored, even up to 60 years, the better are the arrows that are made from them. Before the wood is processed, it is sorted for grain and figuring.

Several arrow makers have gone even farther in the precautions they have taken in cutting trees for arrow wood. They have observed the direction of the prevailing wind to which the tree was exposed. For arrows to be used in the south wind range, for example, they chose wood from a tree that had been exposed to a prevailing south wind. They believed that such arrows would attain greater speed and distance because of being accustomed to the south wind.

The *torba gezi* arrows, used in the practice sack, in contrast with all others, were made of elm. This was bought in billets from dealers in wood, under the designation *samanly*. Good arrows result from finely figured wood, seasoned at least three and preferably up to 20 years.

The inordinate skill and painstaking work required in making good arrows rendered such an arrow a highly prized possession, and its maker was much respected. Much attention was paid to the mending or reconstruction of broken arrows. The process is described by Kani in some detail. Many of the Turkish flight arrows in the collections I have seen have been repaired. Judging the superficial evidence, such arrows are as good as those that have not needed repair. Examination confirms a statement by Kani that breakage occurs most frequently in the foreshaft, on impact with the ground. To provide a new foreshaft or foot, a piece of wood is selected which matches that of the arrow as closely as possible in color, grain and figuring. Repair is still feasible when the broken section is as much as a span and four fingerbreadths in length. With a special knife about a span long, keenly sharpened, having a thin blade in the same plane with one side of the handle, the broken end is carefully trimmed with a diagonal cut about three digits in length, similar to the cutting of a quill with a penknife. The piece selected for the repair is similarly cut. Both parts are then carefully fitted by scraping and filing away all uneven places, and making the contiguous surfaces smooth and plane. After repeated applications of glue, the two parts are firmly pressed and bound together. When the glue is dry, the foot is finished as in a new arrow (fig. 37).

Similarly, a new arrow may be made from the salvaged parts of two old ones. After much use, the foot of an arrow becomes abraded and marred, and although this damage is barely perceptible to the eye, it impedes the flight of the shaft. An arrow constructed from the parts of two others may become a tournament arrow much prized by the seniors. According to Kani, however, an arrow made from new wood to the same shape and dimensions, will without doubt fly farther than a reconstructed one.

In the making of new arrows, processing consists of cutting the desired piece from the billet, splitting it into sticks, and working the shaft to desired shape with a variety of planes. These are specialized in design, some with guide grooves and cutting edges shaped to the rounded contour of the arrow. The block, ***kötük,*** shown in fig. 39 is an essential part of the arrow maker's workbench, before which he sits on the floor. The inclined strip of wood supports the shaft while it is being planed.

The nock pieces were either separately glued to the shaft and well wrapped with sinew, or the nock was made of a single piece of hardwood or horn that had been glued to the shaft beforehand. Brazil wood was generally used, but this was varied with horn from the wild goat. The sides of the nocks were slightly bulbous, but never exceeded in diameter that of the shaft at its largest section. The sides or "cheeks" of the nocks diminished in thickness towards the opening at the "lips". The clearance between the lips was smaller than the width of the bottom of the nock in which the string rested. The "corners" of the lips at the inner sides of the nock were well rounded, to facilitate nocking the arrow. The nock pieces were slightly yielding so that the nock in effect became a spring clip that snugly fitted the string and held the arrow securely in its place. In general shape, the nock reminds one of a tulip blossom (fig. 37).

The arrow maker used a gage plate with openings of proper size for testing the roundness and diameters of the belly, the foot and the neck. He considered the arrow to be 24 units in length of which the first four, measured from the nock, comprise the neck; the next 10½ constitute the belly; the trouser extends to the 17th, and the remainder is the foot (fig. 39). The neck and foot are tapered with planes set very fine, and the shaft is turned continuously and rapidly while it is being planed. When the desired shape and size have been attained, the surface is smoothed with the ribs of feathers, then waxed and rubbed until the arrow is warm. To test its straightness and roundness the artisan brings the nails of the thumb and middle finger of his left hand together, lays the shaft on them at its balance point, and gives it a spin with his right thumb and middle finger. The longer the arrow keeps spinning, the better the qualities being tested.

The center of gravity or balance point is found by balancing the arrow in a loop of thread; its desired location differs in different kinds of arrows. A target arrow, *puta*, with its feathers, should balance at its middle, after which the point is added. All other arrows are balanced without feathers or tips. These are added later. A practice shaft, *gez*, of candle form, with point and nock pieces, is balanced two digits behind the middle; of cord form, at the middle. An arrow with a thick foot requires no extra tip or point. In some cases lead is inserted in a hole drilled in the bottom of the nock to bring the balance point near or behind the middle. Experience shows such arrows to fly farther.

The length of the arrow depends primarily on the stature of the archer and the characteristics of his bow. The best method of finding the correct length for an individual is to give him a light bow, attach the *siper* to his bow hand, and have him make the draw according to all the rules of the art. With proper grasp of the bow, with the drawing hand in contact with the lobe of the right ear, and with the arrow drawn so that its tip rests precisely in the middle of the *siper*, the arrow has the correct length for the archer. If the tip is further back, the arrow is too short; if the tip fails to come back to the midpoint of the *siper*, to the so-called release position *atysh yeri*, the arrow is too long. If the archer tries to draw such an arrow so that its tip comes to the proper position, he cannot avoid departing from correct posture, which is detrimental to achieving the greatest distance.

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Fig. 39. Opposite is a facsimile of Kani's page 277. The captions are translated as follows:

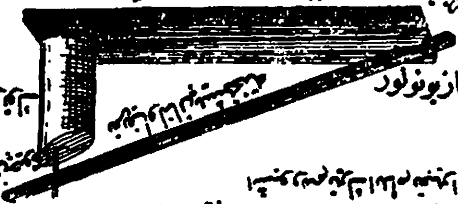
Left: The arrow, with its twenty-four "degrees" of length; beginning at the nock, the "neck" extends over four; the "belly" is ten and one-half; the "trouser" goes to the seventeenth; the remainder is the "foot."

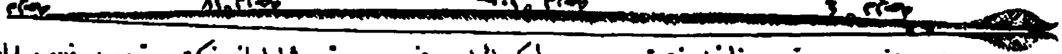
Middle lower: The arrow gauge, called *hadde;* the smaller hole has the diameter of the "neck"; the larger measures the "belly"; the third, with the open side, measures the diameter of the shaft at the nock, after the nock-pieces are attached, which naturally thicken the shaft at this point.

Middle upper: The "block" *(kötük)* of basswood, with a nail partly driven in on top, to which a wooden lath is fastened. On this the nock pieces and nocks are filed to shape. The lath is somewhat yielding, which results in greater uniformity of filing.

Right: The *gezogeti,* or *gez* file, resembles a knife, running to a narrow edge at the end, with a thick back. This back is not angular, as in a knife, but is rounded, like the back of a fish, for filing the arrow nock. Both upper and lower edges have teeth. A used file is preferable to a new one, because it both enlarges the nock and smooths the surfaces well. If a used file cannot be found and one must secure a new one, no matter how fine the teeth, one first files the nock ends of practice arrows only, and not until it has been so used for a time does one employ it for filing and smoothing the nocks and nock pieces of the *pishrev* arrow.

كز اكه سی دسمده عینی بچاق مثالی اغزی اینجه ورك آرقه سی قالین اولوب انجق بچاق صرطی مثال كوشه لی اولیوب بالتو صرطی جینا تیرلرك
كزیرلری دسمده یوارلقصی اولوب صرطی واغزی جیناد یشلی اولور و مستعمل اولانی مقبول اولور كه هم درون كزی چوب وهم
پرداخ ایدر مستعمل اولنیوب یکی یا پدیرلنجه هر نه قدر اینجه دیشلی اولسه بیله ابتدا طوربه وهوا كزلری باش پاره لرنده استعمال
اولنوب بعده تیر و پیشرو بقلرنده مستعملدر





اشبو رسم تیرك اندام تعبیر اولنان بوغاز و كوبك و شلوار درجه لرینك محللری معلوم اولوب
اكا كوره بهر تیری تقسیم ایتمك لازم كلدیكی ایچوندر

بكرجی درت درجه دن دردنجی درجه یه قدر بوغاز اون بچی درجه وسط كوبك اون بدنجی درجه یه قدر شلوار اندن بكرجی درت درجه یه قدر

All the information gleaned from Kani via Hein as to lengths of arrows is somewhat obscure, just as the information about dimensions and drawing forces of bows is obscure. Comment about different lengths of arrows and selection of the correct length for an archer, as given in the preceding paragraph, seems logical enough. On the other hand, all the Turkish flight arrows in the Stone Collection, as well as the few that I have, are of the same length. In view of their differing origins and ages, this becomes a contradiction difficult to reconcile. Our measurements strongly suggest that flight arrows were of standard length. If they were not, the uniformity of length noted must be put down as a startling coincidence. That it should be a coincidence is highly improbable.

Kani further recites some approximate formulas for determining proper arrow lengths. With the bow braced, place the arrow on the string at the nocking point, and mark on it the point of contact of the arrow with the arrow pass *tir getchimi*. Take the arrow off the string, bring the mark in contact with the arrow pass again, but this time have the tip of the arrow point towards the upper *tundj* knot. The proper length is at the point where it touches the knot. All this seems somewhat less than rational, but who will insist that it may not be as reasonable as some of our own practices, kept alive because of tradition?

Kani says about arrow weights that they must be in harmony with the weight of the bow. It was previously brought out that the conditioned flight bow was specified not in terms of its force at full draw but in terms of its mass as found by weighing on a scale. On this basis a bow of 0.7 pound avoirdupois requires an arrow of 247 to 297 grains; one of 0.63 pound, 222 to 247 grains; one of 0.56 pound, 198 to 231 grains; one of 0.5 pound, 173 to 181 grains. Payne-Gallwey stated the limits for Turkish flight arrows as 177 to 205 grains. This, according to

Kani's table, would represent arrows for a bow of medium weight. This range also includes the weights of all the Turkish flight arrows that have been available to us for measurement.

Kani says that the ranges of weights given should be understood as being only generally applicable and that they do not represent the application of an invariable rule. Just as the length of the arrow depends on a number of factors, so also are the requirements as to its weight affected by the characteristics of the bow, and by the direction and strength of the wind in which the shooting is done.

CHAPTER VII

BRACING AND SHOOTING THE TURKISH BOW

Kani describes a number of methods by which the short, strongly reflex composite bow may be braced. Considering the shape and strength of the conditioned flight bow used by Turkish archers, we can appreciate the comment that this is an art that may be difficult to acquire except by personal instruction. The method which appears most direct and certain of success with exceptionally heavy bows requires an accessory called the "lasso" (*kemend*), which makes possible bending the limbs evenly without undue exertion. It is to be recommended particularly because, by its use, the archer avoids "profaning the grip" (*kabza*) which would occur were he to place his foot upon it. In using the *kemend* one foot is placed on each side of the grip, on the inner surfaces of the limbs. Its use is also recommended for bracing lighter bows, for with it there is no risk of damage to the bow or impairment of balance of the limbs which might result from an inappropriate method of bracing.

The *kemend* is a strap of webbing or leather, terminating in two stout iron rings one of which can be passed through the other. The length of the *kemend* must be suited to the stature of the user; but Kani gives no measurements. To brace a bow with it, the archer sits on the ground, takes the strap about his waist, and crosses the ends in front. One loop of the string having been placed in its nock of the bow, one of the rings is hooked in the nock over it. The other ring is engaged with the other nock. With his feet braced against the inner sides of the limbs near the grip, he grasps the ears of the bow and pulls them towards himself far enough so that further bending can be accomplished by the pull with the *kemend*. This implies having to draw the ears past "dead center" by hand. The archer holds the free end of the string in his hand, ready to slip it into the free nock when the bow has been sufficiently bent. He now leans back, and pushes forward with his feet. The free loop is slipped through the ring and over the end of the ear, into the nock. If the *kemend* has the proper length, very heavy bows can be braced with it.

To remove the *kemend* easily after the bow has been braced, it is possible to proceed in any of several ways.

Fig. 40. Showing the method of bracing the bow with the aid of the *kemend* (Hein).

It is obvious that when the bow has been braced, and the loops of the string are properly fitted in the nocks, neither of the rings should be engaging the bow limb nearer the grip than the nock, for then the ring would be "imprisoned" on the limb by the string, and could not be removed. If the larger ring is not placed in the nock, but around the ear beyond the nock towards the grip, and the free end of the string is drawn through the ring before it is engaged in the nock, both rings are readily removable as soon as the string is properly in place and taut. Why the smaller ring should be capable of passing through the larger is not clear; but it may be definitely intended to have one ring so small that it may not slide down the limb beyond the ear. The other ring must be large enough to leave the nock unobstructed, and to fit over the ear easily. This would, in effect, call for two rings of unequal size, but the fact that one could be passed through the other would be incidental, not premeditated. But the selfsame fact would account for the designation "lasso".

Greater leverage or "purchase" on the limbs would be secured if the bending force were applied at the outermost tips, outwardly from the nocks. The *kemend* could quite readily be fitted with specially designed hooks to engage the tips of the ears without slipping. Then the force needed to bend the limbs would be less, but access to the nocks would be blocked by the *kemend* unless the *tundj* loops were first slipped over the ears of the unbraced bow. This method would permit both easy bracing and easy removal of the *kemend*.

Conjecture about the difference in sizes of the two rings may be carried further. If the smaller is drawn through the larger, a running noose results, suggestive of the lasso. If the noose could be drawn snugly around one ear of the bow, with one loop of the string engaged in the opposite nock, and the smaller ring were hooked in the same nock over the loop, bracing could be accomplished as described, with easy removal of the *kemend* afterwards; for this would require only the removal of the small ring, loosening the noose, and drawing the strap and small ring free, through the large ring.

The knots of the *tundj* loops must be located in precisely the right places on the shoulders to prevent having the string slip off; for this would permit the bow to reverse itself by springing violently into its relaxed condition with almost certainty of breakage.

The archer measures the distances between the string and the inner surfaces of the limbs on each side of the grip to assure himself that these distances are equal. Some archers prefer to have this distance above the grip very slightly greater than that below. Should the limbs be drawn out of shape, so that one of them needs to be pressed outwards to make them more nearly alike, one warms that side by friction with the hands, after which the limb may be brought to proper shape by pressure applied with the hands and feet. The archer then holds the bow by the grip, with two fingers, and sights the string against the limbs to make sure that they are free from side warping or cast. This, if present, must be removed by heating and pressing before the bow is shot. Should heating by friction be inadequate, a dull charcoal fire is used. Heating and pressing are continued until the proper shaping has been accomplished. Any places that do not yield to adjustment in this manner must be corrected by rasping and filing. After the *mushamma* has been wrapped about the grip, the bow is kept ready for use by hanging it in the shade, exposed to the wind.

One method of bracing a weak bow without using the lasso is first to engage one loop of the string with the lower nock, the other being slipped over the limb, past the ear, to a point near the middle of the limb. With the belly of the bow towards the archer, its lower end is placed against the heel of the left foot, the upper end is held in the right hand, the middle of the bow is pushed away with the right foot, and the upper loop is worked outwards and into the nock with the left hand. It seems like a feat of minor acrobatics; but it may be not too far wrong so to classify most of the methods of bracing the reflex composite bow.

Another method is to sit on the ground, grasp the bow at the grip with one hand, push the ends of the bow away with the feet while drawing the grip towards the body, and, with the free hand, engage the loop with the nock.

A simple method which requires an assistant is to bend the bow, while sitting on the ground, as with the *kemend*, but drawing the limbs back with the two hands. The assistant then places the loops in the nocks.

Before tournaments the bowmakers carefully inspected the bows of the archers and adjusted the limbs by heat and pressure, as previously described; indeed, it appears in some instances that the bowmakers alone braced the bows to be sure that this was done properly and without damage to the bow, and that the bow would remain stable in shooting. It appears also that assurance of stability was achieved by reducing the amount of reflex curvature by keeping the bow braced over long periods, or keeping the limbs lashed to suitable *tepeliks* (fig. 22), and using a string of correct length to assure proper bracing height consistent with stability. From the description of the *tepelik* and its use, one may surmise that this tool was an important item in the bowyer's kit, as means for assuring stability. If the reflex were reduced merely by keeping the bow braced, this would almost inevitably cause excessive increase in the bracing height, and the wrong kind of bend in the limbs. With a pair of suitable *tepeliks* lashed to the limbs, their shape could be kept unchanged while reducing the degree of reflex. Dr. Eppley's observations in Korea and China* bear out this supposition.

Hein, in comparing the numerous methods of bracing described in the Arab writings with the methods described for bracing Turkish bows, draws the conclusion that the Arab bows were much weaker, or that they were long, with little reflex, and possibly not composite. In principle, most of the Arab methods consist of confining the lower end of the bow beneath the instep of the left foot, pulling the upper end upward with the right hand while pushing the grip downward with the left, and push-

*Page 174.

ing the loop of the string into the nock with the right hand, or having an assistant do so.

On Grasping the Bow Grip with the Left Hand. The *imams* of the archers were of different somatic types. They differed in bodily structure and measurements. Because of these differences, their methods of grasping the grip showed differences. But since these worthies were concerned with Arab rather than Turkish archery, it is justifiable to omit details of their methods and confine attention to the manner in which the Turks held the bow.

The grasp of the bow grip (*kabzi kabza*) is thus defined by Kani: "It signifies placing the middle of the back of the grip against the juncture of the fingers and palm of the left hand". This part of the grip is called *metn*, and the part of the hand against which it is placed, *dyüz*. Persons with a large palm and long fingers should grasp the bow as described. Those with small palm and short fingers should place the *metn* on the distal joints of the fingers. Those with medium-sized palms and fingers should place the *metn* on the second joints of the fingers.

Kani then proceeds: "The relatively loose skin in the opening between the thumb and index finger should be pushed in towards the middle of the palm and pressed tightly against the middle of the bow grip. The middle finger should be pressed, from the back of the grip, above the *mushamma*, between the bow grip and the second joint of the thumb. The thumb nail and its first joint should be tightly pressed against the *mushamma*. The *mushamma* is taken, from the back of the grip, between the fourth and middle fingers. The fourth finger is lowered on the grip, and the grip, below the *mushamma*, is grasped tightly with the fourth and little fingers. The index finger is clasped tightly over the middle finger.

The grasp of the grip with the bow hand should be so tight that if water were poured on the hand from above, none would seep down into the palm. The end of the *middle finger should be so placed* between the grip and the thumb that the arrow in passing may not touch its tip".

Hein questions the last statement, implying thereby that he assumes the arrows to pass the bow on the left. There is no occasion for questioning it if the arrow—as *it does*—passes the bow on the right.

"After the grip has been grasped in the manner described, the fist is inclined to the left and the wrist flexed to turn the fist downward as far as possible. When the wrist has been turned slightly towards the arrow, the shape of the fist resembles the head of a harp, *cheng*, a Franconian stringed instrument. The grasp must be firm until the arrow has left the *siper*. The *imam* Tabari preferred this grasp to any other, and describes it as the "99 form" in finger reckoning.* Mustafa Efendi says, "The index finger lies behind the middle finger and the thumb rests lightly on the *mushamma*; the fourth and little fingers 'step down' from the *mushamma*. They all rest lightly on the *kabza*, and this brings about a tight grasp".

According to Abdullah Efendi, the grasp of the bow

*On the interesting subject of expressing numbers and making computations by *systematic*, sophisticated configurations of the fingers, Ruska in *Der Islam* X, 1920, pp. 87 to 119, gives exhaustive information. He describes the single-hand representation of units, tens, hundreds, thousands, and 10,000; gives many references to publications dealing with the subject, and cites a manuscript, "Wealth of the zealous student of archery" by Taiboga al-Ashrafi al-Baklamishi al-Yunani, who died *ca.* 1368, and mentions the existence of copies in Leyden, Paris, London, Cambridge and Cairo. Ruska refers to "63" as the archer's method of clenching the right hand in drawing the string, and "60" as representing the configuration of the fingers in grapsing the arrow. "Finger flexures" was the term used by the Arabs—*ukbud*. Ruska also *deals at length with the art of finger computing* in an article under the title, "On the oldest Arabic algebra and art of computing" (Zur ältesten arabischen Algebra und Rechenkunst), *Sitzungsberichte der Heidelberger Akademie der Wissenschaft, philosophisch-historische Klasse*, 1917. See also Faris and Elmer, Arab Archery, pp. 20 and 44.

in any kind of practice shooting, particularly with the light *kepade* practice bow, using *torba gezi* and *hava gezi* arrows, the last three fingers should be loose, "to keep the hand quiet". In tournament flight shooting, however, this is wrong because, particularly on hot days when the hand may be moist, it might cause a turning of the grip in the hand, resulting in a bad shot. The tighter the grasp, the greater is the strength which the body transmits to the bow hand; thereby the right hand also acquires more strength. The result is a clean, strong shot, and the arrow travels its maximum distance. When the bow is correctly held, the string stands exactly vertical, without tilt. It is said that, the smaller the space by which the arrow clears the arrow passage, the better the shot.

Many a beginner has the difficulty that the bow string strikes the arm. This is the result of some fault in his technique, such as turning the bow hand towards the right instead of the left; or, when elevating the hand to shoot the arrow at 44°, the arm may not form a straight line, but the left elbow is turned towards the left, so that the fist assumes an incorrect position; or the grasp may be too loose, permitting the grip to turn in the hand; or the fist may, at the instant of loose, fail to resemble the head of a harp, but turn upward and to the right by incorrect flexure of the wrist. Whatever the individual fault, the archer must find it so that he may learn to avoid it.

Corpulent persons or those with some abnormal structure of the arm should shift the *metn* slightly leftward to increase the distance between the string and the arm. There is another kind of grasp attributed to Tahir which corresponds to the "30" in finger computing. An Arab saying about this describes it as the "second form" in which the tip of the thumb covers the middle finger. The other details of the grasp remain unchanged. It is suited to the fleshy hand with short fingers; persons possessing them often develop this grasp naturally, without deliberate intent.

Abdullah Efendi also mentions that he has seen archers who have learned to shoot without instruction by a master. They grasp the bow without any system, like a stick, circle the grip with the index finger overlapped by the thumb, with the middle finger above the *mushamma*. The other fingers come where they may. This grasp is designated Behram's. It may be suited to *tirkesh* bows with large grips, but not to sport bows that require building up the grip with a *mushamma*.

The Draw and the Loose. The construction of the thumb ring has been described. Its use was dictated by the need of effective protection against injury to the thumb by excessive pressure of the string, and for a smooth surface over which the string might glide when loosed. From purely mechanical considerations it is doubtful whether the thumb draw as practiced by the Turks could have been practicable without the ring. In the following section Hein's description of the methods of drawing and loosing with the thumb ring is closely followed. He gives direct translations from Kani, who freely quotes descriptions taken from the older writings.

The singular technique of interlocking the thumb and index finger in drawing and holding the bowstring is characteristic of the Turkish method. The configuration is called *mandal*, the lock, (Arab *qafla*) because the distal segment of the thumb lies in front of the string like the bolt of a lock. Just as there are differences in the grasp of the bow, so also are there differences in the *mandal* as taught by the several *imams*, each representing a different somatic type.

The method of abu Hashim, whose hand was long, was to locate the string in the first joint of the thumb, and to press the tip of the thumb firmly against the middle finger. Abu Tahir Balkhi, whose hand was short, drew the string with the distal segment of the thumb and pressed its tip and nail tightly against the middle finger without extreme flexure of the thumb. The index finger extended over the thumb by an amount that depended on its length. Ishakh, with medium-sized hands, flexed the thumb less strongly than Hashim but more than Tahir. He pressed the tip firmly upon the side of the middle finger, and lightly rested the index finger on the nail of the thumb. Tabari's hold on the string was intermediate between that of Tahir and that of Ishakh.

Kani cites verses from the Arabic to indicate that the Mongolian loose, as described and named by Morse, and characterized by the *mandal*, was known to the Arabs. On the basis of such verses, from the book of Abdullah Efendi, Kani endeavors to describe the *mandal*. His instruction is to form the "63" with the right hand, with the thumb about the string, as follows: Close the little

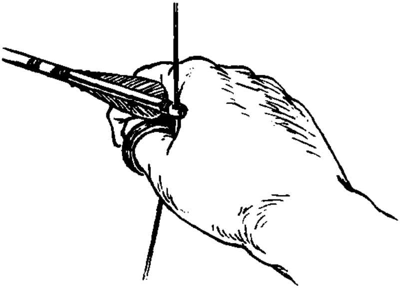


Fig. 41. The *mandal* or lock.

finger, the next one and the middle finger so firmly that the nails bury themselves in the palm. This gives the drawing fingers greater power. The string rests in the first joint of the thumb and remains there until the loose.

The tip of the thumb nail is pressed firmly upon the middle finger. The index finger is laid over the thumb nail so that the distal end of the nail is hidden, but the proximal part, about its root, remains visible. The index finger must not too completely cover the thumb nail, for this prevents quickness of release and is detrimental to securing distance. Moreover the string strikes and may injure the finger tip. Too much pressure on the thumb may cause cyanosis, from impeded circulation. Other causes of a cyanotic thumb are rings that are too tight or too narrow.

Mustafa Efendi's description is about the same, with the comment that if the thumb nail is not visible between the middle and index fingers, the strongest bows can thus be managed. Abdallah ibn Maimun says that the index finger should cover only the distal half of the thumb nail and adds that the nock of the arrow should be firmly seated, without play, at the middle of the third segment of the index finger. The "hanging lock" results when the index finger and thumb are less tightly clenched, so that the fletching of the arrow is more in the open. It is suited only for light bows, and cannot be used in drawing heavy ones. Variants of finger flexures used in drawing, according to Muhammed ibn Abdallah, are the 62, 21, 24, 69, 73 and 83.

When the archer is ready to nock his arrow, he removes it from his quiver and holds it in his five fingers as he would a stick. Then he lays its foot on the arrow pass of the bow and holds it there with thumb and index finger of the left hand.* Thereupon he grasps it near this point with the thumb, index and middle fingers of the right hand, and strokes the shaft with them, all the way to the nock, to detect uneven places and smooth the

*This description gives the impression that Hein was probably confused, for the method described would fit the procedure in preparation for the Mediterranean release. I have tried to follow the instructions given, with the *siper* attached to the bow hand (the arrow pass being on the right side of the bow) and have found it impossible.

feathers. Finally he grasps the nock with thumb and index finger and affixes the arrow upon the string. The archer must take care to nock the arrow at the right place. By sighting upon the string, with the arrow nocked, he can judge whether the latter is at right angles with the string. The final test of a correct nocking point is the shooting of several *gez* or *abrish* arrows, and noting how they leave the bow. For this test they need not be fully drawn. Flight arrows such as *pishrev* and *baki* are nocked slightly lower; the farther back the arrow is drawn in the *siper*, the lower must it be nocked.

The nock of the arrow must lie opposite the middle of the third segment of the index finger which, after the *mandal* has been formed, should rest lightly against the nock without pressure. If there is pressure between the index finger and the nock, it is difficult to keep the string in its proper location on the broad surface *dimagh* of the thumb ring, and it is prone to slip back to the leather insert, *kulak*. It is one of the secrets of drawing properly to keep the string in its proper location on the ring up to the instant of loose. Moreover, special skill is required to avoid loosening the fingers that form the *mandal*, using too much pressure, and "turning" the lock. The position of the index finger over the thumb must be such that the third segment may properly support the nock of the arrow without exerting pressure upon it, to maintain it in its proper place.

When the execution of the loose is faultless, the arrow leaves the string perfectly. If, however, the string rests too far back in the joint of the thumb, and the index finger curls too far about the thumb, then the string and the nock are not properly located in relation to the index finger, and the nock may slip or spring off the string. If the nock is too low, the arrow slants too steeply upward, which interferes with a clean takeoff, and the string may bruise the fingers. Blisters may form and compel one to refrain from shooting for three months. If there is too much pressure against the nock, it is detrimental to the flight of the arrow, which may be broken at the neck.

The stance, position and posture of the archer are important in shooting. Here again there are variations depending on somatic differences.

Abu Hashim, being tall, turned his left shoulder towards the mark, both while seated and standing. The smaller Tahir, quite opposite in stature to Hashim, almost fully faced the target. Ishakh occupied the intermediate position.

In standing, persons of Hashim's type place the left foot forward and the right about one foot behind the left and oblique to the latter. Persons like Tahir stand with the feet side by side. Those like Ishakh place the feet in an intermediate relative position. This is the stance usually recommended for beginners. Another stance* is to place the toe of the right foot forward, towards the mark, to flex the left knee slightly, with the toe of the left foot somewhat to the rear, so that its slightly raised heel is opposite the right ankle, with a small intervening space. The toes are separated about a span. The right foot is firmly planted, the left rests lightly on the ground. Just before the loose the left knee is flexed, and at the loose the weight is shifted to the left foot. It is said that if one arm is weaker than the other, the weaker one is strengthened by putting the weight on the corresponding foot.

It is said that one of the secrets of archery is to utter the name of God in one's heart while drawing, and at the loose to ask Him for aid. Hasan and Husein, according to tradition, were taught by their father, when nocking an arrow to say *bismallah*, and when drawing and

*This description applies to a "left-handed" archer. The terms "left" and "right" should be interchanged for a "right-handed" person.

loosing to say *Allahü ekber*. According to another tradition, it is of great benefit, while shooting, repeatedly to say the following prayer: *Ma sa allahu kana vela ilaha illa llahu vela kuvete illah billah.* (What Allah wills happens, there is no God but Allah, there is no power except from Allah.)

In preparing to shoot, the arrow is drawn back until the right hand touches the lobe of the ear. When a flight arrow has thus been drawn, its tip should be not opposite the bow, but at the proper distance within the bow, in the *siper;* in shooting at marks, the arrow is drawn less far back, so as not to sacrifice accuracy. When, in target shooting, the arrow is drawn back with its tip resting in the *siper*, the archer holds his breath and fixates on the target. Both hands should be in the same vertical plane, with both elbows at shoulder height, and both arms under equal tension, in equilibrium like the arms of a balance. When all is right, the arrow is loosed. There are three ways of accomplishing the draw and loose:

1: *Ikhtilas*: drawing rapidly and loosing without pause as soon as the right hand has reached the ear.

2. *Sakin*: drawing placidly and slowly, and loosing deliberately.

3. *Mefruk*: drawing placidly and slowly until the point of the arrow is opposite the bow in the *siper*, and, after a moment's pause, drawing the arrow full with a sudden, violent jerk, and loosing it. "All masters of the bow highly esteem this method. After the pause, the arrow must be jerked back like lightning, so that the spectator cannot follow what is being done, and may not believe that the arrow was fully drawn. The bow must be under perfect control, and there must be no creep during the pause. While pausing, and holding the arrow motionless, one should count 'one, two, three', then loose 'while emptying the heart' ".

"Emptying the heart means complete concentration on shooting, and the rejection of all other thoughts. This is compared with the concentration required at the beginning of prayer, and is ascribed to Behram. Up to this instant the archer reviews all the positions, postures, rules and regulations which, by dint of long, arduous, painstaking practice, have become part of his flesh and blood; and makes any necessary corrections. At the instant of loosing, however, the mind must be entirely void of these considerations."

To accomplish the loose, the archer first releases the index finger, then the thumb; but this sequence is so rapid that the spectator cannot see nor the archer distinguish the separate movements. Only long practice with a light bow makes these motions so fully automatic that they can also be applied to heavy bows with the necessary ease and precision. If the fingers are not separated quickly enough, the string drags on the "brow" of the thumb ring and there is impairment of the shot. If the fingers are simultaneously opened, the string emits a "blameworthy" tone, the thumb nail and tip of the index finger are injured, and the flight adversely affected.

Upon completion of the loose, the right hand may drop downward but should not move in any other direction. The motion must be so slight that if a cup of water were placed on the hand, it would remain there without spilling a drop. For this reason the archers used to say, when they saw a fellow archer moving his right hand sidewise after the loose, "Comrade, you are letting your cup fall!"

In the *mefruk* loose, the sudden rearward jerk, called the "movement in the *siper*", causes the right hand and elbow to be hurled towards the rear as if by a blow. The execution of this jerk is also called "giving it the whip". At the same time, the left wrist is permitted to relax and the hand to drop. It is considered good practice to permit the right hand to do the same. If immediately after the loose the grasp of the left hand is relaxed, the distance of the shot is increased; but this requires great skill in timing. There is great disadvantage if this is done prematurely, during the loose.

Some archers after the loose throw the right hand and arm backwards as far as possible. Although this of itself cannot harm the shot, it may lead to bad habits, such as a "free loose". In this error the right hand is forced too far to the right, because of incorrect position of the head, causing the arrow to strike and rub the arrow pass. The head must be inclined slightly towards the left. It is advisable to keep the hand at the ear after the shot.

In the so-called "free loose" the right hand touches the face which may interfere with its motion or crowd it to the right, so that the arrow drags on the grip. To avoid this the archer must stand straight, and tilt head and chin towards the left shoulder. If the head is inclined too far left, however, it causes dragging of the arrow in the *siper*, because the archer tries to touch the lobe of the ear with his thumb, thus causing deviation to the right. If the left hand cooperates too much, so that it moves forward and downward at the loose, the fault may develop that this occurs too early, causing drag in the *siper* and reduction of distance.

Aiming is one of the most difficult things to learn in shooting. The fact that it is indirect makes imperative a thorough knowledge and complete control of the bow. An experienced archer aims instinctively, and is more likely to hit the mark thus than by deliberate "geometrical" aiming. He also makes a correction, automatically, with the left hand, for the error that would result from the arrow's not travelling exactly in the direction of the string. Kani discusses aiming at considerable length, from which the inference may be drawn that there were few methods of aiming associated with the draw to the ear with which the Turks were not familiar. To relate them all in detail would go far beyond the scope of this treatise, and would, moreover, burden the narrative with unprofitable detail. A few interesting quotations will suffice.

"In target shooting the bow hand is not held at the level of the forehead, to cause the arrow to depart at 44°, but it is elevated according to the location of the mark. Otherwise there is no difference in the methods of shooting.

"Point blank is about 100 *gez*. The archer sights over the bow hand at the mark. At 120 *gez* he sights at the top of the mark. At 200 he extends the ring finger, sights over it, forms the lock, and closes the bow hand before loosing. At 270 or 300 *gez* he does the same, but sights over the little finger. If the target is nearer than 100 *gez*, the arrow is nocked higher on the string by one width of the nock for each 25 *gez*, which correspondingly lowers the point of the arrow. A very strong bow may be point blank at 300 *gez*. For the most accurate target shooting one must use a bow that is completely under control. If the archer easily draws a 100-*dirhem* bow, he should use one of 80 *dirhem*."

A paragraph on mechanical considerations in connection with the bow appears to be the comment of Hein; if so, it shows him to have a more thorough comprehension of the subject than a mere translator could have had. He may have based his remarks on the following comments by Kani: "When the *mefruk* loose is used, it is advantageous to have the weight of the bow diminish as the position is approached at which the drawing hand pauses. Aiming is also made easier thereby." What Kani evidently meant is that the force should increase much more slowly near the end of the draw than at the beginning, for each unit of length drawn. Hein's comment is that the problem of designing such a bow, impossible of solution in the self bow of wood, has been amazingly well solved in the Turkish composite bow. In this bow the grip and ears are rigid, and the shoulders practically so, hence most of the bending occurs in the arms. The ears are outwardly curved in the braced bow, and the loops rest on the shoulders. The shoulders and ears act as lever arms. At the beginning of the draw a large force is required. As the string leaves the shoulders, and the pull is directly on the nocks, the greater equivalent length of limb requires diminishing rate of increase of force with draw. Hein also makes a comment that is evidently intended to mean that the Turkish bow has the additional advantage over the long bow of having a better acceleration-displacement curve, so that weight for weight it can give the arrow greater velocity.

There follow seven pages of fine print giving a verbatim translation from Kani having to do with errors in shooting and their causes. These are judged to have little value to the practical archer unless he is endeavoring to perfect himself in the Turkish method of shooting. Even then the value of this material would be doubtful; but several quotations provide fair samples, and they are sufficiently interesting to warrant being included here.

"As is generally known, it is commendable if, at the instant of the loose, as soon as the *tundj* are again properly seated in their places, a delightful tone reaches the portals of hearing. This proclaims that the arrow will attain its proper distance. All other tones are signals of errors in shooting, detrimental to the flight of the arrow.

"For example, there is one false tone that arises from the impact of the string against the tip of the right thumb. It is necessary to flex the thumb forcibly, and the string must rest in its joint. If it slides too far towards the tip, and puts a great load on the latter, it cannot properly get away, and strikes the tip. Pain in the tip of the thumb is an indication of this error. It is avoided by holding the string in the joint and not letting it creep away from its proper location.

"If a wrong tone arises from the impact of the string on the index finger, pain in this finger signalizes the error. This results from holding the finger too rigid at the loose. Both fingers should be shaped like a half-moon while they are being spread apart. This must be carefully watched.

"If the arrow wobbles in its flight, there may be fifteen causes: four in the string, four in the arrow, two in the bow and five in the archer." These are discussed most minutely, as are the errors that manifest themselves in other "false tones" of the string and in injuries to the archer.

"That the arrow strikes the bow, thus making a noise, comes from a wrong grasp of the bow, namely, from a loose hold and a loose wrist of the bow hand; from a string not fitting the bow, being either too long or too short; from not 'laying the body in the bow' at the instant of loose, but leaning backward instead of slightly forward; from too strong a bow, and a resulting 'free loose'. A 'free loose' means that the hand stands away from the ear, and is drawn too far to the right, thus causing the shaftment to strike the grip and break, or the arrow to gad and the string to strike the left arm. If, contrary to proper form, the lock is strongly turned, there is deviation to the right. These faults may also cause the string to break. If the right elbow is loose (at the instant of loose it should be strongly pressed together*) and cannot be pressed together because of too heavy a bow, this also produces the 'sound of the grip'. The evidence of this sound is that the arrow flirts or gads, and makes a fluttering noise. This the marker must signal to the archer. For this reason it has been said that the markers are of great value and that they must be expert archers, in order that such things may be observed by those who have knowledge of them.

"If the arrow strikes first the guide, then the handle,

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*Probably forearm against upper arm.

and breaks, it is for the following reasons: The *tundj* are too long and do not seat at the proper places, the knots are not uniform, the arrow is too light for the bow, or the wood is too soft."

All the detailed descriptions of faults catalogued by Kani indicate that these archers were students of form, and that they had probably made more thorough observations of shooting techniques than had the contemporary English archers. Whether their observations and conclusions were correct in all respects is to be doubted. That their accomplishments were noteworthy is a matter of record. Kani's book was published in the same decade as Hansard's. Compared with Kani, Hansard must have been quite inferior as a book of instruction and guidance for the archer who was endeavoring to improve his skill.

CHAPTER VIII

THE TURKISH ARCHERS GUILD AND ITS RULES OF PRACTICE FOR THE NOVICE

Shortly after the conquest of Constantinople (1453), when the bow was still a weapon of war, the archers of that city organized themselves into a guild. This was stimulated by Mohammed II (1451-1481) through his establishing the *ok meidan.* This he established in perpetuity by a decree, so that in later years no one should feel tempted to convert the space into burial grounds or gardens. But this actually happened, during the reigns of Bayezid II, Selim I or Suleiman II. When the archers showed the monarch the charter granted them by Mohammed II, all gardens were ordered abandoned and the field restored for its original purpose. The *ok meidan* was originally acquired by purchase without the exercise of eminent domain. The exact boundaries are described by Kani.

In the reign of Bayezid II, Iskender Pasha donated a guild house and a mosque. Murad IV (1623-1640) also built a clubhouse for the archers, in which inscriptions were placed, perpetuating the names of those preeminent in the knowledge of bows and arrows. This may have been a restoration of the first guild hall. At the time of Mahmud II (1808-1839) the building was in ruins because archery had ceased to be popular. This great lover and promoter of the sport had it reconstructed. It has since fallen into decay, and gives no hint that in years past sultans and princes assembled here to practice the regal sport of shooting with the bow, in all the glamour of the Turkish royal court.

It was customary in the Middle East of mediaeval times to practice flight shooting and to hold tournaments on fields set apart for the purpose, and, upon making a new distance record on a particular field, to erect a stone marker to memorialize the event. The markers were usually inscribed with the name of the archer and the distance, with some laudatory comment that was deemed appropriate. On the field at Adrianople there were six such stones. Of these, five predated the reign of Mohammed II (1451-1481) indicating that the *meidan* at Adrianople was older than the *ok meidan* at Constantinople, since that ruler established the latter. Kani cites records from Abdullah Efendi of 90 stones in 34 different cities, which he mentions by name, that were erected by the precursors of the Turks. Among these cities are Mecca, Alexandria Damascus, Gallipoli, Belgrad, Bagdad and Cairo. This indicates that there were archers' guilds in places other than Constantinople, and that they had tournament fields where archers competed with each other, and the victors commemorated their prowess with monuments.

Archers of former years were of two classifications: those who shot arrows and those who sought acclaim and satisfaction in the drawing of heavy bows. Ibn Bahtiyar makes particular note of the fact that when a "shooting archer" was also outstanding in the drawing of heavy bows, it was unusual and worthy of special mention. Not everyone who could draw a strong bow was a good archer, which showed that more than strength is needed in shooting great distance. In later times the distinction between the two classes vanished.

The Constantinople guild of archers had four classes of members: the seniors, the 900's, the 1000's and the 1100's. The numbers represent the distances in *gez* which the archer had to equal or exceed as qualification for membership in each of the designated groups. The 1200 shots constituted no separate class, but were grouped with the 1100's, because shooting 1200 or over was an exceedingly rare occurrence. Since 100 *gez* are about 68 yards, the above classes, in yards, would be about 610, 680 and 750, respectively; and 1200 is the equivalent of 820. An archer remained in a particular class only so long as he continued to qualify for it. Not until 1946 did we have a flight record in America that would have qualified the archer for the lowest of the Turkish classes of membership, and the 658 yards might not have admitted the archer because it was shot free style, with a foot bow. The regular style record* was 124 yards less, some 86 yards short of qualification for the 900's. Before long we shall see American flight archers qualify for the "1000's".

As in other oriental countries, the practice of archery among the Osmanli was an activity having religious significance and merit. With it there were associated rituals of cleansing and prayers as essential adjuncts. The origin of these rites was ascribed to holy persons, and their methods were described in the terminology of the religious schools of law. The mosque was as essential as the guild hall on the *ok meidan*. Earnest observance of the rites, and recitation of the prescribed prayers while shooting were considered highly beneficial.

The head of the guild was the *sheikh-ül-meidan*, the master of the field, who had to be unanimously elected by the archers and confirmed by the sultan. The *sheikh* was the chief instructor of the guild. To qualify, he had to be in the 1100 class, or must have shot a record distance. He had to be a person of great merit, justice and prudence, and a man of mature years. He had tenure of office for life. He was the field captain at the tournaments. He decided upon the establishment of a new range. He gave authorization for the erection of stone markers. He was the conciliator in disputes. He was chairman of all official meetings. Kani gives the names of all those known to have served in this high office.

Much space is devoted to the description of the conduct of business of the guild, how the head of the guild

*A new record, regular style, was made by Irving Baker at the 1947 National Tournament, with a bow in the 80-pound class. His distance was 576 yards.

was chosen, and how the novice was accepted into his apprenticeship. To become a member of this secret society, this novice faced a course of rigorous training under the guidance of a master whose disciple he became. Acceptance into apprenticeship was accompanied by a ceremonial of recitations of religious sayings and prayers for the soul of the *pir* Sa'd b. abi Wakkas, and the souls of all past *imams* of the archers and of all believing archers since the time of Mohammed. After a prayer by the master that God might make it easy for the novice to learn the art, he hands the latter a bow with the words, "In the name of God", and continues: "In obedience to the mandate of Allah, and to follow the way (*sunna*) of His chosen messenger. . . . " The pupil then grasps the *kabza* with his left hand and kisses it, holds it in shooting position and draws it three times. Certain obligations are imposed on him, like those imposed on novitiates in an order of dervishes.

Among the obligations assumed by the novice were: throughout his life, so long as he were able, not to give up archery; not to shoot animals except those that are noxious, nor those whose flesh cannot be eaten or whose skins cannot be used for clothing; to shoot animals only in the course of a hunt permitted by law; not to shoot at believers or those with whom an agreement has been made; not to shoot in unfamiliar places or in fields that are not open to full view; and not to put hand to bow without first having performed the prescribed ablutions.

Then follows a lengthy exposition of the arduous schedule of practice which the novice must follow for six months to qualify for membership in the guild. In his introduction to this section, Kani refers to the health-giving virtues of the sport. He says that according to those in the medical profession it is known that sedentary habits weaken the body and predispose it to illness. Exercise is therefore important. Whatever its nature, one may at the beginning endure it only a few minutes. Through practice and persistence one soon becomes capable of continuing it for several hours without exhaustion and with complete enjoyment. Persons who at the start can hardly lift a load of one *oka* can, after systematic practice, soon lift a hundred *oka* without bodily harm. According to these precepts, the novice is admonished to begin with a very weak bow and, by degrees, work up to the strongest.

For many days the practice consists only of drawing the bow, without an arrow, under the critical eye of the master. This is continued until the learner can draw the bow 500 times without tiring. Drawing is done with a light bow fitted with a padded string, with the first three fingers. This bow, *kepade,* is used solely for practice in drawing, not for shooting. With it the novice learns all the rules of posture and stance and of holding the bow. He stands with feet together, as in prayer. The body is rigidly erect, the left shoulder slightly raised, the jaw slightly lowered towards the left. The left elbow is directed away from the bow and its tip should point downward. The left hand, like the head of a harp is at the level of the forehead, and an unvarying aim taken with it. This must not be lost.

Like the regular bow, the practice bow must be held vertical, without tilt. The perfect position of the bow is evidence that the bow hand has the proper shape, like the head of a harp. The aim must not be lost while the bow is being drawn. The head must be kept motionless, while the right side of the thorax is raised slightly and the feet are planted firmly on the ground. The string is drawn with the right elbow at shoulder height, and the right thumb passes above the eyebrow to the tip of the ear. The novice, upon reaching full draw, executes a slight backward jerk so that he feels his shoulder blades touching; he then lets the bow down easily until the *tundj* knots come to rest on the shoulders of the bow.

He then pauses during one cycle of breathing and repeats the draw in the same manner. On the first day the learner should several times execute a number of draws equal to the number of the "names of might", i.e., 66. This indicates the religious influence on the system of training as on other aspects of the sport. There is warning against overdoing, even in the absence of perceptible fatigue. Practice is continued and intensified until correct drawing has become automatic and the shoulder muscles have become sufficiently supple.

Thereafter the learner is instructed to develop the draw used in shooting at targets, with the left foot forward so that its heel is about a foot from the middle of the right. It is especially good practice to turn the body at the hips and elevate the right side of the thorax. Elbows and hands should lie opposite each other, and the left fist must be kept immovable on the line of sight. In correct shooting, the bowhand is pushed slightly forward just before the loose. The learner should also practice the draw used in target shooting while seated, being careful to avoid tilting the bow. Without excessive exertion he should be able to draw the practice bow 500 times consecutively; indeed, it is altogether advantageous if he can draw it 30,000 times. Time and effort are expended in vain if one does not proceed in this manner. Only after the refinements have been completely mastered should a strong bow be used. In all practice, a master should be present to guard against the development of faults in technique which would later be difficult to unlearn. At very least, practice should be carried on before a large mirror, so that any errors may be discovered.

Some experts believe that while using a practice bow it is well occasionally to intersperse the drawing of a heavy bow five or ten times. If the heavy bow initiates errors, because of its weight, these can be corrected by returning to the lighter bow. Another method is to give the learner three practice bows of different weights. He begins by drawing the lightest 50 times, pauses for a time and repeats this with a medium bow, and finally with a heavy bow.

The admonition is repeated that the novice, once he has mastered archery, should never completely abandon the art, and should not fail, no matter how busily he is engaged with other matters, every morning upon arising to draw the practice bow 66 times "for the sake of the blessing" and to keep the body supple. Though age and other reasons should require giving up the shooting of arrows, one should, in obedience to divine command, never completely abstain from using the bow, but should draw the practice bow several times each day.

The "lock" is now carefully developed, for which of course a thumb ring and arrow are needed; but to prevent loosing, a hole is drilled in the nock end of the arrow, and

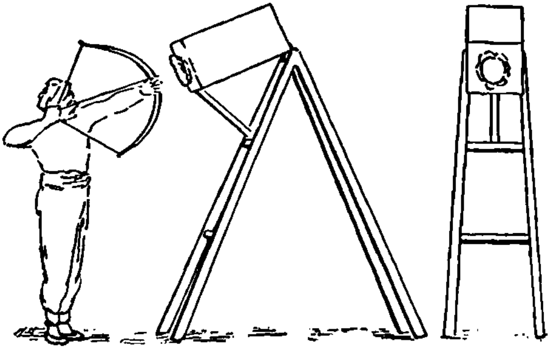

Fig. 42. The practice sack, *torba*, as depicted by Hein.

the string is drawn through it. When the student has mastered the draw with the "lock", he begins with the shooting of practice arrows. Indoor practice consisted of shooting arrows at 44° into the practice sack, *torba*, which was stuffed with shavings, cotton seeds and similar materials. Not a single day may be missed in practice. The bow used for sack shooting is not the practice bow but a weak bow suited to the strength of the archer, completely uniform and symmetrical. The *mushamma* is applied to the grip. The archer places the arrow across the arrow pass and nocks the arrow. After he has correctly grasped the grip and formed the lock, with the arrow resting in the *siper,* he utters the prescribed prayers, draws, and shoots the arrow into the sack. The bow hand must be kept in position momentarily after the loose, so that no bad habit may develop which would later be detrimental when shooting with a stronger bow.

Practice in the field begins when favorable weather sets in. This practice is a continuation of that begun with the sack arrow, *torba gezi,* but with the substitution for the latter of the "air arrow", *hava gezi.* According to one source, such practice requires 40 days, and is carried on with a bow weighing 20 batman (about 130 pounds). The novice is now ready to shoot arrows in the open for the first time. Practice with the *hava gezi* is designed to perfect him in the art of flight shooting, as well as to introduce him to shooting at distant marks. Particular emphasis is put on the "lock", to assure its being properly formed. At the beginning of the day, the novice repeatedly draws a fairly strong bow until his arms grow tired. Then he finishes off the exercise with a light bow. It is beneficial at this stage to shoot the *puta* and *azmayish* arrows, but at the end of the shooting session, the *hava gezi* should be used. Each morning and evening 300 arrows should be shot.

Occasional shooting with the *abrish* arrow is indicated for the purpose of detecting errors in technique. This arrow, with its peculiar fletching, was designed for this specific purpose. The archer is able to watch its course, because of its rapid slowing up and its short range.

Following these many days of practice with the several kinds of arrows mentioned, the learner is finally ready to try his skill with the flight arrows. He begins with those most easily managed, and follows with the difficult. The order in which he uses the flight arrows is *puta, azmayish, baki* and *kara batak*. Of each of these he shoots 60 to 100 each day. In the meantime he continues exercising with bows of increasing weight, to build up his strength. Finally he is permitted to shoot the ultimate, the arrow of competition, *pishrev*. After he has proved his skill and demonstrated his proficiency to the master's satisfaction, he is ready to be received into the archers' guild as a full member.

As a prerequisite to initiation the candidate must give evidence through eyewitnesses that he is skillful in hitting marks, and that he has shot in excess of 900 *gez*. Here we closely follow Hein:

" . . . he brings forward witnesses to his mastery. When the *sheikh* is satisfied, the disciple kneels before him and takes up a bow that is lying near him, strings it and fits an arrow to the string. Having done this three times, he replaces it, all with extreme formality and in accordance with fixed rules. The *sheikh* then instructs the master of ceremonies to take the disciple to his master, from whom he will receive the 'grip' *kabza*. He kneels before the master and kisses his hand. The master takes him by the right hand in token of a mutual covenant patterned on that of the Koran and whispers the 'secret' in his ear. The candidate is now a member of the archers' guild and a link in the 'chain' of succession that reaches back to Adam. Henceforth he will use the bow only when he is in a condition of ritual purity; before and after using the bow he will always kiss its grip. He may now freely take part in formal contests, and in case he becomes a great master of long distance shooting he may establish a record which will be marked with a stone.

"The bestowal of the *kabza* is the outward sign of the disciple's initiation. He has, of course, been long accustomed to using the bow; what is meant by *kabza* is more than a mere handling of the bow: the grip itself implies the 'secret'. The actual grip of the composite bow used by the Turks is the middle part of the bow, on the inner side of which the two horn strips meet, the upper and the lower, separated by a thin piece of horn or ivory, the *chelik* (fig. 3). It is by this middle piece that the bow is made one." Hammer-Purgstall devotes pages to the elucidation of Kani's discussion of this matter—without mentioning Kani. "It is only when one tries to understand this that the metaphysical significance of the bow, which Gabriel had described as the 'power' of God, appears: the grip or *kabza* is the union of Allah with Muhammad. But to say this is to formulate the 'secret' only in its barest form. A fuller explanation, based on the teachings of ibn al-Arabi is communicated to the pupil."

After the ceremony the new member is required to distribute gifts to the *sheikh* and the other members, and to be their host at a banquet. In Kani's day the rules of initiation were made by the sultan, who frequently attended such ceremonies.

The season for competition on the *ok meidan* began on the day of Chidr-Ilyas, "the great spring festival of the Orient", and closed on Khasiṃ day, November 8. During the winter period there was no shooting. Consequently most archers had to develop their muscular power anew each spring. On the other hand, there were those who kept exercising with a bow throughout the winter months, both with the practice bow, in drawing only, and with the practice sack for shooting. During the tournament season there were meeting days each Monday and Thursday, and archers reckoned time during the season in terms of "*meidan* days" after the opening of the guild house. There was no shooting on Sundays or Wednesdays. On other days the field was available for practice.

Competition was usually carried on within the classes. In each of the classes, the archers shot a particular number of arrows. The seniors shot five; the 900's, seven; the 1000's, nine; and the 1100's, twelve. These numbers have a religious basis. In their relationships there is sought a certain "wisdom" belonging to the religious and traditional spheres. Thus the seniors shoot five arrows because, according to tradition, Gabriel gave Adam after his banishment from Paradise, two arrows as a gift from God, on which were inscribed the names of the five prophets: Noah, Abraham, Moses, Jesus and Mohammed. It was in commemoration of these five prophets that the seniors shot five arrows. The number of arrows shot by each of the other classes was similarly rationalized.

Each competition on the *ok meidan* was opened with prayer and a meal. The *sheikh-ül-meidan* presided. There was a prescribed seating arrangement with the *veziers* seated at the right of the *sheikh;* the Koran readers were on the side towards the kitchen; next to them were the guests. If there was room, bowyers and fletchers were also seated at the table. After the prayer the *sheikh* dismissed the gathering with the words *buyurun koshuya*—"On to the competition"!

The Turks invariably shot with the wind. On the *ok meidan* there were five principal ranges, corresponding to the directions of the prevailing winds. These were NE, N, S, SSW, and W; later E and SW were added. To be favorable for shooting, the wind must be uniform at the various levels. The air currents at the surface and at higher altitude must not be in opposite directions. Various methods are mentioned for testing the wind for uniformity. When a towel is held by two upper corners, it must sway gently, as a whole, and not move in waves. The clouds in the sky must be moving in the same direction as that indicated by the towel. If chaff thrown in the air is carried along smoothly and without turbulence, the wind is suitable for shooting. Differences in wind speeds at different levels may account for the fact that an arrow shot at a smaller angle than 44° may carry farther than one shot at 44°. For, in the case of the latter, which rises to a higher level, an adverse wind may be encountered above the height to which the former rises. Winds are most uniform just before sundown, hence this time of day is favorable for flight shooting. The best weather in which to try for a record is characterized by uniformity of wind, clear skies, clear air, clear sun after a rain, with small white clouds moving in the same direction as the wind near the ground, and the shadows of the clouds scooting along like swiftly running horses.

In the closing section of his book, Kani lists the names —with tabulations along the margins*—of all record-making archers, insofar as the stones on the *ok meidan* marking these records still existed, or information about them was obtainable from earlier works. He classifies them according to the directions of their shots, depending on the direction of the wind, and for each direction recites the records made in the corresponding shooting range.

Along with these flight records there are, in many instances, biographical notes about the archers. Lateral deviations of the record-breaking shots from the "mother stone" are also mentioned. The period from Mohammed II to Mahmud II—about four centuries—is covered. In the earliest times the Janissaries were the best archers. Among the names of record holders those of high officials are much in evidence.

In each shooting range a "mother stone", placed with elaborate ceremony by the guild, marked the first record

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*See facsimile of Kani's p. 224, reproduced from the original on page 7 of this book.

shot within that range. It was the endeavor of every member to exceed this distance. Later record distances in the range were invariably specified in relation to the "mother stone". The stones in some of the ranges testify how, generation after generation, for centuries, archers tried to surpass the distances achieved by their forbears. But the oldest records stand unbeaten, not even yielding to the amazing skill of Mahmud II.

CHAPTER IX

RECENT ADDENDA

The reader whose interest has sustained him through the preceding chapters and carried him to this point will, by that evidence, have proved his interest in getting practical experience with composite bows, or with modifications of such bows that might outperform the original types. A few American bowmakers have done notable work in this direction, but hitherto with success that is still short of that of the Turkish archers. The rate of improvement in America is such, however, that we may look with confidence to the establishment of all-time distance records a few years hence. Our bows have progressively decreased in weight while increasing in range. It seems reasonable to predict that few if any flight bows for "regular style" shooting will exceed 90 pounds at full draw, although stronger "foot bows" will continue in use. With both kinds, records will be broken because they will approach more and more closely the requirements which scientific analysis and experiment have shown to be essential, and because archers specializing in distance shooting have been improving their arrows and their skill so that there is little energy loss accompanying the release.

In this and the following chapter we shall present and discuss facts from personal observation and experience, and report communications with other archers who have done much in that branch of archery which concerns itself with shooting the greatest distance possible. It is hoped that this material—together with that of the preceding chapters—may provide a starting point for those who may take up flight shooting as a new interest; and that it may stimulate new ideas among the seasoned veterans of the flight tournaments. Another purpose in writing these chapters is to discuss certain promising lines of development and experimentation, based on experiment and experience, as a further stimulus to discovering the practical methods of making and using the implements of flight shooting towards the achievement of further notable progress.

Wood. The wood in Turkish type composite bows is subjected to no greater stresses than is the wood in the longbow, although the bending of the limbs of the former is vastly greater. This is true because the ratio of thickness of the foundation strip to radius of the bend is no greater, the strip of wood being relatively thin. Moreover, the strip is reinforced by being virtually encased in strong materials, from which it receives support. At the tip of the bent limb, however, the wood is subjected to great shearing stress, where reinforcement by horn and sinew has no effect. The wood must, of itself, have ample strength to withstand lengthwise shear. The wood must also be elastic and resilient, which means that its elastic hysteresis, or loss of energy in bending and unbending, must be small; but since most of the energy is stored in the horn and the sinew, their elastic properties are more important than those of the wood. There is little doubt about the suitability of the various kinds of wood used in longbows to serve as the foundation strip in the limbs of a composite bow. Since the integrity of the composite bow depends on the glue which holds the component materials together, it is important that the best glue and proper gluing technique be used.

If hot animal glue is to be applied to lemonwood or osage orange, preparation of the surfaces is indicated by washing with a 10% solution of caustic potash or lye in alcohol or water. After drying, the surface is sponged with whichever solvent was used for the caustic. Yew, white ash, hickory, maple, rock elm or red cedar may be used without the caustic wash. Such preparation is unnecessary, regardless of the kind of wood used, with the synthetic resin adhesive.

Perusal of the tables of mechanical properties of wood, and other information developed in correspondence with the Forest Products Laboratory suggest that, in addition to the kinds of wood mentioned, mulberry, persimmon, black locust, sweet birch and blue gum might be suitable. Bamboo should not be forgotten; it has been used from time immemorial by the Chinese in their composite bows.

HORN AND OTHER COMPRESSION MATERIALS. The horns of cattle have been said by some experimenters to have no value for facing a bow, and that the only horn worth using is that of the water buffalo. This is borne out by our experience. However, Hein states, and with a picture illustrates his statement, that the horns from longhorn cattle from the vicinity of Aidin were used. The compound curvature of such horns seems almost to rule them out. Aside from this, cattle horns appear brittle and grainy. According to a recent report, privately made, such horn can be "disassembled" into paper-thin sheets by first soaking it in water for a matter of days. Should this be easily possible, it would appear to offer means for producing sheets of flat horn in any desired thickness by gluing a number of such laminations together in a press. The glue, if the best quality is used, may impart plasticity to, or reduce brittleness of such a built-up sheet as compared with the original horn. It seems worth a trial.

The horn of the water buffalo, or carabao, is unquestionably one of the most remarkable materials known as regards compressive strength, stiffness, elasticity, resilience and lightness. A thin strip of it can be bent to a surprising extent, with complete recovery on release. It is hard, but quite easily worked. It can be softened with heating, and retains the shape in which it was fixed while cooling. Since the temperature of boiling water is hardly sufficient to make it easily workable, heating in a glycerin or "prestone" bath to 300° F. is indicated. The Turks heated horn to the higher temperature, after taking it from boiling water, by exposure to glowing charcoal or the flame of resinous wood.

Buffalo horn is obtainable in this country with difficulty, since it has to be imported from India, the Philippines or China, where the carabao is the beast of burden. The cost of importing a single pair, as I have done, is prohibitive. Moreover, there is no assurance of getting a pair that has simple curvature, from which strips of sufficient length and without mechanical blemishes can be sawed. A service to American bowyers would be rendered by importing a quantity sufficient to make them available at moderate prices. Anyone contemplating importation of buffalo horns for composite bows would be well advised to specify that horns with simple curvature be selected. From these it is possible to bandsaw strips that can readily be dressed down to suitable thickness and a proper gluing surface, and that will not cause sidewise bending of the limb in the finished bow. Kani suggests using paired strips, and this seems good counsel.

Horn at somewhat elevated temperature can be readily cut with a draw knife, provided the latter is kept wet during use with soap solution, or other wetting agent in water. Dry horn is easily scraped, rasped or ground on a sanding belt or disk. "Vixen" files are convenient and effective on both horn and wood. A power hacksaw blade, ground with square edges, makes an admirable scraper.

Thermosetting plastic resins, with and without reinforcing fabrics imbedded (laminates) in them have been used and are being sold for bow facing. Some are offered for backing also, but it seems doubtful that they should have special virtue for this purpose. Those that seem most promising for supplanting horn are laminates with fiberglass woven fabric. Their strength-weight ratio is being improved as methods are being found of improving the bonding between the glass fabric and the plastic. An eventual compressive strength of 180,000 pounds per square inch is reported to be attainable, and that 60,000 to 80,000 is within practicable reach. The latter figure is comparable with that for cold-rolled steel, the density of which is about four times that of the plastic laminate. Hence the strength-weight ratio favors the plastic by a wide margin.

Some of our makers of flight bows, lacking horn, have used selected, well-seasoned osage orange wood with sinew backing. Their experience indicates remarkable strength of this wood when used in compression. We have made tests recently on compressive strengths of horn and osage orange, using cylindrical samples having equal length and diameter. The results show that the strength-weight ratio of the osage samples tested is of the same order as that of horn. Until many more experiments, including tests in bending as well as compression, have been made, it must be kept in mind that since horn has other physical properties not possessed by wood, these may make horn superior for the belly of a flight bow.

Creep or Drift. The phenomenon of creep or drift is a deformation which results from a steady load, applied for a long period, to metals, plastics, wood and other materials. The amount of such deformation differs in different materials, being smallest in metals such as steel. It has a bearing on the desirability of materials used in composite bows, whether in tension, compression or shear. Drift is not the deformation known as permanent set, for it occurs within the proportional limit of loading of materials; when the load is removed, the deformation disappears, at first rapidly, then more slowly, eventually almost entirely. When the limbs of a bow "follow the string", part of this deformation is drift—that part which, when the limbs are relaxed, disappears.

Drift takes place more rapidly at high temperatures than at low. It is characteristic of the material in question, and is related to the time during which the load is applied.

The relationships are expressed by the equation $d = kt^{1/n}$, where d is the deformation, t the time, and k the constant which is characteristic of the material. For most materials n turns out to be about 4, so that $1/n$ is $\frac{1}{4}$. For convenience the equation may be expressed in logarithmic form: $\log d = \frac{1}{4} \log t + k$. A specimen to be tested may be in the form of a strip, laid on supports, and subjected to bending by applying a load about a third of that which would produce failure. At definite, noted intervals the amount of temporary set is measured. When the results are plotted with $\log d$ for ordinates and $\log t$ for abscissas, a straight line results. The smaller the slope of the line, and the closer it is to the time axis, the better the material, provided it also has a high strength-weight ratio.

The practical implication of drift in archery materials is the temporary set which a bow may take after it has been kept braced over long periods of time. If the material has large drift, the bow may let down temporarily because of this characteristic, but may return to its original shape and condition after it has been allowed to relax for some hours. Letting down in hot weather, followed by recovery, is an example of drift in bow materials.

When a material is compressed, there is great lateral force that may cause splitting if the material is fibrous in the direction of the applied force and has little cohesive strength at right angles, i.e., across the fiber or grain. Whalebone or baleen fails as bow facing for this reason. In a plastic laminate in which woven fabric is used, the weft serves to hold the material together under compression at right angles to the direction of the weft, and thus accounts in large measure for the compressive strength of the material. A greater ratio of compressive strength to weight would probably be attained if fibers could be randomly dispersed in the plastic and firmly bonded with it. Such construction might also be expected to reduce drift appreciably below its amount for the plastic without the fiber reinforcement.

BACKING MATERIALS. In tension, there is no need for the lateral cohesive strength, for the tension has the effect of tending to reduce the cross section, thereby drawing the material more firmly together at right angles to the direction of the stretching force. Thus, a reinforced plastic for use in backing, should preferably have the reinforcing fibers unidirectional, lengthwise. For this reason also the glue that is used in laying fibrous materials in backing is more important in its function of bonding the backing to the wood foundation than it is in holding the fibers together. Since animal glue, made from hide, tendons and other parts of cattle, is of the same composition as sinew (collagen), the sinew back when finished becomes a highly homogeneous layer, almost unequalled for its function.

Backing, if it is to serve adequately the mechanical function of storing an appreciable part of the energy in a drawn bow, must manifest the linear proportionality in the stress-strain relationship known as Hooke's law: as the tension increases in the back, with bending of the limb, the elongation must increase in the same ratio. If the backing is loose or relaxed at the beginning of the draw so that a certain amount of "slack" must be taken up before it "gets to work", Hooke's law does not apply at first, and the backing fails to store its share of energy. We found in the course of experiments on backing that rawhide glued on under tension and allowed to dry while the tension was maintained was appreciably better as backing than when it was glued on without tension. The Hickman backings of silk and fortisan, consisting of unspun fibers of these materials laid in glue, are best applied under tension. This may be accomplished in a mechanical stretcher which increases the length of the backing strip two or three percent, and keeping the material stretched until the adhesive is dry. It may also be done by maintaining a reverse bend in the limb while the strip is being glued on and until the adhesive has dried. Such preloading, so long as the backing at full draw does not exceed its proportional limit* enables it to store more energy. This is equivalent to saying that preloading of the backing stiffens the limbs of the bow without adding to their mass, and thereby renders the bow more efficient.

When sinew fibers are applied as backing by the method described by Kani, which is essentially the method used today, the drying process is accompanied by a great amount of shrinkage, both longitudinal and lateral. This results in preloading as described in the preceding paragraph. Moreover, when a highly reflex bow is braced, this puts additional preloading in the limbs. Such preloading in tension, compression and shear results in greater energy per unit mass in the limbs, and in part accounts for the remarkable performance of Turkish type bows.

SINEW FIBER. The preparation of a satisfactory quality and quantity of sinew fibers is perhaps the most time-consuming job in the entire project of preparing the materials for making a composite bow. Gallwey states that the neck tendons of cattle were used by the Turks. Kani says it was the Achilles tendon. Kani is probably right; he "was there", and his knowledge came at first hand, whereas Gallwey was wrong in other matters. However, Gallwey relates that when he dissolved the material in the backing of a Turkish bow in hot water, he obtained a great many short pieces, 2 to 3 inches long and an eighth inch in diameter, "as ductile as India rubber". The ability to stretch like rubber distinguishes the neck tendon from the leg tendon. Possibly some Turkish bowyers used neck tendon.

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*The proportional limit is that limit of load per unit area of cross-section within which the deformation resulting from the load remains proportional to the load. Thus, within the porportional limit, Hooke's law applies to the material.

The fibers in their final condition, ready for use, resemble flax fibers so closely that one has difficulty believing that they are not of plant origin. To prepare them, one begins by securing a quantity of leg tendons from a packing house. The fatty and slimy connective tissue is trimmed away, which leaves two firm, round ligaments, joined near one end where they merge into a single ligament. These are put in a warm, dry place for rapid drying. When thus dried and kept dry they are clean and odorless and remain so indefinitely. This point is emphasized because on my initial attempt I used tendons that had been dried without benefit of precautionary preparation; they came from the stock pile at a glue factory. The odor was most disagreeable, and only repeated extractions of the rancid fat with carbon tetrachloride finally subdued the odor to where it was bearable to one not accustomed to working in such an atmosphere. The dried tendons are hard, stiff and translucent. If, after cleaning and degreasing, the tendons are soaked for a few days in a 15% solution of glycerin in water, they do not become bone-hard while drying, and the further processing is thereby made easier.

Modern methods of converting tendons into fibers differ practically not at all from the method used by the Turks. There appears to be no easy way, so it continues to be done "the hard way"—a laborious process. The dried tendons are pounded with a mallet on a smooth surface, to break down their structure. Pounding is continued until the tendon has been converted into a soft, fibrous bundle. This is then pulled or teased apart by hand. An aid in the process is to comb the bundle through a comb improvised from nails or drill rod, mounted in a substantial block, with the free ends sharpened and pointing upward. By repeatedly drawing the bundle across the comb it can be separated into individual fibers which are, at the same time, laid parallel. One bowyer, Robert

Martin, reports that the comb or hatchel is destructive to fibers by tearing many of them, and that he abandoned its use for this reason. He shreds the tendons by hand, and cleans and tapers the ends of the individual fibers with a knife. He calls it slow work. This competent bowyer sorts his fibers into three groups according to length, because this simplifies overlapping the junctures when applying the fibers as backing. Some bowyers prefer the back or loin tendons, others the Achilles tendons, few or none like the neck tendons. Some think highly of horse tendons and prefer them to those of cattle. Others secure those of deer, elk and moose if and as available. Whether any particular kind is markedly superior to others may be doubted. Perhaps long fibers are preferable to short ones. Failure in a bow seldom if ever occurs in its sinew back. This is evidence that neither the sinew nor the glue is a critical item in the construction of the composite bow, and that care in applying these materials is perhaps more important than the materials themselves.

A bow that is backed with sinew thus carries its own insurance against failure by breakage in the back. There is an additional advantage peculiar to sinew. This is the possibility, as need may arise, of increasing the stiffness in parts of the limb that may bend too much, and, indeed, of changing the weight of the bow as desired. The preloading that automatically occurs as the sinew shrinks while drying is a further desirable feature. These points of desirability are compensation to the bowyer for the care and tedium that go into the production of sinew from tendon.

More experimental work may profitably be done in further developing the sinew back, and fully exploiting its possibilities. The shrinkage of the sinew while drying is so great, and accompanied by such force laterally that occasionally the wood is cracked, or bits of wood are pulled out of the wood core. This mishap might be avoided by preparing the properly shaped backing strip in advance in a shallow form or on a suitably shaped strip of aluminum. When dry, such a strip might be preloaded, as is customary with silk and fortisan, while gluing it to the limb. This would eliminate lateral shrinkage forces.

The methods of preparing sinew fiber from tendon, and of constructing the sinew back of a bow, as described by competent and skillful artisans* follow closely the methods described by Kani, as reported in the first edition of this work, with minor modifications suggested by experience. Robert Martin in private correspondence confirms this. He is one of the most painstaking workmen I know; a section of his letter is herewith quoted:

"As for gluing, I get complete satisfaction with the old, original pure animal glue (the high-strength glue described in the first edition of this work—Author) we used in our initial attempts at making a sinew back. I work in a hot room and work fast, and never have any glue failure. I use two courses of sinew for the back, applying the second one two weeks after the first. I have settled on six months as the minimum curing period after the sinew is on before bending the bow. The sinew seems to gain in strength for about two years after application, but the bow can be in use during this period as well as being hung up on a peg. The only advantage in seasoning the back more than six months might be very slightly less follow when the bow receives its final tillering and breaking in.

"In the process of making a great many sinew-backed bows, over a considerable period of time, I have failed to find any short cuts to good results. On the contrary, I find as I go along, I hit upon various ways of getting a better job, all of which require time and labor. At present it takes me much longer to prepare the sinew for the back

*See American Bowman Review: Bruce Robertson, December 1937; Bud and Charles Pierson, March 1938.

than it did ten years ago, or five years ago. The only suggestion I have for any bowyer who wishes to use sinew and desires to turn out good work, without much hard work, is that he take unto himself a few squaws and teach them to shred his sinew."

Curtis Hill, well-known holder of many distance records, has also acquired much experience with sinew, horn and glue in the past dozen years. He uses loin tendons in preference to leg tendons because of their greater length, and finds them equally strong. They are also more easily shredded into fine fibers. Before drying he cleans them thoroughly; drying time does not matter—it may be weeks or months, and thereafter they remain good indefinitely. He says, "I pound them with a wooden mallet until the fibers start to separate, then pull them with brute strength through a comb made of a piece of brass with steel pins until they are very fine.

"I prefer a No. 1 hide glue for putting on the sinew back. I use the glue at about 120°. If too hot, the sinew curls and loses strength. Keep the room temperature 80° or more and be very careful not to chill the bow or the glue. I have applied sinew both in one layer, and in two and three layers. I like to put on one layer, let dry for three weeks, then tiller the bow to weight. Put on another layer, let dry the same length of time, shoot the bow a while, retiller to about 8 or 10 pounds below the desired weight. Before the last layer is put on, set the limbs back; then they will never follow the string. Before the glue sets, I rub the sinew with the back of a knife or a round piece of hard wood to straighten out the fibers and squeeze out the surplus glue. I then wrap tight with linen or cotton bandage and let dry.

"Horn is easy. There is no mystery. Roughen the horn with coarse emery paper or wheel. Do the same with the wood. Warm both slightly, and use good hide glue.

Clamp and let dry for a week. If the joint is a good fit, the horn or wood tears out before the glue lets go."

Reference has already been made to the excellent quality of osage orange and its possible use as a substitute for horn. Bob Martin uses osage exclusively for his bows. He specializes on hunting bows with ears. His experience, and that of such flight enthusiasts as the Piersons, Curt Hill and Bruce Robertson, indicate that superb bows can be made of osage, backed with sinew, the osage taking the place both of the wood core of the composite bow and of the horn facing of the latter. Of all these bows, it must be said, in comparing them with Turkish composite bows, that the American bows bend more nearly uniformly than did the Turkish, so that there is no excessive compression at any point. Neither is the degree of reflex as great as it is in many of the Turkish bows. Perhaps, indeed probably, the oriental composite bow was possible only by virtue of the availability of horn. It is doubtful whether any kind of wood, even the best osage, could have withstood the forces to which the horn in the Turkish bow was subjected.

These comments are by no means intended to convey the idea that horn may be ruled out in American bowyery. In fact, if horn made the composite bow of the Turks possible, its properties when fully exploited by American craftsmen may enable them to take another long step forward in achieving long flight distances. Undoubtedly the judicious use of sinew and horn, in a design that conforms to known principles and requirements, will lead to new records.

Glues. In 1934, while preparing the manuscript for the first edition of this work, the author consulted several authorities* on the technology of glues. It was their opinion that the manner in which the Turkish artisan

*The late Dr. J. R. Powell and Mr. L. B. Lane.

prepared his glue, as described by Kani, would yield an excellent product. They also provided information regarding the processing and properties of modern glues. This information has again been checked with Mr. Lane, to bring it up to date.

There has been little change in glue technology in several decades.* Hot glues are available that have higher strengths than any wood samples that may be glued with them, as shown by the fact that when shearing stress is put on the joint, the wood tears out; it is not the glue that fails. These high quality glues, made from calfskin, kip stock (skins from animals older than veal and younger than beef) and select pieces of skin from mature animals, readily give a jelly strength of 400 grams, corresponding to 10,000 to 12,000 pounds per square inch—a strength of from three to four times the shearing strength of most woods. It is the first run of the properly processed raw stock that yields the highest test glue, and it is this glue which is highly sensitive to temperature and humidity while it is being used. A glue which tests 400 grams jelly strength is quite flexible at normal moisture content. The higher its grade, the greater is its flexibility. If worked at a temperature of 80° to 90°, which is advisable to retard setting, or jelling, such glue should be mixed in the ratio of 4 parts glue to 15 parts water by weight. The dry glue is first soaked in cold water until soft, then heated in a glue pot or water bath at not over 150° to liquefy.

In my early experiments with methods of applying sinew backs, I found it necessary, with the highest grade glues, to work in a small bathroom, heated to 85 or 90° by means of a radiator, a couple of electric heaters, and the hot water running out of the shower bath sprinkler

*Three government publications contain helpful information about glues and gluing. They are: U.S.D.A. Bulletin No. 1500 (1929), "The Gluing of Wood"; Technical Note No. 226 (1940, revised), Forest Products Laboratory, "Glues for Wood in Archery"; and Bulletin R492 (1937), Forest Products Laboratory, "Animal Glues: Their Manufacture, Testing and Preparation."

head. This brought the relative humidity near 100%, creating a tropical environment that is reminiscent of New Guinea. Get everything prepared beforehand, so that you may spend the least time necessary in the hot, humid room, and take three salt tablets before entering; for before you emerge with your bow and its newly acquired back, you will have lost that much of your normal salt content, along with a quart or two of perspiration. A physician would probably name what you get in the process "hyperpyrexia"; in ordinary language it is a Turkish bath—quite appropriate, perhaps, to making a Turkish bow.

One or two such experiences will be sufficient to stimulate interest in glues that can be worked under conditions more nearly normal to the temperate zone. Cold glues, usually made from the offal of the fishing industry, are available. They are relatively expensive and lack the strength of good hide glues. The addition of not more than 10% isinglass (dried fish bladders) to hide glue lengthens the time of jelling but somewhat reduces strength. There is evidence, as noted, that the Turkish bowyer added fish glue to his glue made from tendons, to increase setting time. A little of the strength of 400-strength glue is worth sacrificing for the comfort of a cooler and less humid environment. It is probably still quite strong enough for use in sinew backs. For gluing horn to the wood core, however, such modification may be inadvisable.

Manufacturers of hide glues have realized the advantage of the slow-jelling glues, provided high strength is maintained. Some development work has been done to find suitable liquefying agents, and progress has been made. Liquid glues made from hide, and having high strength, will probably soon become a commercial article.

Adhesives made from synthetic resins came to the fore in large numbers and varieties during the war years.

These, of both the hot press and cold press types, are largely used in the bonding of wood veneers, which thus are rendered water resistant. Other adhesives of this class are so prepared that the woodworker may, in his shop, mix small quantities with cold water and use like ordinary liquid glue, or like the casein glues which only in recent years enjoyed such wide popularity. None of these adhesives is satisfactory for putting on the sinew back; but for gluing laminations of wood together, they have proved themselves highly serviceable. They may not be sufficiently flexible. One resourceful bowyer adds a few percent of ordinary flour to his synthetic resin mix to plasticize it. These glues, like hot glues, require pressure up to 200 pounds per square inch for hard and 150 for soft woods during the curing process. This presses out the excess without starving the joint.

Some processes of joining materials together, particularly dissimilar ones, such as wood and metal, are quite successful; but they require specialized equipment and a nicety of temperature control that lie beyond the ordinary possibilities of the archer-craftsman's shop. On the other hand, one adhesive (Urac 185) seems so well suited for use in the home workshop that it merits special mention. There may be others that have not come to my attention. This may prove ideal for the joining of horn or any horn substitute to wood and other materials. It is waterproof. It has established its worth for fishtail splices in osage orange —a crucial test. Moreover, it does not demand the precision fit of surfaces that is imperative in the usual gluing job. Two components are supplied, one in liquid and one in powder form. These are mixed and applied as directed. The adhesive is termed by its manufacturer, the American Cyanamid Company, "a craze-resistant, low pressure bonding agent for the woodworking industry". Surfaces to be bonded should be absorptive or roughened. Glue line thicknesses should not exceed 20 thousandths of an inch.

This, as can readily be seen, does not require precision fit of surfaces. After clamps have been applied, the work is placed in a cabinet or box heated with electric bulbs or other means to about 140 or 150°. In two hours it may be removed for further work. It should, however, be allowed to age for five days in ordinary room temperatures before exposing it to temperatures below 60°. One manufacturer of archery equipment who has experimented extensively with adhesives of many kinds reports uniformly good results with this preparation. With osage orange and lemonwood, no washing with caustic solution is required.

OBSERVATIONS ON DESIGN. Before proceeding to further consideration of the construction of composite bows, a few principles underlying bow design should be mentioned. The limbs of all Turkish bows that I have examined or seen illustrated are almost uniform in width as well as thickness from grip to shoulder. We know that the moment of force tending to produce bending in a limb decreases from the root of the limb to its tip. We also know that the amount of the bend at any point on the limb depends directly on the bending moment* and on the shape and size of the section of the limb. If a limb is to bend with uniform curvature, its stiffness, which for a limb of constant thickness depends directly on the width, must likewise diminish in constant ratio to the bending moment. The Turkish bow does not follow this principle. It therefore bends much more strongly near the grip than farther out along the limb. Although no proof is offered, it seems reasonable that uniform bending of a limb of unvarying thickness, i.e., bending in a circular arc, results in higher efficiency than excessive bending at one place, and very little at another. For it is an established fact that high efficiency depends on small virtual

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*The bending moment at a section is the product of the applied force and the perpendicular distance of the section from the line in which the force acts.

mass* of the bow; and minimum virtual mass for a given amount of potential energy in the limbs cannot be realized without the largest possible ratio of energy at full draw to mass of the limbs. This requires materials of the greatest possible strength-weight ratio that can store a maximum of energy under large deformation; and limbs so designed that every part is stressed equally but safely within the limit of strength of the materials.

Improvement in performance of the traditional Turkish bow may be expected if the limbs are designed and constructed to bend uniformly, or at any rate to bend so that all parts of each limb are equally stressed. The compression side, i.e., the horn, should probably be more nearly flat than it now is, but the corners should be well rounded. It is sound procedure to begin with a tapering rectangular section of uniform thickness, and to develop modifications from that.

COMMENTS ON CONSTRUCTION. Instead of making the wood foundation of three or five pieces, as described by Gallwey and by Hein, it appears simpler and better to make it of a single piece. The ears may be included as an integral part of the wood foundation, or they may be attached by a single fishtail splice. The limbs should be of equal length, 14 to 16 inches of bending section from grip to ears; and the ears may be from three to four inches long, either with a radius of curvature of about three inches, or straight, as in the Turkish bows. The rigid midsection may be 7 to 10 inches long. The longer middle section permits shooting the arrow off the middle of the bow, with symmetry of the two limbs with reference to the arrow. The limbs should be tapered from a width of about 1½ inches at the widest part near the grip to about ¾ inch at the junction with the ear. It is an attractive and possibly a rewarding project to design a

*See page 149 for an explanation of this concept.

limb for a composite bow with constant stress per unit area at every section, making a limb which varies both in width and thickness, as in the Nagler design of limb which bends in an ellipse.

A substantial aid to construction is a combined bending and gluing fixture, made of 1¾-inch seasoned birch or maple. For ease and accuracy of construction this is practically indispensable. The desired profile of the unbraced bow is marked out on the planed plank, and the latter is carefully sawed along the marked lines with a bandsaw, and the edges smoothed to a good finish. Within 1½ inches of the edges bore a series of holes, spaced about 3 inches, as shown in fig. 43, large enough to ac-

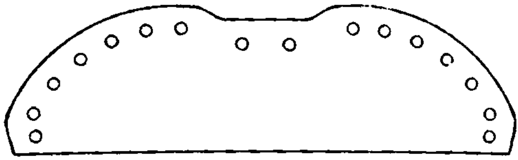

Fig. 43. Gluing fixture for composite bows.

commodate the rigid end of a 3-inch C-clamp. The limbs are softened with moist heat, by steaming or boiling, after which they are clamped to the form and kept there until dry. This gives them the shape of the predetermined curve. The same form is then used as a gluing fixture for attaching the horn strips to the wood foundation, without preshaping them with heat. In the gluing process the horn strips are bent cold and clamped in place until dry.

The use of a properly made fixture of this kind assures correct alignment of the limbs and contributes to stability. Stability is also increased by making the limbs fairly wide at the base, with appropriate taper, as described. The greater the average width of the limbs, the more stable the bow. With limbs of uniform thickness, this construction would produce, roughly, a bend of uniform curvature. In tillering to a uniform curve, the limbs will be thinned down somewhat towards the ears. Dr. Eppley observed that the oriental bowyers achieve stability in their bows, most of which have limbs of contsant width, by reducing the reflex curvature of the limbs with heat, and binding them to rigid forms like the Turkish *tepelik.* The suggested gluing of the horn strips to the wood without first preshaping them to the curve tends to reduce reflex. It also tends to improve the stress distribution in the limbs.

Because of its importance, it is not superfluous to mention again the importance of fitting the horn and wood surfaces together so that a very thin glue line results. The surfaces may be roughened with coarse garnet paper. The flakes of dry glue are mixed with water in the ratio of 2:5 by weight. After standing several hours, the mixture is gradually brought to 150° F. in a water bath or gluepot. If the wood is osage, it requires the usual alkaline wash. Then both surfaces, horn and wood, are given a sizing coat of glue thinned from the regular consistency with four parts of water at 150°, and allowed to dry. The parts to be glued should be warmed to 95° or higher, which may be done in a box fitted with electric light bulbs. Heating should be thorough. A warm, humid room contributes to success. Spread the glue thinly on both surfaces, and allow it to become tacky; then press the clamp together. If the parts fit as they should, the pressure needs not exceed 125 pounds per square inch.

On the Turkish bow the two horn strips were in abutment at the midpoint of the grip. If the horn strips are not sufficiently long to meet in the middle, they may extend just beyond the limbs onto the rigid section, and the gap filled with an additional piece of horn, well fitted between the ends of the strips.

After a couple of days the clamps are removed and the horn scraped to the desired thickness. The bow is now ready for application of the sinew. The back of the bow is first "filled" with a sizing coat of glue. The glue for applying the sinew is mixed as before, but thinner, in the ratio of 1 parts of glue to 5 of water. It is kept hot in a shallow dish or vessel which is set in a water bath, of size and shape to allow easy manipulation of the fibers in the glue. Three ounces of glue, dry weight, is sufficient to cover the entire back with surplus for unavoidable waste. The fibers, in bundles of various lengths between 2½ and 6 inches, or longer if made from loin tendon, are worked about in the hot glue until they are completely saturated, and the excess glue is stripped out between the thumb and finger. The fibers are then applied to the back, a small bundle at a time, until a layer of uniform thickness has been built up on both limbs without interruption at the grip, and with the junctures between ends of bundles properly offset. Excess glue is removed by stroking the sinew with a metal rod, or rounded, smooth piece of wood.

When the first layer has thoroughly dried—experienced bowyers allow two to three weeks—a second and even third course may be similarly added, but without increasing the reflex, as described by Kani. According to the strength of bow desired, the total thickness of sinew may be up to ¼ inch maximum. A bow 48 inches long, measured along the edge of the limbs, with a 10-inch handle section, and an average thickness of 9/16 inch, is estimated to draw 120 to 150 pounds, depending on the elastic properties of the materials and the initial reflex. The horn and sinew are readily worked down with a scraper and a "vixen" file.

Bracing the composite bow, especially when its weight exceeds 100 pounds, requires extraordinary strength and skill, and must take much practice even with the *kemend*.

The only way in which I have been able to accomplish this feat, particularly in the shop, is to make a fixture or rack, consisting of a stout board, with a strong shelf near one edge for the grip, the plane of the bending being parallel to the surface of the board. On each side of the supporting shelf, far enough out to trace the paths of the outer ends of the limbs, where the ears are spliced into them, a series of holes is bored, about an inch in diameter. Stout pegs are fitted into the holes with an "easy" fit, so that they may be readily inserted or withdrawn. The pegs may be moved along, from one hole to the next, first behind one limb, then behind the other, as the limbs are alternately bent, one step at a time. By this process the amount of bending at each step is small, and is determined by the distance from one hole to the next. The effort required to do the bending through one of these small steps is small; and at no time is the bent bow far out of symmetry. Moreover, the pressure of the stout pegs behind the limbs gives security. When the limbs have been bent far enough, the string is placed in the nocks, and the step-by-step process with the pegs is reversed until the braced bow is found to be stable. It is then removed from the rack. To unbrace the bow, the process used in bracing is reversed.

CHAPTER X

SOME SCIENTIFIC CONSIDERATIONS

To one who has an abiding interest in archery, there is great incentive and stimulation to scientific inquiry in reading about the achievements of the Turkish archers. They shot a half mile or more, and the development of their equipment proceeded by cut-and-try methods through the centuries, with constant improvement which culminated in the weapons used in distance shooting by the Turkish archers' guild. What did they possess that we lack? To be sure, our flight specialists have made great progress since the days, in the nineteen twenties, when 300 yards was exceptional and 400 unattainable. They have been steadily improving their equipment and several records of more than 600 yards have been made. To my knowledge, none of them has made a full composite bow, probably for lack of suitable horn, that performs as well as do the bows of selected osage orange with sinew backing. And none has made a composite bow that approaches in performance those of the Turks.

In the earlier chapters of this book we have the story of how the Turkish craftsmen made the bows and arrows, and how the archers used them. In this chapter we shall develop information of a technical nature, having to do with flight shooting in particular, that has come out of experiment and experience of recent years. The old information together with the new may assist those who are interested in the art of distance shooting to exploit more effectively the possibilities of wood and other materials suited to their craft.

Let it be recognized, before we take off into the technical realms, that the skill of the archer is responsible for many yards of the distance he shoots. The Turks appreciated this fact. We have seen in a previous chapter an account of the many months of arduous practice demanded of the novice before he was admitted to the guild, where he might enjoy, as one of its benefits, participation in tournaments on the *ok meidan*. It is likewise apparent that the attainment of exceptional distances requires bows and arrows that conform in all respects to certain well established scientific principles, and that exemplify the best in the bowyer's art in the application of these principles.

THE BASIC PRINCIPLES. Of these, the most fundamental is that which relates to the storage of energy in the drawn bow, and its transfer to the arrow.

At the instant the archer is ready to loose, the energy in his drawn bow is equal to the work he did in making the draw, diminished by the energy lost in the limbs because of less-than-perfect elasticity of the materials of which they are made. This represents the greatest possible amount of energy available for transfer to the arrow. Actually there is inevitably some loss of energy during this transfer. The smaller this loss, the greater the efficiency of the bow-and-arrow combination. Numerically, the efficiency is the energy, in percent of the energy in the bow at the instant of loose, that is transferred to the arrow. Thus, if the energy that gets into the arrow is three-fourths that in the drawn bow, the efficiency is 75%. In practical situations the efficiency varies over a wide range—from about 35% to 85%. It takes but little imagination to suggest that we desire to approach as closely as possible to an efficiency of 100%. But high efficiency alone does not assure maximum distance, for highest efficiency is achieved only with relatively heavy arrows. Maximum distance demands high initial velocity, which excludes the use of heavy arrows for flight shooting. To understand all the implications of these comments, it will be useful to explore further the concept of energy, and see where it leads.

WORK AND ENERGY. In mechanics, a branch of physics, work and energy are closely related, if not synonymous. Work involves exerting a force, like a push or a pull, through a distance. In the technical sense, no work is done when you merely hold up a weight, or push against an immovable object; but if the object moves as you push it, or if you elevate a weight through a distance, you do work, and the amount you do is measured by the product of the force and the distance. Thus you do measurable work in drawing a bow, and the drawn bow contains energy equal to that work; and it can be converted into another form of energy, which is characteristic of moving bodies, in the flying arrow.

In its broadest sense, energy is a condition of matter which renders it capable of doing work—of exerting a force through a distance. It may be mechanical, chemical or thermal, or in such forms as light, and sound, and electricity; and we have heard much in recent years about nuclear energy. A wound spring, an elevated weight, water impounded behind a dam, and a drawn bow are examples of mechanical energy called *potential*, capable of doing work because of position or condition. A projectile in flight possesses kinetic energy, as does any matter in motion, because it is in motion.

It is characteristic of energy that it can be transformed from one kind into another. When the bow accelerates the arrow, potential energy in the drawn bow is converted into kinetic energy which appears in the moving arrow and the moving parts of the bow. When water flows through a turbine, its potential energy, due to its elevation, is converted into kinetic energy as it moves into the turbine; here the kinetic energy of the water is tranferred, in turn, to the whirling rotor of the turbine.

All mechanical motion with which we deal gives rise to frictional forces that resist the motion. The effect upon a freely moving body is to reduce its velocity, eventually to stop the motion completely, and to generate heat by friction in so doing. The energy of the moving body will then have been transformed into heat, and is lost so far as further useful work is concerned. Thus, energy that has been converted into heat by friction is not recoverable. On the other hand, potential energy is usually convertible to other useful forms, before its ultimate degradation to heat at temperatures too low to be useful.

When the bow accelerates the arrow, we are dealing with energy of the recoverable kind. It is being recovered, for the most part, in the form of kinetic energy in the arrow. But some of it, transformed into kinetic energy in the moving parts of the bow and the string, is useless with respect to its effect on the arrow after the latter has become free of the bow. This helps to clarify the statement previously made that the kinetic energy in the arrow, expressed in percent of the potential energy in the drawn bow at the instant of loose, is a measure of the efficiency of the bow.

Energy is measured in the same units as work. When you push a packing-case along the floor, say with a force of 30 pounds required to overcome friction between the case and the floor, and skid it a distance of 10 feet, the work done is 30 x 10 or 300 foot-pounds. All of the energy expended in doing this work is lost in heat through friction. But if you elevate a mass weighing 30 pounds to a floor 10 feet higher, you have done the same amount of work as when you pushed the case across the floor, namely 30 x 10, or 300-foot pounds; but in this instance the work you did is all recoverable, because the weight at the higher level is capable of doing 300 foot-pounds of work in descending to the lower level.

In one respect, a bow at full draw is like the elevated weight. The energy is potential and returnable. It differs from the elevated weight in that the force exerted on the string in drawing the bow was not a constant force, as is the weight; rather, it is zero at the beginning of the draw, and gradually increases to that at full draw. The curve which represents the force at each length of draw between the two limits is the static force-draw curve of the bow. The work done in drawing is the *average* value of this force multiplied by the distance through which the force is exerted, or the total length of draw.

FORCE-DRAW CHARACTERISTICS OF BOWS. The shape of the f-d curve depends on the geometry of the bow, i.e., the kind and length of the limbs, their shape and attitude in the relaxed condition, and the height of bracing, i.e., the distance between the string and the grip. Data for such curves can readily be obtained by measuring the corresponding values of force, with a spring balance, and length drawn, with a yardstick, and plotting the pairs of values.

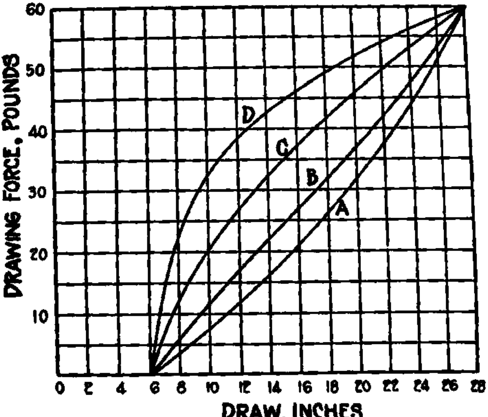

Fig. 43A. Force-draw curves of typical bows.

A short, straight bow, as every experienced archer knows, "stiffens up" noticeably towards the end of the draw. This happens because, during the last part of the draw, the force per inch of draw increases to such an extent that it may be as much as three times as great as it is near the beginning of the draw. Such a bow is unpleasant in "feel" and difficult to shoot well because slight variations in length of draw caused by uncertainty in holding cause large variations in velocity of the arrow. Curve A in fig. 43A shows this clearly. It is the f-d curve for a straight, four-foot bow. Curve B is the curve for a six-foot straight bow weighing the same at 28 inches, and with the same bracing height. The closer approach to uniform increase of force for each inch of draw throughout the distance drawn is noticeable.

When a bow of the same length as that of curve A is provided with rigid ears having a three-inch radius, so set in relation to the limbs that the string is tangent to the outer ends of the ears at full draw, and tangent to the inner ends of the ears when let down, we obtain the interesting result shown in curve C. The action is stiff at the beginning, but in the last half of the draw the force per inch is nearly uniform, and appreciably smaller than for the straight bow of the same length. The effect of a small change in draw is only 45% as great as it is for the straight bow. Such a bow is pleasant to draw and easy to hold at full draw.

If the limbs of the bow with which the data of curve C were obtained are strongly reflexed, as in the Turkish bow, the situation is still further improved. This is represented by curve D, which shows the action to be exceedingly stiff at the beginning, but so much eased after half-draw that the nearly constant force per inch at increasing draw is the lowest in any of the four bows being compared. The following comparison is made from the curves.

Bow	A	B	C	D
Force in pounds to half of full draw....	23	29	39	47
Additional force to complete draw....	37	31	21	13

Force-Draw Curve and Energy. We have shown that the work done in bringing a bow to full draw is the product of the *average* force and the distance drawn. An examination of a force-draw curve shows that the average force for the entire draw may be found by adding the forces represented by the ordinates, or vertical lines extending from the base line to the f-d curve, taken at equal intervals, and dividing the sum by the number taken. It is a straight, arithmetical average. Accuracy is increased as the number of intervals, and hence the number of forces taken, is increased. This average value, multiplied by the full length of draw, is not only a measure of the work done in making the draw and hence of the energy in the drawn bow; it is also a measure of the area included between the f-d curve and the base line, and the longest ordinate, or vertical line, at full draw. Whatever the shape of the f-d curve, the area under the curve is a measure of the energy stored in the bow.

Reference to the curves of fig. 43A shows that the least energy is stored in the short, straight bow; that the six-foot straight bow contains 20% more; the short bow with ears, 46% more; and the Turkish type, 57% more. Since all the bows used in obtaining the data for the curves had the same weight at full draw, it is evident that the Turkish type bow not only stores the maximum energy, but is also easier to hold at full draw, in comparison with the other types for which f-d curves are shown.

Energy, Drag, Distance. When, during the several hundredths of a second in which the bow accelerates the arrow, the latter attains a velocity v at takeoff, the amount of energy it has acquired from the bow in this short interval is expressed as $\frac{1}{2}mv^2$, where m is the mass of the arrow. As soon as the arrow is set in motion it encounters drag, or air resistance, the effect of which is to retard the motion, and produce a gradual slowing of the speed. During each second of travel, the arrow loses velocity by an amount of several feet per second.

If there were no drag, the maximum distance, measured horizontally, that could be attained by an arrow with velocity v, shot with an initial angle of 45°, would be v^2/g, where g is acceleration of gravity. Thus an arrow of 200 fps (feet per second) would travel $200^2/32.2$, of 1242 feet—just over 400 yards*. Because of retardation of the arrow by drag, aside from other causes such as faulty shooting, the distance of a 200-fps arrow would probably be somewhere between 15% and 25% less than the distance in vacuum, i.e., without drag. The slowing up due to drag depends on length of the arrow, surface area, surface finish, size and nature of stabilizing vanes, and shape of shaft, all of which have a part to contribute to the total drag. Moreover, the retarding force is not constant for a given arrow; it varies as the square of the speed relative to air. Thus the retarding force at 200 fps would be four times that on the same arrow at 100 fps, and the slowing-up effect is substantially greater at high speeds than at low. Finally, and highly important, is the fact that the reduction in speed is less for a heavy arrow than for a lighter one at the same speed, assuming both exactly alike except in mass. This means that, with the same initial velocity, the heavier arrow flies farther than the lighter.

By making careful, accurate measurements of velocity of arrows of various weights, all shot with the same bow, and repeating the measurements with various bows, we have learned that there is greater transfer of energy to a heavy arrow than there is to a light one. At first glance

*Note that the "vacuum" range in yards is approximately 1% of the initial velocity (in fps) squared.

this fact might suggest shooting heavy flight arrows to get maximum distance. But this would be an error, for the greater energy in the heavy arrow is gained by virtue of its greater mass, and at the expense of velocity. Putting the observation in reverse, it is found that the lighter the arrow, the higher its velocity from a given bow, although its energy is less than that of a heavier arrow.

From the observations stated, the following conclusions are drawn: 1) If there were no drag, greatest distance would be obtained with the lighest possible arrow that would stand up under the thrust of the bowstring. 2) Since there is drag, an arrow must have finite mass to serve as a reservoir of energy to "keep going", i.e., to keep the slowing-up process caused by drag at a minimum. 3) If mass is increased too much, the initial velocity will be so diminished that the distance, even in vacuum, would be diminished. 4) Consequently, for any particular bow there is some particular mass of arrow that will fly farther than either a lighter or a heavier one. Discovering that optimum, or best mass of a flight arrow for his flight bow becomes one of the problems to beguile the ambitious flight shooter.* Another, of at least equal importance, is that of designing and making a bow of such characteristics that it will transfer the maximum amount of energy to an arrow of optimum mass. An understanding of underlying principles helps in the quest for the answers.

Virtual Mass. Archers of all eras undoubtedly recognized differences in cast in bows; bows of equal weight and draw do not produce the same velocity in the same arrow. Indeed, this difference among bows is observable even when their energy available at full draw is the same. The differences among bows which render some of them

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*From available facts and certain reasonable assumptions, the author ventures a guess that the optimum mass of a well-finished flight arrow of wood, for flight bows of present types, will be somewhere between 175 and 200 grains.

"live", "quick", "snappy", ...
Ascham in 1544 refers to such a bow as "a lugge"— ... be measured and expressed in units of mass. This cha... teristic has been called "virtual mass"*. It may be ... tured physically as a fictitious mass which, if it had ... same velocity as the arrow at the instant the latter le... the string, would have precisely the amount of en... that was left behind in the bow—the amount that fa... of being transferred by the bow to the arrow. Curio... but fortunately, the virtual mass is practically cons... for any particular bow, regardless of the mass of the ... row. A bow of small virtual mass succeeds in transfer... a large part of its energy to the arrow, depending ... course, on the mass of the latter also; whereas a bow ... large virtual mass would transfer a smaller part of ... energy to the arrow. It is therefore the bow with s... virtual mass, other things being equal, that is the effic... bow. A general principle is that the bow which has ... greatest ratio of potential energy at full draw to vir... mass is the most desirable for flight shooting.

The question immediately and naturally arises, "H... does one go about designing and constructing a bow ... minimum virtual mass?" Although it is much easie... ask the question than to give the answer, there are s... known principles to be followed; we do not, as yet, h... the complete answer. Theory and experiment, with ... tempering of experience, must continue together in ... search.

We know that energy which is left behind in the ... when the arrow leaves the string is of the kinetic t... largely residing in the moving string and limbs. As ... motion diminishes through the dissipation of the ene... the latter changes from the kinetic form to heat. ...

ity of the arrow. But this energy is actually the sum
any small "pieces" of energy, each of the form $\frac{1}{2}mv^2$,
"piece" being associated with a minute part of the
or the string, each of some small mass m with some
cular velocity v, all of them different. The small
ent of mass near the bow tip has greater velocity than
near the grip; and the small element of mass of the
g near its middle has greater velocity than another
element of one of the loops.

Vith aid from this description of the physical signifi-
e of virtual mass, which we desire to make as smal
ssible, we may contemplate ways and means of attain
his desirable objective. First, make the mass of th
as small as possible, for this makes the sum-total o
e small elements of mass that make up the bow an
tring a minimum. Second, make the velocity remain
n the limbs and string when the arrow leaves th
r as small as possible. If it were possible so to desig
w that this remaining velocity were zero, so that a
on stopped "dead" and remained so, then we woul
a bow of 100% efficiency, for under these condi
all the energy in the drawn bow would have bee
ferred to the arrow, with none left in the bow. Th
of perfection is probably not attainable, but it ca
pproached. The difficulty is increased when fligh
ws of small mass are used. Even with these, 75%
ency should be possible.

'o reduce the mass of the bow without limit, to mak
ctual and hence its virtual mass small, is obviousl
practicable. For we must provide whatever amoun
aterial is needed in the limbs to store the energy
draw that is required to cast the arrow with the de

too, with a minimum of mass. What is desired, of course, is the greatest possible storage of energy in limbs of the lowest possible mass, with drawing force which is within the archer's ability. The conflicting requirements of maximum capacity for energy and minimum mass must be compromised. Good elastic properties being imperative, we shall take them for granted. In addition to these, the highest possible strength-weight ratio represents the best compromise possible between the conflicting requirements mentioned. This emphasizes the importance of knowing all the properties of all the materials that enter into the construction of the bow. No less important is the manner in which the materials are disposed in the limbs, so that it assures their most advantageous use.

Desirable Properties in Materials for Bows. To store energy, limbs must be made of materials that have mechanical properties suited to the functions to be performed, in accordance with the location of the material in the limb. The simplest case—to illustrate—is the limb of a self bow, made of wood. As the limb is bent, the wood on the concave side of the bend undergoes compression; that on the convex side experiences tension; that in the mid-layer is subjected to shear. The wood must therefore be sufficiently versatile to withstand all such stresses if it is to be suitable for a bow. The greater its ability to resist the strains imposed on it, the better it is suited for the purpose. If, along with great strength it is light in weight, which is the same as saying that if its density is low, its suitability is greater. The last statement is merely repetition of the assertion that high strength-weight ratio is desirable.

Resistance to bending, commonly called stiffness, usually denotes that the three characteristics above enumerated are present. But there must be no brittleness; toughness is needed. Under tensile strains, on the back of the limb, there must be proportional elongation; under compressive strains, on the belly, there must be proportional reduction of length or condensation; under shearing strains, in the mid-layer, there must be proportional yielding, longitudinally. This means that all the strains, which, by Hooke's law should be proportional to the stresses, must, by that token, be strains in materials as nearly perfect in their elastic properties as may be. It means, likewise, that these properties be such that as soon as the stresses are removed, the strains must disappear—in other words, as soon as the external force is removed, the internal distortions must disappear—and the wood must resume its original state. If this happens rapidly, instantaneously, without sluggishness, it is evidence of great resilience, the property of yielding up stored potential energy with minimum internal loss. In reciting these points of desirability, we are merely saying, in a roundabout way, that the greater the ability of the wood to store energy without breakdown, and to give it up without delay, the better it is suited for bow limbs.

To expect a single piece of wood to measure up in all respects to these requirements as to tension, compression and shear, is expecting more than is reasonable. Yet there are certain kinds that do measure up surprisingly well. What kinds? Why, yew and osage, of course; that is precisely what has put them at the top of the list for bow woods. There are others, not quite so good. These two favorites suffice as examples. The greater density of osage as compared with yew finds compensation in its greater strength; thus its strength-weight ratio, on the average, is equal to or better than that of average yew. For wood, osage has amazing hardness and compressive strength; next to horn, it is probably the best compression material readily available to the bowyer. Almost every kind of wood, free from knots, pins and other blemishes, shows up well in tension. In most kinds, tensile strength may be double or triple the compressive strength. Some kinds of bamboo should not be overlooked as material for composite bows. In tensile and compressive strength, they exceed the corresponding properties of most kinds of wood.

The stiffness of the limbs in a bow, which depends, in the first instance, on the material itself, is affected by design and dimensions. A convenient measure of stiffness is the force applied at the end of a limb to deflect the tip one inch. The greater this force, the greater the stiffness. For a given material, the stiffness depends on width and thickness, and diminishes with length. If the thickness is constant, the stiffness is in inverse ratio to the length, meaning that if the length is increased, say, 10%, the stiffness is decreased 10%. It also varies directly as the width: increase width 10%, stiffness increases 10%. With length and width fixed, stiffness varies as the cube of the thickness, t^3. Increase the thickness by a factor, and the stiffness is increased by the cube of that factor. For example, an increase in thickness of 10% corresponds to a factor of 1.10; this number cubed, $(1.10)^3$, is 1.33. Hence an increase of only one-tenth in thickness of limb increases stiffness by one-third. Increasing stiffness in the limbs is the same as adding weight to the bow. Shorten the limbs, widen or thicken them, and the bow becomes heavier. But the increase in weight derived from increasing thickness is achieved with the addition of a minimum of mass to the limbs, as compared with widening them.

These considerations, applied to the general proposition of packing a maximum of energy into a minimum volume of limb, clearly suggest short limbs, and thick limbs rather than wide. But thickness has a limit, for the thicker the limb, the greater the compressive and tensile strains put upon it, and the smaller is the stability of the bow. Thus, the process of making the adjustments among these dimensions to a nicety, to secure a bow of desired weight and high efficiency as the end-product, requires skill plus good judgment based on knowledge and experience.

It seems next to impossible that any single material should have all the desirable characteristics that have been discussed. But there are materials better than any known wood as regards strength-weight ratio in compression, combined with other needed characteristics; there are others, similarly, for which the same can be said regarding tensile properties; there may be others in the same class as regards resistance to shear. The existence of such materials is the probable explanation of the development of the Turkish composite bow; for it combines materials with the best known characteristics, each for its particular function, in a manner that utilizes them most advantageously. It may be conjectured that those who were responsible for bringing the composite bow into being—men of experience, keen observation and excellent judgment, working to improve the weapon down through the centuries—had no technical knowledge of tension, compression and shear. Had they had that knowledge in applicable form, their success might have come sooner than it did. But the fact remains that they were successful in applying their experience with the behavior of materials to the creation of a weapon which, from the technical point of view, far surpassed any other of its kind.

In the light of these incidental but important considerations, let us resume examination of some of the factors that may bring us nearer the goal of producing a bow with maximum stored energy and minimum virtual mass. In review, the latter demands small actual mass in limbs and string. Moreover, the action of the limbs should be such that at the instant the arrow leaves the string, there may be as little motion or "active" elastic deformation as possible left in the bow, for this represents energy that cannot be transferred to the arrow. It is too late.

Consider the second requirement first, for this has to do with geometry and dimensions, in the design of the bow. From high speed photographs we have found, in a longbow, that after the arrow has taken off, the bow executes oscillations which rapidly die out, while the string vibrates with decreasing amplitude which rapidly falls off. Flight archers have experienced the importance of keeping the mass of the string very small, so that in some cases the string is made so light that it breaks at the shot. On the basis of the concept of virtual mass we can compute for a certain bow of 190 grains virtual mass that if the weight of the string can be cut 50%, it increases the efficiency of the bow with an arrow of 190 grains from 50% to 53.7%. Such an increase in energy transfer would, at 600 yards, increase the distance by about 40 yards.

The greater cast of a short bow as compared with a long one of equal weight, and probable greater energy at the same draw, is a fact of experience which verifies the assertion that short limbs perform with greater efficiency, which indicates smaller virtual mass of the short bow as compared with the bow with longer limbs. The reason for this is clear from previous considerations. These also provide a conclusive explanation for the fact that users of the longbow in years past considered a distance of 300 yards so exceptional as to be almost unattainable. The longbow, because of its long limbs and other features of design has large virtual mass; and its energy storage per unit volume of the limb is low in comparison with that of the short bow with limbs of uniform thickness and rectangular or modified rectangular limb section.

A bow with ears, especially one with reflex limbs, is capable, as shown by its force-draw curve, of storing more energy, for given length of limb and force at full draw, than a similar bow of equal length and weight without the ears. Thus, more energy is available to accelerate the arrow. In addition, the ears reduce the amount of string that may lose energy in vibration; and it appears that such a bow, when braced, has less possibility of executing oscillations after the arrow has gone. It seems certain, therefore, that the short, reflex bow with ears, and with limbs working throughout their length at high energy density, is the bow of most promising design for maximum performance.

For a bow of that type, the force required for each inch of draw is higher than it would be for a bow of the same design but with less, or no reflex. Hence the total work to full draw, and, accordingly, the available energy, in increased by reflex. The effect of the reflex is to pack more energy into the limbs which, of course, requires that the materials used in them be capable of taking the strains without breakdown, and without going beyond the point of failure of Hooke's law—beyond the proportional limit. In the short, reflex bow with ears we recognize the Turkish type. Our analysis convinces us that the Turks were on the right track—if we were not previously convinced by their distance records.

Can the Turkish type of composite bow be further improved? We not only believe this possible, but have a conviction that this will be done. With the unprecedented developments in the plastics field, with new adhesives for bonding dissimilar materials, with constant improvements in strength-weight ratio of materials, there will come, sooner or later, the development of bows that will be more efficient with light arrows than anything that has thus far appeared. Materials will be combined in a manner that will exploit their mechanical and elastic properties to the utmost. A step in this direction is the disclosure in Hickman's U. S. patent No. 2,100,317, where it is shown how to combine laminas of materials so that the strain is less, on the average, for a given amount of loading, or energy content, than it is in any hitherto described bow limbs. The patent also shows a novel design of bow, with limbs thus constructed*. Hickman has had some remarkable results with this design and modifications of it. It is especially adapted to flight bows. This patent undoubtedly points the way to major improvements in the design and construction of flight bows. Those experimenting in this field should study this patent with great care, and use it as a starting point in their experimentation.

A promising line of approach to limbs of small virtual mass, by way of high strength and light weight, is the construction of a composite limb in which the middle layer, which is subjected principally to shear, is made of material of low density, such as cork, or balsa wood with the grain running perpendicular to the thin lamina. The thickness of the latter governs the stiffness of the limb, for given thicknesses of backing and facing. For the former, a preformed lamina of sinew, applied under tension with hot glue would seem worth trying. For the latter, a lamina of buffalo horn, or selected osage, or of one of the stronger thermosetting plastics, reinforced with unidirectional fiberglass, or fortisan, might well qualify, with Urac 185 as the adhesive or bond. It would probably be necessary to "fence in" the middle layer with strips of wood around the edges of the "sandwich filling", between the tension and compression laminas. In a bow limb so constructed, several inches towards the tip would have to be made of wood, to provide material to which an ear might be bonded, or a nock constructed for the string. After experience had been gained in the combination of suitable materials in simple limbs, other forms, such as the Turkish and those shown in the Hickman patent might be constructed.

Arrows. Is it possible to write specifications for a flight arrow? Can we, with the knowledge we now have, say precisely what should be the dimensions, shape, weight, finish, stiffness and other characteristics to secure greatest

*See also "Archery: the Technical Side" by Hickman, Nagler and Klopsteg, page 50 et seq.

distance with some particular bow? The answer is not an unqualified affirmative. But, although we cannot write exact specifications, we have a reasonably secure foundation of technical knowledge to guide experiments towards developing better flight arrows.

At the beginning of this chapter, the subject of energy was treated at some length, and the transfer of energy from bow to arrow was discussed. To obtain the greatest possible transfer, we found that maximum efficiency for a given bow-and-arrow combination is indicated. We found that, whatever the characteristics of the bow, efficiency for that bow increases as the mass of the arrow is increased; but with increased mass of arrow, its initial velocity is decreased. Were there no drag to retard the speed of the arrow, the greatest distance with a given bow would be obtained with the lightest possible arrow that could withstand the thrust of the string. Hence it follows that if the drag can be diminished, a lighter arrow may be used, with good prospect of greater distance. For the greater distance, if achieved, two factors would be responsible: the greater starting speed, and the smaller retardation caused by drag.

In practice, this means that everything possible should be done to reduce drag to a minimum. Drag is affected by shape, stabilizing means and surface finish, and it varies as the square of the speed at a given instant. All three of the physical characteristics of the arrow should be made as favorable as possible. Skin friction and turbulence of the air cause energy loss and hence retardation. To minimize these, an arrow as short as practicable, streamlined to reduce turbulence, with a highly polished surface, and smooth sheet plastic for stabilizing vanes, are indicated. A short arrow is incompatible with a long draw; but a long draw is desirable for reasons previously explained. This leads to the obvious answer—the answer the Turks had, centuries ago—of using a *siper* or an arrow-guide derived from it, to permit a long draw with a short arrow. Some modern free-style flight bows have the equivalent of a *siper* permanently attached. The guide is limited in its extension towards the string by the distance the latter follows the arrow from its normal braced position. For this reason such a guide, with a three or four inch inward extension is practicable with a bow braced as high as the Turkish, but impracticable with a longbow, of which the string follows the arrow to within a few inches of the grip. A highly polished metal surface encounters minimum skin friction as it moves relative to the air. Perhaps this argues for metal flight arrows.

In aircraft, reduction of turbulence or "laminar flow" is brought about by streamlining the parts. In an object as long, relative to its diameter, as an arrow, the effect of streamlining may be small, but we have no positive, experimental data concerning it. Streamlining would consist of shaping the arrow like a greatly elongated lighter-than-air ship, with a rounded tip and a pronounced taper aft. One wonders how much turbulence is produced by the nock of the arrow, and whether improvement would result from tapering the rear end of the shaft to a blunt point, and having the string fitted with a small, light-weight socket to engage the point. In producing such a streamlined shaft, it would be important to assure sufficient strength to prevent buckling under the thrust of the string. In a flight arrow particularly, strength-weight ratio is important, and stiffness, or spine has an important bearing on performance, especially when the three-finger or similar loose is employed. With the new releasing devices, this is of smaller consequence. The strongly-barreled form characteristic of Turkish flight arrows provides for great stiffness in relation to mass. Whether this shape is good from the standpoint of streamlining is something to be investigated.

Some day—and we may hope not too far in the future—an enterprising experimenter will construct a fairly simple wind tunnel and make fairly accurate measurements of drag with air speeds ranging from 150 to 350 fps, using various shapes, lengths and finishes of experimental arrows. When such data have been obtained and analyzed, it will be possible to determine the best features of design in arrows, and a close approximation to perfection will be possible.

It is a matter of experience that a flight arrow that takes off smoothly, with little distortion, whip or yaw flies farther than one that begins its flight "nearly broadside", as some do. The release as generally practiced in America and England causes lateral forces at the instant of loose which may cause buckling and violent contortion of the shaft. This type of release demands accurate spine-matching of arrows to a particular bow. The instantaneous effects of such lateral forces have been determined by high speed still photography (Klopsteg) and high speed motion pictures (Hickman). The pictures prove that the three-finger release produces pronounced bending of the arrow at the instant the string slides laterally off the fingers. In this phenomenon are found the explanation of the "archer's paradox" and the requirements in "spine matching" of arrows* and bows. The arrow may have large initial bend as well as yaw, which disappear only after it has travelled some distance, with time enough for the oscillations set up in the shaft to die out, and the drag of the vanes to stabilize the missile. The increased drag on the arrow during this interval of straightening out absorbs much energy at the expense of distance. The effect is to produce excessive retardation during the initial phases of the flight as compared with that which obtains when the arrow is moving smoothly and tangent to its trajectory.

*See "Archery: the Technical Side" by Hickman, Nagler and Klopsteg, N.F.A.A., 1947, p. 181.

The loose with the thumb ring introduces less tendency towards sidewise acceleration and distortion of the arrow than does the three-finger release. The Turks probably had no awareness of spine or of the archer's paradox; there was little occasion to discover them, or worry about them. An appreciable part of the great distance of travel of their arrows was no doubt to be credited to the smooth, unimpeded takeoff of their arrows.

During the years since about 1940, or a little earlier, archers in the middle western and western states have been experimenting with release aids that depart widely from the three-finger as well as the oriental loose. They are returning to modifications of the pinch draw, in which pressure is applied not to the nock of the arrow, but to a simple arrangement made from a strap. In another form of release aid, a "block" of wood, horn or plastic is provided with a ledge or seat on which the string is retained, the block being so designed that a firm grip with the hand upon it enables a strong bow to be drawn with its aid. The loose is effected either by relaxing the grip, which permits the block to tilt slightly, thereby allowing the string to quit the retaining ledge; or by slightly relaxing the thumb which has been exerting slight lateral pressure on the nock of the arrow, thus keeping the string seated on the ledge, awaiting the loose. These accessories introduce a minimum of lateral force at the loose to distort the arrow, and probably excel over the thumb ring in this regard. Their successful use probably requires less practice and attention to details of technique than does skillful use of the thumb ring.

Such departure from tradition is to be highly commended, for too often deeply-rooted tradition—however much we treasure it—is prejudicial to progress. Information about the aids to drawing and release has been supplied by M. B. Davis, H. R. Henderson, Curtis Hill and Charles

Pierson, to all of whom grateful acknowledgment is made.

The question has been raised by "traditionalists" whether the use of these aids is "legitimate". The answer is ably given by W. B. Wescott in "Archery" for February 1946. In essence, the devices are identical in purpose with tabs, gloves and rings: to protect the fingers and to make possible an effective loose. The gain in distance resulting from the improved release is reported by flight archers to be from 10 to 20%.

The simplest of the strap-type string pullers is shown in fig. 44. The loop in the strap provides for anchorage of the device to the fingers, and pinching of the free end of the strap, which is doubled about the string as shown, between the thumb and second or third phalanx of the index finger, permits a fairly strong draw. The leather in contact with the string should be smooth and hard-surfaced. Powdered rosin on the outer surface increases friction and decreases the force needed in the pinch. A thin sheet of rubber under slight tension, cemented to the outer surface of the strap also provides increased friction. The supposition that this also "snaps" the strap out of the way of the string at the loose is probably fallacious.

The free end of the strap may be modified as shown in the middle view of fig. 45. It is provided with an enlargement, as shown—analogous to the bulbous nock in the primary pinch draw—consisting of a short piece of quill or rib of a feather, about which the free end of the strap is glued. This puller, shown in use, is depicted in fig. 46. With the strap type of string puller, the nock of the arrow must tightly fit the string just above the strap, so that it is firmly held in place until released. A wrapping of dental floss is suitable for enlarging the nocking point of the string.

By using a wider strap, the free end may be split into two strips with enough space between them for the arrow (fig. 45, top). The symmetry of this arrangement is thought to reduce any resultant lateral force at the loose practically to zero. The free ends pass about the string in opposite directions. In the sample illustrated, the free ends curl outward because of the rubber strips cemented to them. Since the arrow is secured between the two strips, it is not so essential that the nock fit tightly on the string.

An early form of the shooting block is described by Dr. E. Mylius in the "Archers Register" for 1904-1905, from which the illustration reproduced in fig. 47 is taken. This is made from a piece of wood or horn, shaped to fit the grasp of the closed hand comfortably. At one end it has a pair of flattened projections, constituting a ledge

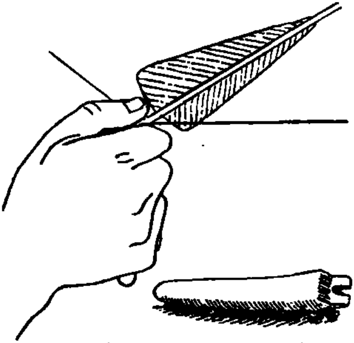

Fig. 47. Shooting block by Mylius, 1904. (Archers Register.)

on which the string may rest, with the nock of the arrow in the space between the projections. During the draw the string is held on its seat by pressure of the thumb against the side of the nock. The loose is made by relaxing the thumb. Mylius states that he tried all the kinds of loosing aids described in "Badminton", but finds the one he devised superior to any of them in the sharpness of loose, and in its adaptability to bows of all weights. In analyzing the Mylius drawing block, it would seem that the "ledge" for the string must be so constructed that no unnatural flexure or rotation of the wrist or forearm is needed for keeping the string easily in its place with slight pressure of the thumb against the nock of the arrow. The design for best performance must be determined by trial and error—an observation which applies to any kind of release aid.

A recent adaptation of the same principle, with a single rather than double ledge for the string, is illustrated in the bottom view of fig. 45, and the same device in use is shown in fig. 48. The wedge-shaped block is made of plastic, and a leather loop is glued to it for insertion of one or two fingers to secure greater traction. As used by Herb Henderson, the string is kept in place by firmly gripping the block at such an angle that it cannot slip out of the groove in the block. At the loose, the block is turned slightly, thereby displacing the string from the groove. Excellent results are reported with light bows. A "hard" serving on the string, such as leader material for fishing lines, is desirable when a release aid of this kind is used.

Two "western" modifications of the shooting block are shown in figs. 49 and 50. Both are made of plastic, with single ledge, although a double ledge may be used in either. Fig. 49, reported as a development by Frank Eicholtz, is roughly triangular in shape, with the ledge on one side near the base of the triangle. The base is shaped to fit the first and second fingers. In drawing, the hand is closed over the block, and pressure of the thumb on the string keeps the latter in place on the ledge, as shown in fig. 51. Fig. 50 shows a form of block used by many of the Californian flight archers. The projection which engages the little finger adds to security of the hold and may serve as a "fulcrum" about which the block may rotate away from the string when the grasp of the block is relexed, thereby facilitating the loose. The loop about the wrist is a convenience which has no function in the draw and loose. Another "block" with a double ledge for the string, made by Curtis Hill, is shown in fig. 52.

Experimentation is in progress among many flight archers with these and other shooting aids by which a better loose and greater distance may be secured. From the results thus far reported, it may be taken for granted that flight shooting has seen the last of the Mediterranean or other finger releases. Since the devices under discussion appear to remove the premium on accuracy in spine matching, because of the reduction or elimination of lateral forces that come into play in the Mediterranean loose, their application to target and field shooting should also be explored.

It seems assured, with the great interest in archery that has developed during the past decade, that efforts to approach technical perfection in equipment will continue, as will the efforts to improve techniques in the use of that equipment. The new materials now available and becoming available challenge ingenuity in experiment and design. They hold potentialities of improving bows and arrows beyond anything we now have. Such improvements maintain a standing challenge to improve skill in shooting. If our scoring at the targets, our successes in the field and our distances in flight do not, in the next decade, surpass the records of the past by substantial margins, the fault will not lie in the implements of our sport.

APPENDIX I

A Royal Order *(ferman)* by Mahmud II to Mustafa Kani (1835)

In addition to the numerous treatises on shooting by many authors, (Ed.: Here follows citation of a long list of authors' names) there have been written about it at the shooting grounds numerous detailed works in prose and poetry, in the Arabic, Persian and Turkish languages. Despite this fact, it is impossible for all who desire to learn this art to obtain all of these treatises and works. Even if this were possible, their profitable study would be difficult. Besides, these works for the most part, because of their dealing with so many extraneous matters and useless things, are verbose and almost impossible to comprehend. Moreover, the newer work, *Minhadyi rümat* by Wehid Efendi, is as rare as it is lacking in utility. It is therefore probable that even if the matters of instruction and learning, dealing with outstanding refinements and their value, were to be transmitted orally, the novices would not be able to acquire thoroughly the fundamentals of the art and its verities, so that in time they would become lost. Accordingly, you will secure and read those books and treatises, the *hadiths* and the *sira*-books, so that under my royal patronage the novices may acquire complete knowledge of the *sunna* of the Prophet, and by diligence come to possess the degrees of both worlds. You are directed to compile the knowledge which you yourself acquired from my royal person, according to your ability to comprehend it, in a brief and usable presentation. Therein you will gather together and record the regulations prevailing in our time. You will prepare a treatise on archery, for the use and benefit of all who are devoted to its practice.

APPENDIX II

Excerpts from Letters and Notes of Marion Eppley

Shortly after the first edition of this book had been published, Dr. Marion Eppley took the opportunity afforded by a world tour to look up makers of composite bows in Korea and China, and to make inquiries in Constantinople regarding some of the uncertain and obscure matters that had eluded Hein, and perhaps Kani also. With his permission, the following quotations are made from his letters and notes, in which he reports his observations of certain details of construction and adjustment of composite bows. The craftsmen he found engaged in such work were in Korea and China; the art of bowyery has disappeared from Constantinople. His comments provide excellent collateral information on the construction and management of horn-wood-sinew composite bows, and help to shed light on the material from Kani.

"I had ample opportunity to see what is involved in using the composite bow today. The heating of the bow before use was demonstrated, as was the method of construction, as well as the use of the *tepelik*. This practical demonstration supplemented the statement in your book wonderfully, and, I think, gives a wider interpretation to much of what Kani says.

"The *tepelik* seemingly serves two purposes in China. First of all, it is used to string a heavily reflexed, powerful bow, let me say new bow. Secondly, it is used to weaken a too powerful bow. To weaken a bow, the *tepelik* is tied on and allowed to remain sometimes two hours, sometimes longer, as you will see in the notes.

"The use of the *tepelik* in stringing a bow in my opinion answers a question as to the manner in which Turkish bows were strung and what their shape was after they were in use.

"You remember the form of most of the bows I had at Queen's River was that of an incomplete 'O' or a 'C'.

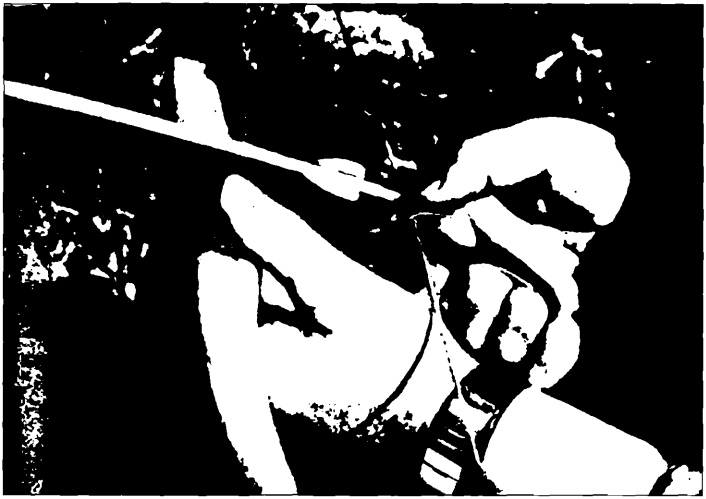

Fig. 44. Simple string puller, sometimes called "flipper". (Courtesy M. B. Davis, photo by Maynard L. Parker).

Fig. 45. An assortment of string pullers. (Loaned by H. R. Henderson, photo by author.)

Fig. 46. Fig. 45b shown in use (H. R. Henderson.)

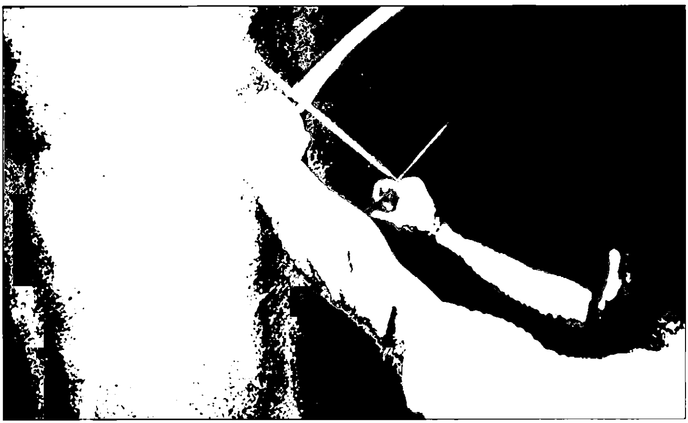

Fig. 48. Fig. 45c shown in use. (H. R. Henderson.)

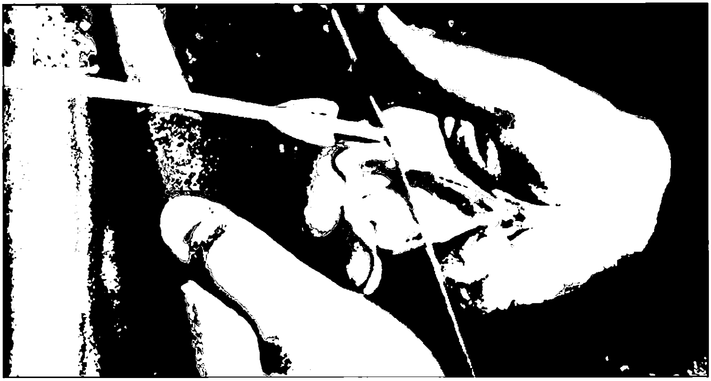

Fig. 49. Shooting block of lucite. (Courtesy M. B. Davis, photo by Maynard L. Parker.)

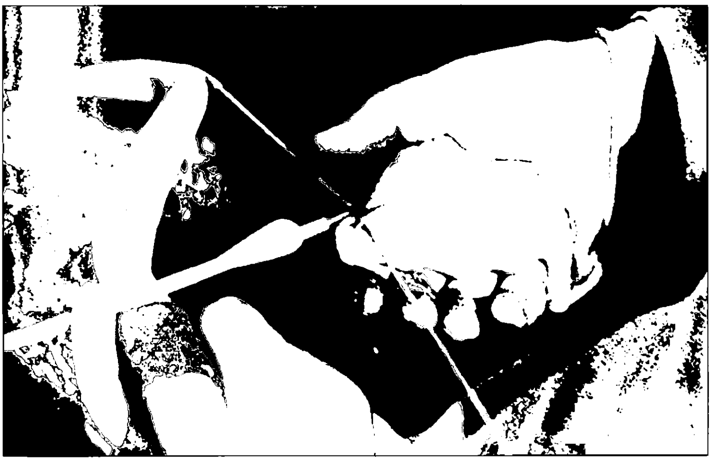

Fig. 50. Another modification in lucite. (Courtesy M. B. Davis, photo by Maynard L. Parker.)

Fig. 51. Drawing hand with pullers shown in figs. 49 and 50 in use. (Courtesy M. B. Davis, photo by Maynard L. Parker.)

Fig. 52. String puller by Curtis Hill. (Photo from Charles Pierson.)

This is very much like the form of the Chinese bow.

"To string a weak bow, the man squats on his heels with his knees close together, and puts the bow across his knees, holding the free loop of the string in his left hand along the ear of the bow. The right hand grasps the other ear of the bow. By using the knees as a fulcrum and drawing the arms back, the bow is bent and an assistant slips the string in place over the end of the ear and sets it on the bridge. This is quite impossible in a powerful bow which is heavily recurved, and, as I said above, the *tepelik* is used to string such a bow. However, a bow that has been kept strung (and they seem to keep their bows strung almost indefinitely) loses this strongly reflex oval shape. This was the case with the majority of the Chinese bows which I got; is the case with the unused Korean bows as compared with the used one I got in Korea, and is also the case in a number of Turkish bows. In fact, the Turkish bows with the strong reflex, as you will remember, came to all sorts of positions when strung, but the one small bow, covered with green leather, which had a more open form with merely the backwardly turned ears, came to the proper 'Cupid' shape when strung. It had been worked into usable condition.

"When I was in Constantinople in 1924, I got a very powerful bow which had the strongly reflexed 'C' shape. The Turk from whom I got it said that it had never been used. I rather doubted him, but I believe now that there is something in what he said; and that a used bow takes a more open shape, and because of the open shape, irrespective of its strength, was very much easier to string.

"You will see a statement about putting the bows in the sun to restore reflex. One of the old Chinese bow-makers said that this would bring the bow back to shape, but he did not have time to do it. His statement, however, seems to have been absolutely correct, for the partial sunning which he gave the bow and which he seemed to consider insufficient, actually did restore the reflex curve.

" . . You may remember that we had trouble with the one Korean bow we tried to string, and with the Turkish bows, because they tended to twist back on themselves unless they were very highly strung. This apparently is a perfectly natural phenomenon until the reflex is taken out, either by allowing the bow to remain strung or by tying it to the *tepelik*. If the tendency is too pronounced, but the limbs do not bend as required, then you will notice, as I say in my notes, that heating over the charcoal fire and a reshaping of the limbs comes into play. The thing that astonished me was the ready way in which a composite bow can be bent into shape, either over the knee before heating, or over the knee or on the edge of a table or similar surface after a gentle heating. They do things to them that we would never think of doing to one of our wood bows, and yet it seems to have been all right after they get it done."

Notes

"Constantinople—The *ok meidan* is still known. It is not used, however. Toz Koparan is a suburb of Constantinople. This archer is known to several Turks with whom I spoke.

"The guide—an engineering student speaking excellent English—was asked, 'How long is a *gez?*' He answered, '*Gez* means any distance; it has no particular length.' When it was explained to him that arrows were shot so many *gez*, he said. 'There is an old soldier, an officer, I will ask him.' The officer, a man, of 50 to 55 years of age, indicated that a *gez* was a pace. I asked him through an interpreter, what kind of a pace, and the answer was 'an ordinary pace used in walking'. The *gez* seemed entirely familiar to him.

"In the arms section of the Seraglio Palace is a splendid collection of bows and arrows. Some of the Turkish bows are of much greater length and thickness than any I have ever seen. There are also Persian and Tatar bows. These latter were like the Turkish bows in decoration, not quite so heavily reflexed, and about twice as long. Arrows of many kinds are also exhibited. A few arrows were long: probably 30 to 34 inches, no doubt for the Tatar bows. The Turkish bows were all of about one length; the standard described (in the Klopsteg book). The authenticated Turkish bows, made by some notable personage, were small (short) and the arrows short and rather thin.

"Two attendants were in the bow section of the museum. By means of this book, I indicated that I wanted the length of the *gez*. One showed a length of about 28 or 30 inches on the slabbed floor, between joints, and the other wrote '75' on a piece of paper. The other said 'centimeters'. I wrote '*gez* 75 centimeters' on the back inside cover of this book, and showed it to them, and both nodded their heads in strong approval.

"Several Turks said that no bows are made in Turkey today. One man, guiding another couple, said that there were archery clubs carrying on shooting. Asked if bows were made today, he said, 'No, they use old bows.' He said he himself shot and knew something of the use of the *siper*. From his description of their adjustment, he was only partially correct in his statements. My guide said afterwords that if there were any clubs he did not know of them."

"Keijo, Korea.—I bought a bow, arrow case and seven arrows. A nice-looking Korean of seemingly good class who came up said through an interpreter that it was a strong bow. He produced a thumb ring from his pocket (not for sale) and put it on his thumb to illustrate the method of drawing (same as illustration in Klopsteg book so far as ring is concerned). Bent bow over knee to equalize arcs of limbs. String had knot just at forward end of bridge, sharp bends in limbs. Ears bending down away from string somewhat. Strung bow over both knees while in squatting position. Shifted right end to knee and slipped loop of string in place.

"In another place I found a man working over a bow to bring it to shape. He had a brazier with a very dull charcoal fire, giving off a little heat. I could almost hold my hand permanently within 4 inches of surface. He braced the bow with an ordinary piece of string, lashing string in place on ears; no loops. Heated gently over fire and then bent bow to suit taste. Licked sharp point of bend to moisten it and then heated slightly over charcoal, moist area about 4″ long. He was at this all afternoon, putting back of bow on floor and holding it with bare feet and bending it around. He got results too slowly to convince me of his expert knowledge, but the bow was still intact after an hour or so!"

"Peking.—The Chinese (Manchu?) bow is a lath of bamboo to which two ears of some hard wood are glued at an angle away from the belly. The bamboo is about ⅜ inch thick. It is scored with a file or some such implement to give it a rough surface and make the glue hold. Both sides of the lath are coated with glue, which is made from the back tendons of cattle. The glue must be fresh and strong, that is, freshly prepared; glue cooked five days is all right; ten days no good. Let glue dry and heat bow over the stove before applying sinew. Heating indicated was very slight. Same heating no doubt applies to horn, but no mention was made.

"Fish glue from mouth of fish is apparently used over sinew as a final coating to give polish. I could not make out surely if it was added to sinew glue for liquidity, but think they got what I was asking and that the above fish glue is added in the quantity of about one-fifth. I asked many different questions about this before getting the thought over at all but am quite sure it finally registered. Leg sinews of cows are used for backing sinew, shredded by hammering on a hard surface. An iron hammer and anvil were indicated. They were very finely shredded and clear white.

"Soak sinew over night in lukewarm water, heat over stove a minute, make up a skein or bunch and dip in glue. Then apply to bow on inside surface of bamboo, i.e., on inside of tube. Smear with glue. Shreds are of same length, at any rate no definite proportions of long and short lengths are used. The mouth of a fish for glue is most certain, as I drew pictures of a fish and fins and they shook their heads and indicated the inside of their mouths.

"Horn is evidently from water buffalo, as a horn was shown me which was obviously such. Some horn came from an animal having only one horn (rhinoceros?). This is the best kind.

"Horn is put on outside of bamboo. Thuan showed me strips of horn evidently prepared commercially for bows. The Chinese seem to prefer (and prize) clear, transparent, yellow horn. Black horn with a white patch went to the emperor. Birch-bark is the proper covering for sinew backing. This they showed me. Paper is also used on cheap bows, but it is not so good. Bark looked like paper birch or our canoe birch.

"To bend the limbs of a bow to equality, heat all sides so that the bow feels warm to hand all around. A bend near the grip can be modified over the knee. The bowyer heated the horn with a piece of burning charcoal held in tongs and passed back and forth along the horn side close to the horn several times. Also bend the limbs slightly over the knee while cold to rectify or equalize the bend of the two limbs.

"To string the bow, squat down on heels, engage a loop in the lefthand nock, and hold loop and ear in left hand. Leave other loop free of bow. Take other ear in right hand. Put bow across both knees, bend, and when bent enough, assistant puts other loop over free end of bow and engages it in nock at right end.

"Then put end of bow on ground, holding bow nearly vertical and pull string away from bow, holding string short distance below bridge. Do this also at other end (I don't know what this does; perhaps it sets the string in the nocks). Look at bend and rectify.

"To unstring, do the same as for stringing, pushing right loop over end, a one-man job.

"To restore bow to reflex shape, unstring and place in the sun. This may take one to three days, depending on intensity of the sun. Old bowmaker did this with old bows, having horn uppermost. It worked.

"Feathers on arrows were fixed in position by heating over fire and adjusting roughly. Then small iron tool like a dull chisel was heated and used to take out kinks in feathers, spot by spot. Arrow was held against a wooden rod slightly larger than the arrow shaft while this was being done.

"In all cases a dull red charcoal fire was used to warm the bows and feathers. It burned in an open basin and gave off very little heat.

"To string a strong bow a device was used like the *tepelik* shown by Kani. It consists of a pair of curved pieces of wood, each with a slight longitudinal groove running along the convex side. Near each end of the grooved piece a hole is drilled at right angles to the convex surface. Through this a rope is passed, held in place by a knot countersunk on the convex side. The bow is placed with its belly in the groove of the convex side, with the end of the *tepelik* near a bridge and inside of it. It is bound there with a rope which was drawn tightly around the limb several times and tied. The ear of the bow is then passed under a rope tied loosely around a narrow bench, forming a loop, with the rope at right angles to the long dimension of the bench. The back of the bow is uppermost. A block of wood with a notch in it to receive the inner side of the *tepelik* is laid on the bench at a suitable spot to support the *tepelik* and act as a fulcrum. The bow is then bent by downward pressure on the overhanging limb until the other limb is brought completely into the groove of the *tepelik;* then the other end of the latter is also lashed to the limb with a rope. The same operation is then performed on the other limb, and the string adjusted to the proper length. The ropes on the bench are then cast off. Different lengths of these wood segments were used for bows of different sizes.

"When a bow is too stiff, the segments are left on the limbs. Two hours of this reduced the weight of the bow. All of the bowmakers had these devices.

"One large bow was so strong that when first strung by the above methods I could not move its string by hand, nor could I bend it over my knees. After standing strung for about ten days it softened enough for me to unstring it over my knees."

APPENDIX · III

Excerpts from Letters of Ingo Simon

Archers who specialize in shooting for distance do not require having Mr. Ingo Simon identified for them. They remember that for many years he held the record for distance, made at Le Toquet in 1914. This modern record of 462 yards was made with a Turkish bow of 65 pounds, with a thumb ring and a *siper*. After publication of the first edition of this book the author entered into correspondence with Mr. Simon. He owns some 80 composite bows, many of them from Sir Ralph Payne-Gallwey's collection. Recently he wrote that he has given the collection, together with his fine collection of early American rifles, to the University of Manchester.

Some of Mr. Simon's comments have been quoted in Chapters III and IV of this book. It is unlikely that any contemporary archer has had an equal interest in, or practice with composite bows. Further interesting excerpts from his letters are quoted in the following paragraphs.

"I have one of the flight bows mentioned by Kani as 'conditioned' but have never shot with it. Mahmud Efendi's were of the leather-covered type, as were those I shot with at Le Toquet in 1914. I have had one other 'conditioned' flight bow from Damascus, the first I ever had. It broke. I fancy they were not meant to last long, but to shoot a limited number of shots at extreme tension, hence their rather rough finish.

"The *siper* is quite simple and is used on the right of the bow; the groove around it or rather on both sides comes just level with the front of the arrow groove. The shield (*tabla*) is loose, sliding in and out easily. It just does not touch the bow like the groove itself. Mahmud Efendi did not use this protection. His *siper* had no place for the shield.

"It is not possible to use the Turkish ring loose on the left of the bow. The arrow tends to draw to the left.

It is not possible to use the three-finger loose on the right of the bow for the opposite reason. I have got hold of only two bows in 17 years, one from Anatolia where I had an acquaintance in the English army, and the other came from there too but was given me, also through the army. Sometimes one gets them through carpet dealers but that source seems to have dried up—alas! Many were given me by Sir Ralph Payne-Gallwey.

"I use the thumb ring loose exclusively. I do not think it has less tendency to buckle the arrow—one answer to that is that most bows used with that or similar looses use barreled arrows which are stiffer. It is a most difficult loose and must be exactly right to get the best results, and I am really only getting to understand it now after all these years. 'If we could only dig up an old Turk for a few hours', my friend Sir Ralph used to say. When the loose is right and the arrow fits the bow and the bow fits the body there is, so far as one can see, no unsteadiness as the arrow leaves the bow, whereas if not, it seems to go nearly broadside for a while. When properly done, there is no doubt about a much sharper loose and better cast. My shots of 462 yards were with a bow of not over 65 pounds, so the superiority of cast in bow, arrow and loose is pretty obvious.

"I have used a tape around the handle of the bow for shooting but the *mushamma* I have is too stiff and bulky and I do not know how to fix it. One needs something in a strong bow to keep the wrist straight. It tends to cave in, as you know. That is no good for the *siper*.

"I have been experimenting with various different shapes of rings. They are a matter of individual fitting and choice; also different for different purposes, I think. (A distance of) 487 is marvellously good for a wooden bow and of course 615 shows what can be done with enough strength and proves, if proof were necessary, that Toz Koparan could shoot over 800."

Author's remarks: The letters from which the above excerpts are quoted were received just prior to World War II. The surmise in the first quoted paragraph that flight bows of the "conditioned" type were not meant to last long is not borne out by the sources used by Hein. The life of the Turkish bow was supposedly equal to the span of a man's life, and upward to 120 years. In another letter Mr. Simon relates that immediately after the 1914 meeting at Le Toquet, where he made his record shot, World War I broke out. He left his Turkish bows and other archery tackle in a London hotel for safe keeping and entered military service. Upon his return, these valuable possessions had disappeared, and have not been found. He also reported that the bow and arrows used by Mahmud Efendi, which for years had been kept at the clubhouse of the Royal Tox in Regents Park, had been lost. The comments in the last paragraph above refer to Prouty's regular style and Curt Hill's free style record, made at Battle Creek.

APPENDIX IV

A Glossary of Turkish Words Relating to Archery

In the following list of words, those are included which occur most frequently in Kani's "Excerpts". They are spelled out in Roman characters, with pronunciation almost invariably in accordance with the following approximate phonetic equivalents:

a as in art.
e as in prey.
i as in hit.
o as in or.
u as in true.
ei as in height.
ö as in German Umlaut ö.
ü as in German Umlaut ü, or French u.
kh is pronounced like Scottish ch in loch.
gh is pronounced like soft kh.

The accent is always on the last syllable. The transliteration, according to these equivalents, cannot be claimed to be more than an approximation to the Turkish; for the latter employs sounds that cannot be represented by ordinary English spelling.

abrish, a practice arrow with peculiar feathering, to keep its range very short.

ayak, the foot; the lower end of the bow; the forward end of an arrow.

azmayish, a practice bow for shooting practice arrows of the same name; an arrow with an iron tip, used in shooting for prizes.

bash, the head; the upper end of the bow.

chelik, a small plate of bone or ivory, inserted between the abutting ends of the horn strips, in the middle of the bow grip.

dimagh, the portion of the thumb ring that covers the ball or surface of the distal segment of the thumb, to protect it against pressure from the string, and to permit the latter to slide off easily at the loose.

dirhem, a unit of weight, equal to 49.3 grains or 3.2 grams.

eshik, the wood foundation of the siper. Its upper side carries the horn groove; its lower surface is hollowed out to fit the outer surface of the bow hand below the base of the thumb. Into this hollow the tasma is glued. Laterally and posteriorly it is grooved to receive and hold the tabla.

gez, an arrow; the length of an arrow; the unit of length in which distance records are reported by Kani, probably about 24.5 inches. The gez may have been identical with the Turkish pic and the Arab guz, which were about 24.8 inches.

hadde, an arrow maker's gauge.

hadith, a saying based on the words and deeds of Mohammed, handed down orally and later codified into rules of conduct.

haki, *a flight arrow used in practice, somewhat heavier* than the tournament arrow pishrev.

hava gezi, the practice arrow without feathers, shot outdoors with a light bow.

imam, the official in a mosque who recites the prayers and leads the devotions of the faithful.

kabza, the bow grip; the middle part of the bow, having mystic significance in the rites of initiation of a candidate into the archers' guild.

kabza boghazy, the juncture of the bow grip and the bending portion of the lower limb.

kara batak, a flight arrow used in practice, somewhat heavier than the pishrev.

kassan, the ridge section of the bow limb; Arab, siyah.

kemend, lasso, a strap of leather or webbing, terminating in metal rings, used in bracing a strong, reflex bow.

kepade, a light bow used for practice in drawing only.

keser, a small adze-like tool for working wood and horn.

kötük, a block of basswood forming part of the arrow maker's bench.

kulak, an insert of leather glued in the thumb ring.

mandal, a lock; Arab, qaflah; the intertwining of thumb and fingers to hold the bowstring firmly while the bow is being drawn.

maska, a skived morocco leather with which the groove of the siper was lined; also the process by which such leather was glued.

mefruk, a type of loose used in flight shooting.

meidanlyk, the wrapping or serving on the bowstring.

mushamma, (pronounced mushanba according to Hammer) a strip of waxed linen, about two feet long, which is wrapped about the bow grip to fill out the bow hand and provide a firmer grasp.

ok, an arrow.

ok meidan, place or field of the arrow; the tournament field of the archers' guild, used in flight competition.

pir, a Muslim patron saint.

pishrev, the tournament or competition flight arrow; also the tournament flight bow.

puta, a target arrow used in practice.

puta yayi, a target bow.

rotl, an oriental unit of weight. In Turkey it was 176 drams English weight, i.e., 4815 grains or 11 oz. avoirdupois.

samanly, billets of seasoned elm from which the sack arrows were made.

sheikh-ül-meidan, the chief of the archers' guild.

shest, the thumb ring. Also zyghyr.

sinir, sinew fibers made from tendons.

sinir kalemi, a bowyer's tool for applying sinew backing to a bow.

siper, the groove of bone, horn or ivory which is fastened to the bow hand, to permit a long draw with a short arrow.

ssal, the bending portion of the bow limb.

ssalla, the competitive shooting on the ok meidan.

ssalla koshusi, a squad of archers in competition, using the same kinds of bows and arrows.

ssalla koshusu, shooting for prizes.

sunna, the Muslim Way, based on the life and teachings of Mohammed, as expressed in the hadiths.

tabla, the oval plate attached to the siper for protection of the bow hand.

tashin, a toothed scraper used in preparing horn for gluing.

tasma, the leather underpiece and strap for fastening the siper to the hand.

tendyek, a boxwood fixture, shaped something like a wrecking bar, for pressing the wood and horn together in the gluing process.

tepelik, a curved fixture of boxwood or cornel, for reducing the reflex in limbs and shaping them to the desired curvature.

timarli, bows that require conditioning by heat before use.

timarsyz, leather-covered bows that required no conditioning before use.

tir getchimi, the arrow pass at the upper end of the kabza.

torba, the sack into which practice arrows are shot with light bows.

torba gezi, the practice arrow for sack shooting, without feathers.

tundj, the loop of glue-treated silk, tied into the skein of silk thread, to form the end of the bowstring and engage the nock of the bow.

yai, the complete bow.

zyghyr, the thumb ring.

INGO SIMON'S COMMENTS HAND-WRITTEN IN THE 1947 REVISED EDITION

Page 30 *The reign of Sultan Bayezid Khan was from* 1481–1512

Page 32 *The distance in* 1948 *shot with a* foot bow so far *drawn* by hand *was* 610 yards.

Page 38 Mahmoud Effendi's bow was not a Timarli—but a fine specimen of the usual leather covered bow (such as I used)

Page 57 *Referring to line 6* We never settled whether sinew or silk

Page 76 *Referring to line 19* Those that I have seen are a little over 25"

Page 117 *The reign of Mohammed 11 was from* 1451–1481
The reign of Mahmud 11 was from 1808–1839

Page 123 *Referring to line 7* Khirghiz bow of Guglielminis, Paris.

Page 125 *Referring to line 12* Vide Chinese bow—very little glue in sinew—just enough to keep it in place.

Page 133 *Referring to line 27* I found Russian isinglass did the job perfectly in rehorning bows

Page 136 *Referring to line 14* There was a very broad bow in the Wien museum very flat and not a flight bow—bigger though not much.
Referring to line 28 The longer handle makes a longer therefore heavier string.

Page 138 The horn and wood of a Turkish bow were longitudinally grooved with about a dozen very small grooves—giving the glue extra surface to hold to.

Page 180 *Havi gezi* Probably used for practice into a strawfilled barrel.

Page 187 *Sinew*, stacked . . . 50,

INGO SIMON'S COMMENTS HAND-WRITTEN IN THE 1934 EDITION

The page numbers refer to the 1947 and 1987 editions.
The numbers in brackets are for the 1934 edition.

Page 38 (24)	*Referring to line 20 (17)* . . . also making the glue supple by heat.
Page 38 (25)	*Referring to line 33 (10)* . . . or hessian, laquer or bark.
Page 39 (25)	*1st full paragraph (both editions)* . . . shortest I have had was 42½ ins. I could not shoot with it above 350 yards.
Page 42 (29)	*Referring to the 2nd paragraph (1st paragraph)* Many best class bows have brown and light horn
Page 48 (35)	*Line 16 (last line)* Not by any means in all bows
Page 54 (41)	*2nd paragraph (both editions)* All the strings I have seen were dyed. Not the Tundj
Page 65 (47)	I have heard that there is a bow in Istanbul which has the sipur attached to it. (not to the hand)
Page 102 (69)	*Line 8 (6)* Point blank about 65 yards
Page 102/3 (70)	*Last two lines continuing to next page (1st part paragraph)* Most of all in the Tatar (Chinese) bow

SCIENCE LOOKS AT ARCHERY*

A Review of Scientific Studies in Archery and Their Applications

By PAUL E. KLOPSTEG

Foreword

The writer has realized for some little time that the value of the relatively large number of articles on the scientific phases of archery would be increased if they could be unified and reviewed in language deliberately non-technical. In preparing the present article, he has had in mind the average archer as he knows him from numerous personal contacts—a splendidly intelligent, enthusiastic devotee of the bow, who has followed other courses than science and engineering in his life's work. His interest in archery is great. It is the writer's greatest hope that this presentation will give the above-pictured average archer a fairly clear idea of "what it's all about," and enable him to find his way without difficulty through those of the original papers that may interest him.

Introduction

During the past several years there have appeared many articles in the archery journals and in others, concerning scientific investigations of the bow and arrow, both theoretical and experimental. Many archers may have felt that perhaps reasonable editorial judgment was used in publishing such material, but what of it? A good hunting story would have been much more interesting. What possible benefit can there be to the archer in an article full of mathematics and technical expressions? Some of our oldtimers in the game are more candid and openly express the thought that the English longbow, noble heritage from bygone centuries, is good enough for anybody, and incapable of improvement. To question the correctness of its design is close to, if not quite, sacrilege. Any departure from the dimensions and shape of limb of the traditional longbow is inconceivable. It reminds one of the dear old lady who couldn't tolerate the modern versions of the Bible because they are so different from the way Saint James wrote it!

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*Published as a monograph Bulletin No. 1 of the Archery Review, July 1935, and

Another idea not infrequently expressed is that nothing of practical value can come out of the kind of work done with paper, pencil, algebra, geometry and calculus, because it is "theoretical". The word "theoretical" has through usage acquired a connotation of "impractical", and "out of touch with reality", "visionary". Fortunately such implication is absent in the great majority of the scientific investigations in archery which have been carried on, and results of which have been published. Also, fortunately, the investigators have in every instance been archers themselves, with a sufficiently practical turn of mind and sufficiently discriminating attitude to temper and test theory with practice. The result has been a decided advance in knowledge of the fundamentals of the bow, the arrow, and their performance. This advance has, for example, placed bow design on an engineering basis, so that one can, with assurance, establish all specifications for a bow, and design it to meet these specifications, with great improvement in both cast and action.

The purpose of this series of articles is first, to summarize, with all possible simplicity, the scientific and technical papers that have appeared during the past four years, so that the interested reader may know what has been accomplished in the painstaking analyses and experiments of those fortunate scientists and engineers whose avocation is archery. They have devoted untold hours and much outlay to private investigations in this field. They have done the work in their so-called spare time, after having spent most of their waking hours in pursuit of the necessities and comforts of life for their families. They have applied their ability and skill far into numerous nights and Sundays and holidays to discovering the secrets held by the bow and the arrow. Their purpose? To learn all that may be important about the fundamentals of the performance and use of these implements, so that improvements might perchance be made in their design, and all archers might benefit thereby. Their motive? Tremendous interest in and deep love of the bow and arrow. Their reward? The satisfaction of seeing their work bear fruit in improved tackle, and better shooting, and greater enjoyment of the sport by all; and, perhaps, increasing interest, and a rapidly growing number of those who would shoot in the bow.

A second purpose of this article is to see what ideas with practical applications may be developed from the summary, and to determine how they may be applied. The value of any idea is, after all, the extent to which it contributes to the practical side of archery. Will it contribute to greater certainty in the securing of hits? That is the ultimate desideratum, the final test. All work can be tested from this point of view, and if it proves itself capable of making such contributions, it is valuable and worthwhile. It has value from another point of view also. To one who thinks of the bow more deeply than to regard it as nothing more than an implement for propelling arrows, the fascination of securing detailed knowledge about these matters is indescribable. It endows bow and arrow with subjective beauty which all the more endear them, and their use, and the materials of which they are made, to him.

In the comprehensive review which follows, certain simple technical expressions will have to be used. To simplify matters for the reader, and to insure clarity of meaning in the discussion, it will be well first to consider a few basic concepts.

A *force* is a push or pull, which is perceived through muscular action or reaction, and measured by a gravity balance or a spring scale. When the former is used, it balances the force being measured against the pull or force of gravity on standard or known masses of iron or brass, called weights. With the spring scale, sometimes called a dynamometer, or force meter, the force, which may be of muscular origin, stretches the spring an amount which can be read on an indicating scale. The scale is graduated according to the pull of gravity on standard weights. A force can make itself known in several ways. It can change the velocity of a material body. For example, the force of the bowstring on the arrow changes the velocity of the latter from zero to some 150 feet-per-second. Air friction exerts a force on the arrow in the opposite direction, thus slowing it down by some 10 or 15 feet-per-second during each second of flight. Force can produce distortion or deformation in an elastic object, thereby enabling the latter, in turn, to exert an equal and opposite force. The muscular force on the bow limbs during the draw is an excellent example. Force can also produce steady motion of an object against frictional resistance, as in pulling or pushing a box across a floor.

Mass is the amount of substance in a body; it is not weight, but is measured by weighing, i. e., by finding the amount of force with which gravity pulls on the object whose mass is being found. Weight is always dependent on gravity. It is a measure of the amount of substance or material in the arrow.

It would make for clearer expression if we abandoned the term "weight" of a bow, and substituted "drawing force", and if we were to say that a bow "draws", instead of "weighs" so many pounds. Then it would be clear, when we spoke of the "weight" of a bow, that we meant its mass, as found by weighing, and not its drawing force, measured by pulling the string with a spring balance, or force meter.

Velocity is rate of change of position, or speed. If an arrow changes its position, from bow to target, a distance of 100 yards, in two seconds, then its rate of change is 50 yards or 150 feet, per second.

Similarly, *acceleration* is rate of change of velocity. If an arrow leaves the bow at 180 feet-per-second, and three seconds later its velocity is 150 feet-per-second, its average acceleration (negative) is 10 feet-per-second per second, for the rate of change in velocity was 30 feet-per-second in three seconds. Likewise, if, at the loose, the arrow velocity is increased from zero to 180 feet-per-second in .02 second, the average acceleration (positive) must have been 9000 feet-per-second per second; for, had the velocity continued to increase at the same rate, for a whole second, instead of only 02 second, the astonishing value of 9000 feet-per-second would have resulted.

Hardwood is said to be more dense than soft wood because a certain volume of it contains more mass; *density* is mass per unit volume such as pounds (of mass, as found by weighing) per cubic foot; grams per cubic centimeter; ounces or grains per cubic inch.

Work, in its simplest terms, is the product of average force and the distance through which the force acts. When the force sets an object in motion, without friction, the work done on the object is changed into *kinetic energy*, or energy of motion, which is one-half the product of the mass of the body and the square of its velocity. The moving body is, in turn, capable of doing work, or exerting force through a distance. A good example is the penetration of a target by an arrow, where the frictional force, while retarding the arrow, acts through the distance of penetration. In this case the work done *by* the arrow *against* the frictional force is transformed into heat energy, warming the shaft and adjacent straw in the target, and is thus lost insofar as further ability to do work is concerned. The energy is said to be dissipated. When the work is done against an "elastic" force, such as the force exerted by the limbs, and transmitted through the string, much of that work can be and is recovered when the string drives the arrow forward. The energy is conserved. In this case the limbs of the bow store up the energy expended in bending them. The energy so stored is called *potential energy*. To illustrate this idea, suppose that a bow is drawn, an inch at a time, and that the force on the string increases uniformily, that is, the same amount for each inch. This would be the approximate result for a long bow. If, for each inch of draw, the force increases two pounds, then at two inches, it will be four pounds; and at 21 inches, 42 pounds. This applies to a 28-inch arrow, with 7-inch bracing height. Since *work* is the product of average force and distance, and the work in drawing the bow is stored as potential energy in the limbs, we note that the potential energy is at one inch, 1 inch-pound; at 2 inches, 4 inch-pounds; at 3 inches, 9 inch-pounds; at 4 inches, 16 inch-pounds, etc. The potential energy available for projecting the arrow evidentally is proportional to the square of the distance drawn. This shows the value of a long draw. If the force-draw curve, or graph, is constructed, the potential energy is measured by the area under the curve. For full draw, this area represents one-half the force at full draw, which is *average* force for the entire distance, times the distance drawn.

In the usual sense, *efficiency* is a figure which expresses the amount of useful power delivered by a machine as a percentage of the power delivered to the machine. Power is the rate of doing work, and the concept does not readily lend itself to direct application to the bow. But the concept *energy* does, and we may very properly set up a definition for bow-efficiency based on the idea of work or energy. The *efficiency of a bow* on this basis is the energy output of the bow i.e., the kinetic energy of the arrow, expressed as a percentage of the energy put into the bow. The higher the bow efficiency, the larger is the amount of energy transferred from the bow to the arrow.

For purposes of this discussion, then, we shall adopt the above definitions and explanations for the terms, mass, force, velocity, acceleration, density, weight, work, potential energy, kinetic energy, and efficiency. We shall assume the reader to be familiar with them, so that they may be used without further explanation. In reviewing the various papers that have been published on the scientific aspects of archery, I shall take the liberty of interspersing comments, to bring out the significance of certain parts of the work, or to develop ideas as to their practical benefits.

The Bow

The first of the series of scientific researches on the bow is reported by Hickman in the Journal of the Franklin Institute. The experimental study was directed towards finding the effect of fiber backing on the weight and efficiency of a bow. In most of the experiments reported, a lemonwood bow drawing a little over 30 pounds at 27 inches was used. To obtain efficiency values, velocity measurements on the arrows shot with the bow had to be made. For this purpose, a modified form of Aberdeen Chronograph was used, and data were obtained which enabled the investigator to plot curves showing *displacement*, *velocity* and *acceleration* of the arrow, while during twenty to thirty thousandths of a second, it was being driven forward by the string. The curves are shown for four different masses of arrow, namely 230, 365, 545 and 635 grains, all shot with the fiber-backed bow, and then repeated with the fiber backing removed. Other curves are shown, giving the relationship between mass of arrow and velocity, indicating higher velocity for all arrow weights when the bow was fiber backed than when the backing was removed. Removal of the backing changed the drawing force from 32 to 30 pounds, and a new fiber back raised it again to about 31.5 pounds. With the original fiber back, a 350-grain arrow had a velocity of 134 feet per second; with fiber removed, 125 feet per second; with new fiber back, 132 feet per second. All the shooting was done with the aid of a shooting machine, so that variations which might have been introduced by hand shooting were avoided.

Efficiency curves are also given for the three cases, showing that, with a 350-grain arrow, the efficiency was 63% originally; with fiber back removed, 56%; with new fiber back, 61%.

Hickman next tested an osage orange bow, (a) backed with rawhide, drawing 49 pounds at 27 inches. With (b) *rawhide removed*, it drew 46 pounds; (c) backed with .16 fiber, 45 pounds; (d) backed with .046 fiber, 46 pounds. For cases (a), (b), (c) and (d), the efficiencies for a 400-grain arrow were 43%, 46%, 47% and 48%, respectively.

This indicated that the rawhide (which was almost 1/16 inch thick) actually reduced efficiency, and that the fiber gave a very slight increase over that of the unbacked bow.

It is necessary to exercise caution in drawing conclusions from these, as from any experimental results obtained with bows and arrows. It would be erroneous, for example, to conclude that backing a bow increases its efficiency; or that backing with fiber increases, while backing with rawhide decreases the efficiency. What definite conclusions, then, may be drawn? Not any that are generally applicable to all bows; but the experimental facts of Hickman's work have provided us with information from which we may arrive at the following highly probable conclusions:

Fiber backing, or any other material which has better mechanical properties under tension than the wood to which it is glued, will increase the efficiency of the bow if the presence of the backing does not throw excessive strain on the belly side of the bow; but unless the backing constitutes an appreciable part of the mass of the limb, it cannot be expected to have much effect on the performance of the bow. On the subject of backing more will be said later; at this point it may be remarked that unless rawhide, gut, sinew and other fibrous materials of animal origin are dried under tension, they will not be either as strong or as elastic as they are when tension has been applied during the drying process. Only in the latter case will they approximate Hooke's law under a tensile stress, i. e., that the elongation is in constant ratio to the applied force. It therefore seems likely that rawhide would give better results if it could be applied to the bow while under considerable initial tension.

Regardless of effect on cast or efficiency, which are not greatly influenced by backing in most cases, backing has its place in the construction of bows. If there is any reason to anticipate that a sliver might rise out of the back of a bow, a thin layer of backing of whatever kind is good insurance against this happening, and therefore against breakage of the bow from such cause.

As mentioned above, the early experiments of Hickman were carried on with the aid of a mechanical shooting device, or shooting machine. The earliest shooting machine is obviously the crossbow; and our modern machines, constructed to hold any kind of bow, are "crossbows with a college education". Elmer used a simple form of machine in 1913, and an improved form in 1925. Hickman's machine was designed for portability, so that it can be easily disassembled and packed in a carrying case. Two valuable features characterize his design. First, there is the swinging arm, to the end of which the bow is clamped, and which is normally held against a laterally adjustable stop by spring tension. When an arrow is shot, the arm, with the bow, swings away from the side of the arrow passage, showing that a very considerable momentary lateral thrust is exerted by the arrow against the bow. The other feature is the pneumatic release, which disengages the string without the slightest jar or displacement of the bow support. My machine was patterned after Hickman's; the principal change was a bow clamp which is "articulated" like the wrist of the bowhand, so that the bow is entirely free to move as it will under the impulsive forces that come into plav when the arrow is discharged. It is also possible, in this clamp, to secure the bow with any desired degree of lateral torque or twist of the handle, so that it may be made to shoot the arrow in the line of aim.

On the subject of shooting machines, the observation may be made that although it is probably impossible to construct a machine that will exactly reproduce hand shooting in every detail, yet a properly constructed machine is a valuable means for certain investigations, since it releases every arrow at precisely the same length of draw, and in the same manner. It is also capable of selecting arrows that are properly matched, especially if the bow is used for which the arrows are intended and if this bow is properly mounted in the machine. The bow clamp is very important to the correct matching of arrows.

Next in our review is a notable series of papers by Hickman, published in Ye Sylvan Archer, beginning in November 1931 and continuing through September 1932, dealing with static stresses in the bow, as related to length of draw, these being computed, for different kinds and conditions of bows, from formulas developed in the first paper of the series. By ingenious designation of the important values in the diagram of the bow, and effective simplification of the relationships involved, the formulas permit easy computation of the string tension, force required to draw the string, displacement of the bow tips, strains in the limbs, and work done in drawing, all as functions of the draw. With the formulas it is possible to find the relative values of all the above quantities at any point of the draw. These disclose the following interesting facts:

(a) After the bow is about half drawn, the displacement of the tips is approximately equal to half the draw, measured from the back of the bow*. For example, at a draw of 20 inches the displacement of the tips, measured from their positions when the bow is straight, or unbraced, is 10 inches; at 25 inches, 12½ inches; at 28 inches, 14.2 inches.

(b) The tension in the string is highest in the braced bow, least at approximately half draw. The variation is not great. Roughly, in the longbow, the tension is constant throughout the draw.

(c) In the longbow, the force exerted by the drawing fingers on the string is nearly proportional to the distance drawn. In other words, the force at half draw is about one-half the force at full draw.

(d) If the limbs bend in true circular arcs, the stress at any limb section is proportional† to the angle between the tangent to the limb at the tip and the line joining the two tips. Application of the formulas to bows with and without the rigid middle section shows that for bows of equal force at full draw, the various quantities mentioned above are about the same in both cases; the conclusion is that the difference in shooting quality between them does not arise from static conditions but from dynamic performance.

When a given bow is braced at different heights, the formulas enable one to compute how the stresses in the limbs vary with bracing height; likewise the variation in string tensions, and the force-draw relationships.

Although the string tension increases with bracing height, the total variation in tension between low and high bracing, and beween zero draw and full draw, is not great. Maximum tension occurs in the string of the high braced, undrawn bow.‡ The stresses in the limb are shown to increase considerably with bracing height, indicating that high bracing is more hazardous to the safety of the bow than normal or low bracing. Because the distance drawn is reduced with high bracing, the work done in drawing diminishes as the bracing height is in-

*More accurately, from the neutral layer.

†The stress is also inversely proportional to the radius of curvature of the bent limb.

‡It is a matter of experience, on the other hand, that, when bracing a new bow with a string that gives low bracing height, the latter is more likely to break than is a string that is shortened to give normal bracing height.

creased, there being little difference in force at full draw. For a given bow there is a certain bracing height which gives maximum velocity to an arrow, this being more pronounced as the bow is shortened. A 64-inch bow had an optimum, or best, bracing height at 5 in.; a 72-inch bow, on the other hand, showed best results at 7-inches, although the difference between 6 and 7 inches was small.

It is my observation that variation in velocity, due to changes in bracing height, is not so important a factor in consistent performance of the bow as is the variation in the manner in which the arrow leaves the string and passes the bow handle as the bracing height is changed. One advantage of high bracing, if the bow "can take it", is reduction in string slap against the arm. In this there is nothing new; Ascham wrote about it in 1544.

Some interesting results are obtained when the formulas are applied to finding the relative values of the various stresses and forces for different degrees of reflexing, for the perfectly straight bow, and for the bow with a permanent set, i.e., one which has followed the string by different amounts. For complete information, the original curves should be consulted. Briefly, the tension in the string, at full draw, is almost the same for all the bows, whether straight, reflexed or with large initial set or string-follow; but the initial tensions, at the same bracing height, may be almost zero for the bow with great initial set, and very large for the highly reflexed bow. The force-draw curves are especially significant: the bow with great initial set starts with large force per inch, but eases up considerably at full draw.

Altogether, the reflexed bow is the more desirable; and if one possesses such a bow, the fact of its not having broken in use is eloquent testimony to the high quality of the wood, for the stresses are decidely greater with increased reflexing.

Ascham wrote of the difference in effect upon an arrow between a light string and a heavy one. Hickman's measurements of arrow velocity when strings of different weights were used confirm Ascham's observations, and establish a law of mechanics which states that the velocity of an arrow when shot with a string of certain mass is the same as if the string had no mass, and one-third its actual mass had been added to that of the arrow. For example, a string of 300 grains gives an arrow of 400 grains the same velocity that a string weighing zero would give an arrow of 400, plus 1-3 of 300, or 500 grains. This shows the value of using a light string, especially in distance shooting. It was also established that in a bow of dense material, and consequently with limbs of large mass, a change in weight of the string has less effect on cast than with a bow made of wood having low density. The effect of air resistance on the string was found to be imperceptible.

When the formulas are used in studying those differences in forces and stresses which arise from differences in length of the bow, it is found that the initial tension in the string on a short bow is decidedly less than that in a long bow of the same drawing force. It rises more rapidly with length of draw in the short bow, however, so that at full draw the difference is much less. The stresses in the wood, and their variation with draw, cannot be worked out as a simple function of bow length, because dimensions and shape of the limb have an important bearing on the subject. As might be expected, the tips of a short bow move farther for a certain length of draw than those of a long bow.

There has been much conjecture about the effect of heavy tips upon the cast of a bow. The experimental results reported by Hickman give at least partial enlightenment on this matter. A six-foot bow of 30 pounds draw at 25 inches was used for shooting arrows of four different weights, and their velocities measured. These measurements were made with the tips free and with weights of 49, 95 and 185 grains; and repeated with all the load removed, as a check on the first measurements. With the lighter arrows, the change in velocity produced by loading the tips was not over one percent, and with the heaviest arrow of 663 grains, it was not measureable. With stronger bows, the effects would be even smaller. The tests show our instinctive supposition that heavy tips reduce cast to be not well founded. Evidently, with heavy tips, acceleration is not so great at the outset, but the transfer of momentum from limbs to arrow takes place as effectively as with unloaded tips. Air resistance on the moving limbs was found to have no effect on cast.

In an additional series of articles early in 1932 Hickman develops certain conclusions from elastic theory as applied to the bow. The bowyer who desires to understand the elementary mechanics of the bow will do well to become thoroughly familiar with these articles. The first of them, which might logically have followed the other two, shows that there are two different types of limbs that bend in circular arcs when force is applied to the tips. The first is the limb of constant thickness, tapering uniformly, with straight sides, from a certain width at the dip to zero width at the nock. The second is the limb of constant width, which diminishes in thickness to zero at the tip, along parabolic profile lines. The first shape—an elongated isosceles triangle in plan view, and of constant thickness—is found, in an unpublished analysis, of which Dr. Hickman kindly gave me a copy, to have a much shorter period of vibration, for a given length, than the second. This means that the limb, when drawn aside and released, without an arrow, returns to its undeflected position faster, and that acceleration of the limb, from is deflected position, is greater.

Having had the opportunity of discussing these matters with Dr. Hickman early in 1931, Klopsteg set to work to make experimental investigation along these lines. During that year he outlined and carried out a series of experiments designed to obtain facts about the design of bow limbs. Bows with limbs of various shapes of cross-sections were designed, constructed and velocity-tested, with different weights of arrows, by means of a chronograph. All results pointed to superior efficiency of the bow with either rectangular or modified rectangular limb section as compared with the traditional rounded belly, whether it be Roman arch, parabolic, semicircular or high-stacked. The differences were so pronounced that no doubt was left as to the proper shape of limb section. In the description of this work these facts were brought out. In a paper published five months later construction details were given. That many archers have proved to their own satisfaction the correctness of the published conclusions is attested by the rapidly growing numbers of bows in which the limbs are made with a flat instead of rounded belly.

In 1932 Klopsteg devised a graphic method for designing a bow to any desired specifications. By this method, the best shape of limbs for maximum performance from a given stave can quickly be laid out. The method is based on sound scientific and engineering principles, and introduces into bow design the exactness which characterizes the work of a structural engineer. In the construction of the bow, some deviation from theoretical design may be necessary because of the nature of wood, and the characteristics of a particular stave. The experienced bowyer can readily determine where and how much to depart from the design data.

In the paper on the proper cross-section of the bow limb, the principles of correct design are laid down. Assuming that the finished bow will have proper "action", namely, that it is well balanced, shoots without jar, and propels arrows that are suited to it without interference or slap at the arrowplate, the most important additional specification which we impose, to achieve the perfect bow, is maximum cast for given drawing force. It is easy to demonstrate that the arched or stacked belly is fundamentally wrong. The fiber stresses—compression on the belly, tension on the back—are directly proportional to the distance of the fiber from the neutral axis of that section.* Wood has rather severe limitations in the matter of compressive strength and the compressive force which it will withstand without reaching the point of elastic failure, i.e., the pressure at which it undergoes a permanent yield. Pronounced following of the string is evidence that this pressure has been exceeded. Its tensile strength, as found at the Forest Products Laboratory, and, specifically for yew wood by Overacker, is very considerably higher than its compressive strength. Acordingly the distance from the neutral axis to the outermost fiber of the back should be correspondingly greater than the distance to the outermost fiber of the belly. But the tradional shape brings about the opposite condition; the compressive force at the surface of the belly is anywhere from 20 to 40% greater than the tensile force at the back in that section. It ought to be vice versa. The section ought to be so shaped as to place the neutral axis at the very least midway between belly and back.

The rectangle meets this requirement. There are other figures, like circle and ellipse, which likewise do so, but it can be shown that the rectangular section, with uniform limb thickness, and straight tapering sides that meet at the nock, has higher restoring force, when deflected or bent from its position of rest, in relation to its effective mass, than does any other symmetrical section that can be used in limbs that will bend in uniform circular arcs. Because of its characteristics, the rectangular section makes possible a bow of given draw-

*When a limb is bent, there is maximum tension at the outer convex surface of the back, and maximum compression at the inner concave surface of the belly. At any cross-section, the tension diminishes as we pass from back towards belly; becomes zero at a certain point, then changes to compression. The line passing through all the points so defined is called the neutral axis. The neutral axis has the property of passing through the center of gravity of the section. The geometric surface described by all the neutral axes along the bow may be termed the "neutral layer."

ing force in which the maximum stresses to which the wood is subjected are greatly reduced from those in a stacked bow of the same length and drawing force. It makes possible a shortening of limbs if that is desirable. It has the effect of stressing the wood equally at any section of the limb. Furthermore, limbs of the same length as those of the stacked bow have decidedly more cast, provided the width-thickness ratio has been correctly chosen.

The graphic method of designing a bow, previously mentioned, gives limbs that taper, but not uniformly along straight lines. Their sides are curves which, at full draw, give equal bending moments per unit area at every section. In a limb of uniform thickness, this requires bending in circular arcs; and that the width, at any point, be proportional to the perpendicular distance of that point from the fully drawn string.

The writer's bows, thus designed and constructed, whether of yew, osage, degame, or red cedar, show efficiency values from 15 to 35% higher than those for corresponding traditional bows. One of these bows of osage, tested by both myself and Hickman independently, gave the exceedingly high efficiency value of 93%, allowance having been made for the mass of the string. From the practical archer's point of view, this means lowered point of aim, or, if he chooses, a lighter bow for the same point of aim. It makes possible a straight longbow which, for an archer of average stature, will put his point of aim on or below the target at 100 yards, with a 45-pound bow.

Nagler presents a design of bow in which the limbs bend in elliptical arcs, instead of circular; they bend more at the tips. He reasons that since a bow weak in the middle is inefficient†, one that is weak at the tips should be "in the right direction". Experimental facts bearing on this question are not available. A thoroughgoing investigation of the matter is a tremendous job, because conclusions cannot be drawn from results on a single bow. It requires comparative data on several dozen bows at least. Until such comparisons prove the contrary, it seems reasonable to assume that the elliptical form of bending of the limb is not superior to the circular‡, and

†This assumption may not be correct. There have been no measurements, to my knowledge, to determine relative efficiencies of bows with rigid mid-section, and those that bend in the handle.

‡Since, as shown by tests, the writer's bows have high efficiency values, ranging from 70 to 85 percent, very slight increase in efficiency is at best possible. Some energy loss in the limbs and string is inevitable. If this is 10%—probably a conservative estimate—it leaves a very narrow margin within which to effect improvement.

it is more difficult to lay out, and to tiller to correct form. Nagler's articles present, in addition, some excellent "random notes" that are worth any serious archer's while to study carefully.

While we are still on the subject of bows, several additional articles should be mentioned. An article on desirable qualities in bow materials discusses the mechanical and elastic properties of wood and other materials that are essential to their suitability in a bow. Another discusses a bow grip so designed that the "point" support can be shifted, thus moving the line of force between the nock of the arrow and the point of support of the bow off the center of the latter, and nearer the arrow passage. It results in less arrow slap, and smoother departure of the arrow from the bow. The same question is briefly discussed in the construction article and others. Unquestionably better action results if the force of the string acts along the axis of the arrow instead of being directed towards the middle of the handle.

It can be said very definitely that smoothness of action, and absence of kick in a bow, depend primarily on two factors. The first is dynamic balance of the limbs. By this is meant that the limbs should move through their respective arcs of travel from full draw to the braced position in precisely the same time, and that they should transmit equal impulses through their respective sections of string to the arrow. The second condition is that the bow be highly efficient, a condition somewhat depending on the first factor of dynamic balance, on the quality of wood used, and on the design of the bow. When the efficiency of the bow is high, it means that a high percentage of the energy in the limbs is transferred to the arrow, leaving very little in the bow to produce unpleasant jar or kick. A bow of low efficiency, like some steel bows I have tested, is likely to kick severely. If in "smoothness of action" we include absence of arrow slap against the bow—and it seems reasonable to do so—attention must also be paid to the direction of thrust of the string on the arrow, and, obviously, to proper matching of arrow to bow, as discussed elsewhere in this review.

In his recently published book Klopsteg devotes a part of the last chapter to considerations of the reflexed, Turkish type of bow, provided with ears, or curved-back tips. He gives experimental force-draw curves for the straight longbow; for a straight short bow; for the latter provided with ears;

and for the latter, with ears, and with limbs strongly reflexed. This throws light on the superiority of cast of the Turkish type of bow as compared with a longbow of the same drawing force.

One subject of great interest that has been only touched upon in previous publications is the question of reenforcement of either back or belly with materials more adequately suited than the wood in the self bow to withstand tension and compression. The Turkish composite bow is the outstanding example of such reenforcement, with its back of sinew fibers laid in a matrix of glue, and its belly of that superb compression material, buffalo or antelope horn. In the straight bow, backing has but one function, namely, insurance against slivers rising out of the back. In general, it adds nothing to, and may diminish, cast. Parchment or very thin drumhead stock is excellent. It is quite obvious, of course, that the backing material, assuming that it has approximately the same elastic properties as the wood to which it is glued, adds some weight to the bow; the stiffness of limb is increased in proportion to the cube of the thickness of the limb. The increased stiffness may or may not be accompanied by increased efficiency.

If material of greater tensile strength and higher Young's modulus than wood is used for backing, it has the effect of moving the neutral axis farther from the belly and therefore increasing the maximum compressive force on the belly. It may therefore increase the tendency to break by compression failure. Such material should therefore not be used unless the belly is, at the same time, strengthened by facing it with material of higher compressive strength. If some synthetic plastic can be developed or discovered having the mechanical strength and elastic properties of horn, it will have great value for strengthening the bow, to withstand greater compressive stresses. There are plenty of suitable backing materials, but very few that can do the more important job of reenforcing the belly.

The Arrow

The arrow has fared rather meagerly, in comparison with the bow, as regards mathematical and mechanical analysis. Some experimental work has thrown light on its behavior as it passes the bow. The flight of the arrow, with due regard for air resistance, has come in for more analytical study, but the experimental data are scant. There has, however, been evidence of the value of some of the theoretical work that has been done. Of this we shall treat more fully below.

In two articles, Klopsteg describes the results of an investigation made, during the winter of 1932-33, by means of high-speed photography. The reader who is interested should consult the original articles. In them are reproduced a number of "lightning flash" photographs, showing clearly how an arrow "snakes" or oscillates its way past the bow. Other photographs show the path of the string, in side and plan views, as well as the motion of the bow hand during the shot. Deductions from a study of about 200 photographs are given in The Archery Review for January, 1934. Hickman, through contact with Electrical Research Products, Inc., has recently had access to the high speed motion picture camera developed by that company, and has thus screened several reels of film showing the arrow being discharged by a bow, both in the shooting machine and by hand, in extremely slow motion. These remarkable pictures confirm in all respects the "stills" taken by the "lightning flash" method.

The oscillation of the arrow, so clearly shown in the pictures, is the clue to what constitutes "matching" of an arrow to a bow. In the first place, the arrow must be stiff enough so that it will not perceptibly buckle under the acceleration given it by the string. At the same time, it must have a period of oscillation which is properly timed with the passage of the arrow across the bow handle. This means that it should oscillate rapidly enough, after the oscillation has been initiated by the loose, to insure that the rear end of the shaft will be vibrating away from the bow while it is passing the latter. If it vibrates too slowly, the tail of the arrow may strike the arrow plate with considerable impact, and the arrow is thrown to the right of the line of aim. If the arrow is too stiff, the impulse between the foreshaft and the arrow plate may cause considerable leftward deflection.

All this leads to a consideration of the much used and little understood term. "spine". Incidentally, the effect of spine upon accuracy of flight is greatly diminished by supporting the bow off center towards the arrow plate,* so that the force of the string will act as nearly as possible along the axis of the arrow. Most bows exert their force in a line to the right of the arrow, through the middle or even to the right of the

*Another way of accomplishing the same thing is to reduce the belly on the side away from the arrow plate, or the back on the same side as the arrow plate.

middle, of the bow handle. This introduces a so-called component of the force to the right which has the effect of increasing the sidewise thrust of the foreshaft against the arrow plate. When such action is present, it causes increased lateral errors, and makes equality of spine in a set of arrows exceedingly important.

Aside from the discussion of spine by this writer the subject has been treated in a paper by Rodgers and another by Rheingans. One must distinguish between spine of an arrow, and the spine characteristics of wood from which arrows of equal spine may be made. It should be possible to measure the latter, and in this way select squares or dowels from which arrows of equal spine may be made. Rodgers and Rheingans have given formulas for doing this.

Both writers agree that stiffness and density are the two physical properties of wood which determine the spine of an arrow made from it. Rodgers adopts the formula $C = w^2d$ where C is a quantity which he calls the spine-weight coefficient, w is the weight per linear inch in grains and d the deflection, measured in 32nds of an inch, in a 26-inch length, produced by a force of .643 pound or 3700 grains, acting on the free end of the stick, which is clamped at one end. The above formula applies to square sticks only; for a round stick, it must be multiplied by .955. It will be noted that the units employed are arbitrary, and, to obtain comparable values for C, it is necessary always to use sticks of the same length, and obtain the deflection in 32nds of an inch with the same weight, and express the weight per inch in grains. The weight per inch is directly proportional to density, and the deflection is inversely proportional to stiffness. The lighter the wood, the smaller will be w; and the stiffer the wood, the smaller will be d. Hence the lowest values of C obtainable by such measurement represent the lightest, stiffest wood.

Rheingans, by similar reasoning, obtains $N = DW^2$ where W is the weight of the dowel, D is the deflection, and N is a "spine rating number". Rheingans measures the deflection in inches, of the dowel supported at two points, 28 inches apart, loaded with a 2-pound weight; and expresses the weight of the dowel in grains.

Obviously the spine rating numbers will differ from the spine-weight coefficients, because of differences in units chosen. Rheingans also suggests a "universal" spine number in which the modulus of elasticity for the material in question takes the place of the deflection in the spine rating number. With the formula for the "universal" number he compares various kinds of wood, and finds spruce, Sitka spruce, Port Orford cedar and Norway pine to head the list, with bamboo and birch well up; yew, black walnut, oak, lemonwood and osage are at the bottom of the list of 21 species.

The spine of an arrow may be called a dynamic characteristic, since it has importance only while the arrow is being accelerated by the string, and passes the bow. To express it numerically, Klopsteg has suggested the formula $S = K f/m$, where f is the frequency, or number of oscillations of the arrow per second, and m is the mass of the arrow. K is a constant factor. It can easily be seen that f depends on stiffness, density, dimensions and shape of the shaft; it will be largest for the stiffest, lightest arrow, and will be greater for the barreled arrow than the cylindrical shaft. The lighter the arrow, the smaller will be m, its mass. The largest value of S, or the greatest spine, is thus found in a shaft that is very stiff in relation to its density; and can be increased by increasing the shaft diameter, especially at the middle. It is of interest that this approach leads to results in harmony with those of Rodgers and Rheingans. What is needed is standardization of units, dimensions, formula, and method of measurement.

Many archers have confused spine and stiffness. Measurement of stiffness alone is not spine-testing. For equality of spine, it is necessary that stiffness, mass, shape and distribution of mass in the arrow be the same. This probably accounts for the difficulty of producing well-matched arrows.

To the inquiring mind, the flight of an arrow represents, in addition to a thing of esthetic appeal, a wealth of problems. How is it affected by air resistance? What of the shape of the feathers, and the surface of the shaft? If the initial velocity and angle of departure with the horizontal are known, is it possible to calculate the path, i. e., find its position at any given number of seconds after it left the bow? What is the angle of departure for greatest distance of flight? Several investigators have turned their attention to these and other questions that have a bearing on the characteristics of arrow flight.

The first of the papers of reference is by English, who develops approximate formulas for finding (a) the position of an arrow at time t after it has been discharged with initial velocity V at a known angle of departure; (b) the range of the arrow; (c) the trajectory, or path of flight; (d) the time of flight; (e) the maximum height of rise; (f) the angle of fall; (g) the remaining and striking velocities. Experimental data were obtained in careful measurements, with a shooting machine constructed so as to insure projection of the arrow precisely in the direction of its axis, without side thrust. This precaution was necessary for securing experimental conditions corresponding as closely as possible to theoretical assumptions. Velocities were measured with a ballistic pendulum. Fortunately an indoor experimental "laboratory" giving a 50 yard range eliminated errors and disturbances due to wind. Calculations by means of the formulas, from the data so obtained, gave satisfactory agreement with directly measured values of the computed quantities.

The work of English was apparently the first of this kind for which theory and experimental verification were published. Although there were certain erroneous premises and assumptions, the work had practical value in that it presented the first means for determining the effect of air resistance on the flight of the arrow. Klopsteg used the English equations for computing arrow trajectories for two cases, viz.: 140 f. p. s., 325 grains; and 180 f. p. s., 400 grains. In each case, trajectories were computed for initial angles giving maximum ranges, somewhere near 45°; and low initial angles, giving trajectories for the approximate distances customary in the York and American rounds. For all these initial angles, trajectories were also computed on the assumption of unresisted flight, i. e., without air drag. For details, the original paper should be consulted. It was found that maximum range in both cases was obtained for an angle somewhat less than 45°, and that any elevation between 39° and 43° would give the same range within a yard or two. Another interesting result—not unexpected—was that the loss of range, at maximum, with the lighter arrow at lower velocity, was about one-third, because of air drag; whereas, the heavier arrow at higher velocity lost only a little over one-fifth of its maximum range without air drag.

Higgins makes a theoretical study of the aerodynamics of an arrow, in which he applies his knowledge and experience in aeronautical engineering. He develops an expression for drag which takes into account the dimensions and kind of shaft, the effect of feathers and the broadhead of a hunting arrow, so that he is in position to calculate drag for an arrow of any kind. His equations are probably more accurately representative of actual conditions than those of English, but they are considerably involved. One adverse comment on the paper by Higgins is that he has given no evidence of experimental verification of his equations; he shows curves of "actual" values and values obtained "by formulae", but without explanation of how the "actual" values were obtained. Assuming that they rest on the substantial ground of careful measurement, the work of Higgins is a masterpiece, and represents one of the really big jobs in the scientific study of archery.

With reference to maximum range, Eugene Conner, in the Archery Review for July 1933 gives a most interesting quotation from the scrapbook of Mr. Peddinghans. It is a clipping from an article by Will Thompson, published, as Mr. Conner surmises, in *Field and Stream,* about 1879. Thompson gives results of shooting various weights of arrows from various bows of widely different drawing forces, for utmost distances. Each distance given is the average of ten shots for one arrow from one bow. The tabulated results show that a 54-pound snakewood bow, backed with lemon, shot slightly farther than a 62-pound split bamboo, and appreciably farther than a 70-pound snakewood. In general, the distances increased with mass of arrow, except that the heaviest, 5 6 in weight showed some reduction in distance in every case. A 44-pound rosewood bow shot all arrows, ranging in weight from 4/0 to 5/6, about the same distance. The results show—remembering that the velocity of an arrow from a given bow decreases with increasing mass of the arrow—that there is some mass of arrow for each bow for which the greatest distance is obtained. This is due to the fact that the heavier arrow—assuming the same "form factor" in air resistance—is able to overcome air resistance more effectively than the lighter, and thus to compensate for lower initial velocity, and travel farther. But as velocity diminishes, the range—even in the complete absence of air resistance—is diminished; so we can readily see that for each bow there is some weight of arrow with which greater range may be obtained than with either lighter or heavier arrows.

So long as the feathers are well selected, and attached to the shaft with perfect symmetry, there seems to be little or no choice as to shape or size. However, a long, low feather is undoubtedly better in a wind. Spiralling seems unnecessary.

and, in a flight arrow, undesirable. Art Young, shortly before his death, told me that for a silently-flying hunting arrow, the stiffest sections of feathers perform best, especially if the vanes are long, and cut as low as possible without seriously affecting steering quality. To prevent perceptible "steering" by the broadhead, its blade should be plane, and in accurate alignment with the axis of the shaft.

Aiming Methods

In addition to the researches that have been made on the mechanical properties of the bow and arrow, and the conditions that affect their performance, a number of papers have been published on studies of aiming, holding, sights and points of aim. Advantages of the sight over the point-of-aim marker have been enumerated. In a comparison between the two, it becomes evident that, so far as the technique of shooting is concerned, there is no difference whatever between them. A sighting device in effect produces a fixed point-of-aim; it is precisely like putting a massless extension upward on the pile of the arrow, and sighting over that at a point of aim. The length of this imaginary upward extension is determined by the distance of the target. In addition, the sighting point makes possible lateral adjustments for wind. It also gives the archer some freedom as to position on the shooting line. If the sight—which may be simply a bead—is artificial, so is the point-of-aim marker. The principal difference between them is that the sight has the great advantage of convenience; when changing distance, shifting the sighting point is far less bothersome than moving the point-of-aim marker. On the other hand, since the technique of shooting involves so many psychological factors that are not well understood but which have a profound effect on scores, the individual archer should investigate whether in his own case the sight or the marker gives better results.

This review is not controversial; on the contrary, it is intended to be an uncolored presentation of the conclusions reached in various investigations. As to the "propriety" of using the sight or the marker, no conclusions based on facts can be reached, since this is altogether a matter of opinion. It is interesting in this connection to note that in certain archery events in England, such as the Scorton arrow shoot, the use of a bead on the limb of the bow is permitted, but not the marker. If "artificialities" are to be banned, both should be excluded; but no rules can be made against the archer's selecting some "natural" marker on the ground. Perhaps the best test of an archer's ability to gage the proper elevation for a particular distance would be to have such uniformity of terrain between shooting line and target that no natural marker could be found. He would then be compelled to estimate the location of his point-of-aim for each shot, or to shoot instinctively.*

Using the data obtained in the study of the flight of an arrow, with allowance for air resistance, as a basis, Klopsteg computed tables and curves that give the relation between the target distance and (a) the distance of the point-of-aim marker on the ground, measured from the target, and (b) the distance of a sighting point or bead above the axis of the arrow, for arrow velocities ranging from 130 to 180 feet per second. Computations were made for 325-grain and 400-grain arrows. From the tables it is possible, knowing arrow weight, to obtain approximate arrow velocities when the locations of points of aim for different target distances (or sight settings), are known. When the arrow velocity has been found, a single determination of the location of the point of aim, or sight setting, for a known distance, enables one to set points of aim or sights for any other distance. The curves also show that for every arrow velocity within the values mentioned, there are two different target distances for which the distance from the target to the point-of-aim marker is the same. For example, with an arrow of 161 f. p. s., the marker is 30 yards from the target for the 80-yard range; it is precisely the same with the target at 45 yards. Likewise, with a 140 f. p. s. arrow, the marker for the 60-yard range is 20 yards from the target; it is also 20 yards from the target when the latter is 35 yards away. The same computations give point-blank distances for each arrow velocity. These distances are: 130 f. p. s., 63 yards; 140 f. p. s., 72 yards; 150 f. p. s., 82 yards; 160 f. p. s., 92 yards; 170 f. p. s., 103 yards; 180 f. p. s., 114 yards. Depend-

*While the manuscript for this article was awaiting publication, the writer, with suggestions from Walther Buchen, devised a round which he has designated the "Art Young Round", in memory of Arthur H. Young, who died on February 26, 1935. The feature of the Art Young Round is that no two shots are at the same distance, a fact which makes point-of-aim markers impossible and sights practically useless. It consists of 36 arrows, each hit counting 1. There are six marks, which may be small straw bosses, like those used in archery golf, placed more or less at random in a field. Likewise there are six shooting stations. The shortest distance between any station and mark is 30 yards; the greatest, 80. From each of these the archer shoots six arrows successively, one each at the six marks. The round puts a premium on skill in field rachery, at which Art Young excelled.

ing on the archer's stature, his anchor, and the length of draw, there will be slight variations in these values. Such a tabulation enables one to determine his arrow velocity by finding the point blank range for his bow and arrow; and from it, the marker or sight settings for all the ranges.

AROUND THE WORLD
With Dr. Paul Klopsteg

Author of "Turkish Archery and the Composite Bow"
Co-author of "Archery, The Technical Side"

Reprinted from *Archery* (NFAA) Vol. 24, no. 2 (Feb. 1952) 4–5

Since it appears to me that much of the improvement in our bows during the past ten to twenty years must be attributed to what we have been able to learn about composite bows, particularly those of Turkey, along with our better understanding of the scientific and engineering fundamentals of the bow and its action, I wouldn't be too much surprised if, among the readers of "Archery" there are some to whom the story of a 1951 "adventure" might have some interest.

I had in mind writing this earlier, but a sudden impact on my plans and more or less peaceful existence occurred which made Amanda, my wife, and myself displaced persons. Displaced, I mean, in the sense that we suddenly transferred to Washington after having only recently completed and occupied the dream house we had long planned. That dream house, in Glenview, Ill., is in a wonderful spot, secluded, overlooking a forest preserve, and with no possibility that the view can ever be spoiled; there can be no more building in the area. Furthermore, I can set up a target for whatever range I like, up to 100 yards, on my own property. Well, the dream house is closed, and we live in a one-room "efficiency" apartment in Washington.

Of course, we didn't come here for any trivial reason. When I was "tapped" last fall to come here and take on the Division of Mathematical, Physical and Engineering Sciences of the National Science Foundation, it was a challenge, and I'm the kind who never lets a challenge get by without doing something about it so here we are. Whether we go back to the peaceful, sylvan surroundings of the dream house next fall or continue on here is about fifty-fifty. We shall have to decide that later.

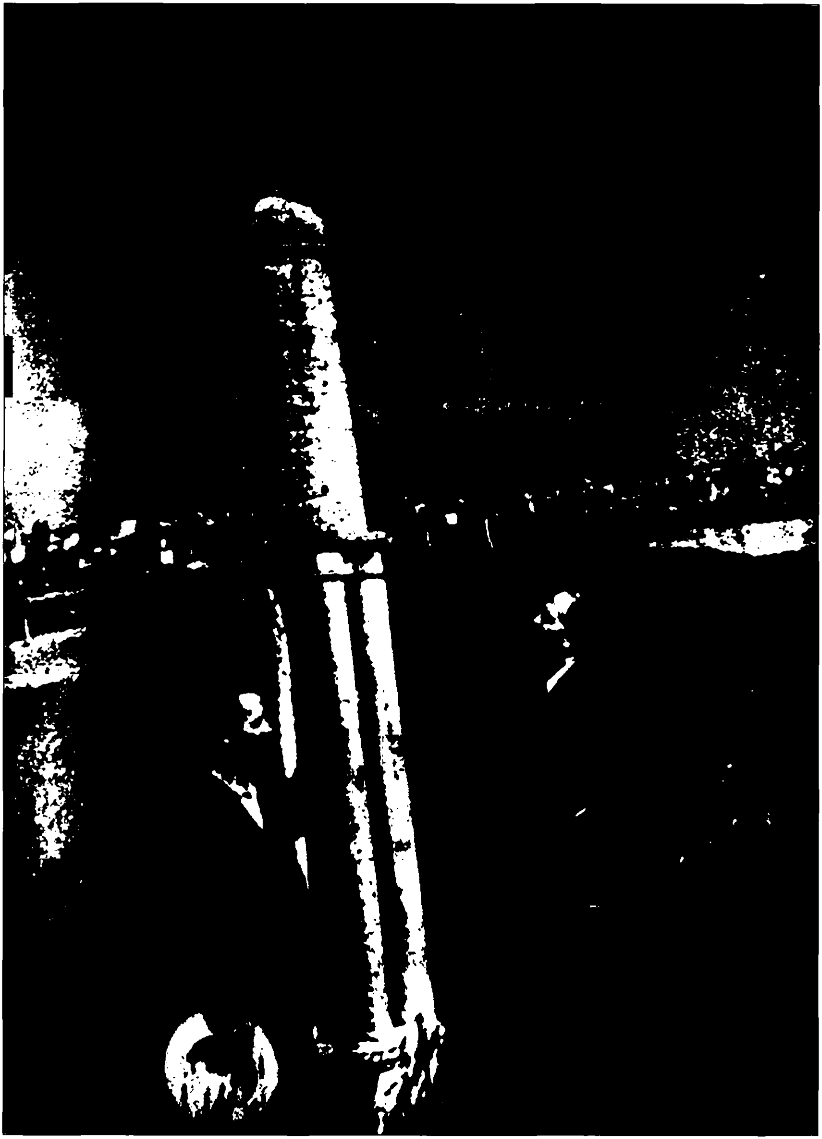
As I started out to say, we had adventure in 1951, one part of which has to do with the Turks and their prowess in flight shooting.

Early last year, I was invited by the government of the Punjab in Pakistan to come there to give aid in education in technology and the sciences. The problems arose in connection with the study by an outstanding University Commission, government-appointed, of the organization and operation of the University of the Punjab in Lahore. I looked at the globe and saw that Lahore was about half-way around from Chicago. Then I called Amanda on the phone and said, "How would you like to fly around the world with me?" Her recovery from the shock of such an invitation was fairly prompt, and her answer was, "I'm game if you are." So we were both game, and got ready for the journey. We flew by way of Hawaii and Manila, had a week in and around Delhi, and then spent nearly six weeks in Pakistan.

After the job had been completed there, we started homeward. I said "started", not "turned", for we continued in the same direction. After a stopover in Karachi, our next stopover was Istanbul. I apologize for the time it has taken to reach that point. Having arrived, let's go on with the story.

As you can believe without trying too hard, I had spent a lot of time during the past twenty years or so learning what I could about the bows and arrows of the Turks, and you recall that I wrote down much of what I learned in "Turkish Archery and the Composite Bow". Much of what I had read had its setting in Constantinople, which became Istanbul a quarter of a century ago. I had also read a great deal about English archery, and found, on a visit to England some five years ago, that the old shooting fields there are pretty well built over, and no longer identifiable as shooting fields. It also seemed, and still seems, rather singular that in a nation which emerged strong out of the middle ages primarily because of its effective use of the bow, there is hardly a specimen, and no intact specimen, of the old longbow by which English history was so largely fashioned.

All of this had me prepared to discover very little by on-the-spot personal observation that I hadn't already read about in the



Dr. Klopsteg (right) and unidentified companion, examine a marble column with inscription marking where record-breaking arrow landed.

Tombstone of one of the old Janissaries, in a burial ground on the ok meydan. Note bow and arrow inscribed near the top.

various sources I had consulted. In particular I remembered that very little was apparently known to English writers on archery about Turkish archery of the fifteenth century, and those which followed. One of these writers, three-quarters of a century ago, said: ". . . there was (if there is not now still in existence) an extensive piece of ground set apart for the purpose (practice of archery) upon an eminence, in the suburbs of Constantinople, called ok meydan, 'the place of the arrow'. This place was full of marble pillars, erected by those archers who had excelled in shooting their arrows at any remarkable distance . . ."

With this comment in mind, and with the expectation that historic places, such as the ok meydan, might have experienced the same fate as Finsbury Fields, I had little expectation of finding anything exciting. Our room at the Pera Palace Hotel overlooked an "eminence" about a mile away, with extensive open spaces, in the middle of which stood, prominent on the skyline, a minaret. To get our bearings in a strange city, we bought a map locally printed, to identify various points of interest and to locate them for an eventual visit. As nearly as I could tell, the open fields visible from our room were identified on the map as "ok meydan". Believe me, it sent both pulse and blood pressure up with excitement.

Skipping details, I was fortunate next day in making a journey to the minaret, in company of a Canadian-born resident of the city who has lived in Turkey most of his life, and who speaks the language fluently. A quick survey of the area disclosed many "marble pillars", many of them with inscriptions. We had indeed found the ok meydan, the field of the arrow, the field on which, beginning in 1453, the Janissaries of the army of Mohammed the Conqueror and their successors, had shot the remarkable distance records reported in my aforementioned book. I do not doubt their record of a half mile, nor do I doubt that the record has not, since their time, been equalled. Neither do I doubt that the remarkable rate of improvement in bows of the laminated and composite type in America during the past decade, along with improvement in arrows and shooting methods, will see that record broken before many years.

The day after the visit to the ok meydan, where I took many photographs, I had the privilege of a visit to the Serai Arms Museum, in the Seraglio of the former sultans of Turkey. Here I saw several hundred Turkish composite bows on exhibit, behind glass, all very old, and probably used on the ok meydan. These bows are all inscribed with the maker's names and dates of completion. The curator, through my interpreter, told me that they had hundreds more in storage, and that they couldn't be shown for lack of exhibit space. When I expressed regret that someone hasn't made a thorough study of them, he said—in Turkish, of course—"There wouldn't be anything in that, they're all alike."

Personally, I am convinced that a rewarding study of the bows and of the ok meydan could be made. The Turks are unaware of the historic treasure they have. Some day, be the Good Lord willing, I want to get back there and make the study. It will take a lot of arranging, no doubt. But I have already made a start. Within the year I hope to have a new survey made of the area, showing the original boundaries, and having all the marble pillars and other markers located on the plat. Further than that, I hope to have each existing pillar identified by location, with translations of the inscriptions.

When we have that, we can go on from there.

MEASURING FLIGHT DISTANCES

By Paul E. Klopsteg

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Enthusiasts for flight shooting with whom I have recently discussed their particular interest in archery have mentioned the increasing difficulty in measuring the distances of large numbers of shots rapidly and accurately. The problem becomes more formidable as the distances become greater. Without the refined methods used by surveyors it is practically impossible to measure distances upwards of 400 yards with the accuracy that is implied when such distances are expressed in yards, feet and inches. When a tape line—usually not over 100 feet long—is used, the inches have no significance, and one must accept the fact that the inevitable errors in measuring permit of accuracy no greater than within about one foot in these long distances. Moreover, since the archer does not stand precisely on a "zero" point while shooting, any distance, however accurately measured, would be in doubt by at least a foot, and possibly more.

At most tournaments in which provision is made for flight shooting, the use of surveying instruments is ruled out simply because instruments of sufficient precision are not readily available, and even less readily available are skilled surveyors to use them. The well known conditions at such tournaments dictate that the simplest possible means be devised for measuring the distances with reasonable speed and with an accuracy of the order of 1 foot.

Other conditions that must be provided for are that the arrows may deviate considerable distance to the right or left of the axis of the field, which is the line marking the intended direction of the shots. If all arrows could be kept within a few yards of that line there would be no serious problem, for then the distance measured along the axis to the point of intersection with a perpendicular line from the arrow would be the distance within the error specified. When the lateral deviation becomes many yards, however, the distance from the shooting station to the arrow may be appreciably greater than the distance measured along the axis.

One method that immediately comes to mind is to measure the perpendicular distance from the arrow to the axis, as well as the distance along the axis to the point of intersection with that perpendicular, and from the well known formula for a right triangle, calculate the hypotenuse. For shots in the 400 to 700 yard bracket the method is cumbersome and slow. The figures become so large and unwieldy that seven-place logarithmic tables or calculating machines would be needed to handle them expeditiously. The direct measurement with a tape line would be equally slow and less accurate.

The method that seems best suited for the purpose requires some advance preparation. It gives the results quickly within the accuracy suggested. Figure 1 shows the principal of the method. The shooting position is at S and the axis of the field or intended direction of shooting is ST. Archers should stand within a few yards of the shooting station. The figure represents a plat to be laid out on the field as a sort of diverging grid in which the corners of the unit areas are marked by stakes. Only the axis line needs to be marked with lime. The grid comprises stakes in parallel lines at right angles to the axis at each 25-yard point from 400 to 700 yards inclusive. This bracket of expected ranges can of course be varied at will. The 700-yard line is also laid out in 25-yard units to points 100 yards to the left and right of the axis, respectively. The unit areas are thus seen to be trapezoids with two parallel sides and with the other two sides slightly diverging. The lines of stakes perpendicular to the axis are designated by the letters A to M inclusive, and the diverging lines by numbers from 1 to 9 inclusive, the line of the axis being 5. Thus the plat follows the general plan of an indexed map, so that any particular stake is designated by a letter and a number, for example, G4. The stakes, totalling 117, which can readily be made from ¾ inch dowel, are prepared in advance. Each stake has marked on it its designation by letter and number as well as the distance of the intersection which it marks from the shooting position. For example, "J3" may be lettered on the top end, and the distance (626 yd., 2 ft.) on the side, near the top.

In the appended table I will be found the precise location of

LINE	4 and 6 Feet	4 and 6 Inches	3 and 7 Feet	3 and 7 Inches	2 and 8 Feet	2 and 8 Inches	1 and 9 Feet	1 and 9 Inches
A	42	10.3	85	9	128	7	171	5
B	45	6.4	91	1	136	7	182	2
C	48	2.6	96	5	144	8	192	10
D	50	10.7	101	9	152	8	203	7
E	53	6.9	107	2	160	9	214	4
F	56	3.0	112	6	168	9	225	0
G	58	11.1	117	10	176	9	235	8
H	61	7.3	123	3	184	10	246	5
I	64	3.5	128	7	192	10	257	2
J	66	11.6	133	11	200	11	267	10
K	69	7.7	139	3	208	11	278	7
L	72	3.8	144	8	216	11	289	3
M	75	0	150	0	225	0	300	0

TABLE I
DISTANCES OF STAKES FROM AXIS ALONG PERPENDICULAR (LETTERED) LINES

each stake. Its distance from the shooting position is given in table II. From this table it is seen that any arrow which falls in the zone between lines 4 and 6 may be measured along the axis to the intersection of its perpendicular with the axis, such as RV where R represents the arrow, without introducing an error greater than 1 foot.

Assuming the field to have been laid out as suggested, the process of determining the distance of any particular arrow becomes simple. Suppose P represents an arrow whose distance is to be measured. The number and distance of the stake nearest

	5 Yards-Feet	4 and 6 Yards-Feet	3 and 7 Yards-Feet	2 and 8 Yards-Feet	1 and 9 Yards-Feet
A	400 - 0	400 - 1	401 - 2	402 - 2	404 - 0
B	425 - 0	425 - 1	426 - 2	428 - 0	429 - 1
C	450 - 0	450 - 1	451 - 2	453 - 0	454 - 2
D	475 - 0	475 - 1	476 - 2	478 - 0	479 - 2
E	500 - 0	500 - 1	501 - 2	503 - 1	505 - 0
F	525 - 0	525 - 1	526 - 2	528 - 1	530 - 1
G	550 - 0	550 - 1	551 - 2	553 - 1	555 - 2
H	575 - 0	575 - 1	576 - 2	578 - 1	581 - 0
I	600 - 0	600 - 1	601 - 2	603 - 2	606 - 1
J	625 - 0	625 - 1	626 - 2	628 - 2	631 - 1
K	650 - 0	650 - 1	651 - 2	653 - 2	656 - 2
L	675 - 0	675 - 1	676 - 2	679 - 0	682 - 0
M	700 - 0	700 - 1	701 - 2	704 - 0	707 - 1

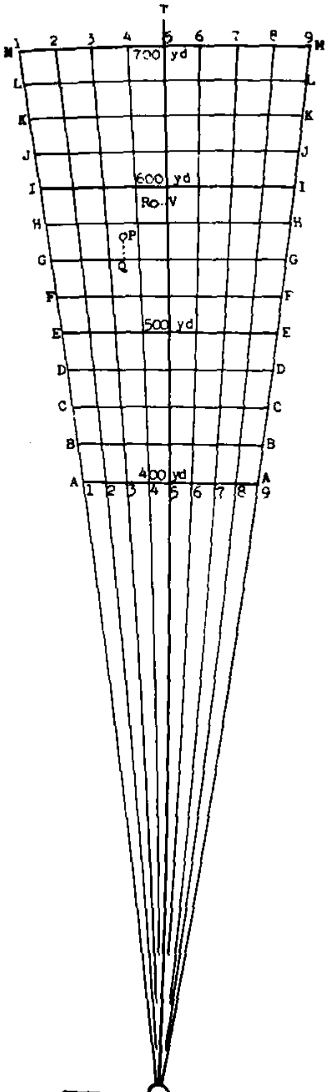
TABLE II
DISTANCES OF STAKES FROM SHOOTING POSITION

the shooting station in the unit area in which P has fallen is recorded. In this case it would be G4, the distance of which is 550 yards 1 foot. Four persons do the measuring, two of whom have an ordinary line which is stretched between G4 and G3. The other two with a tape line measure the distance PQ, approximately parallel to line 4, and add this distance to that recorded on stake G4. It is not required that PQ be exactly parallel to line 4 since small variations from parallelism introduce no appreciable error. Strictly speaking, the distance, of course, is SP, but the direction of line SP is virtually the same as the direction of line 4. This would be true of any arrow in any of the fields of the grid. In measuring with the line, inches are disregarded if the number is less than 6 (or less than .5 foot on a surveyor's tape) from the nearest lower 1-foot mark; if greater than one-half foot, the next higher 1-foot reading is taken.

If for record purposes it is desired to have a double check, the distance from P to each of the "near" corners G3 and G4 is measured and recorded. This locates P within its area of the grid, and from the measured values the distance can readily be computed with accuracy, or found graphically by means of a plat laid out to scale on a drafting board.

To lay out the field, start with locating the axis, and, if desired, marking it with lime. On this line, number 5 in the plat, drive the previously prepared stakes A5 to M5, inclusive, at 25-yard intervals, *as accurately measured as possible*. Use a 100-foot surveyor's tape. At these intervals, lay out the perpendicular lettered lines, and drive stakes as indicated in table I. These lines should be accurately perpendicular to the axis line. This can be done by the "3–4–5 method", utilizing the fact that a triangle with sides of these relative lengths is a right triangle. As a convenient guide, the stakes along the axis line 5 may be painted with a red band around the top, and those along the lettered lines, particularly the 100-yard lines, with other colours. The stakes should be long enough to be readily visible. If set carefully according to table I, they will be in accurate alignment in both lettered and numbered rows.

My own consideration of the problem, fortified by con-



Measuring the perpendicular distance from the arrow to the axis.

sultation with experts in surveying, convinces me that the method proposed comes near being the simplest and most accurate that can readily be employed by the layman. Although the so-called stadia or telemeter method employed in surveying would be faster and would not require advance preparation of the field, its accuracy is hardly better than 1%, which would mean an uncertainty, at 500 yards, of 5 yards, or 15 feet. Its use seems to be limited to distances up to about 300 yards, with the accuracy indicated. The next best method would be to use two transits with a base-line, laid out on the shooting line, of several hundred yards, with the shooting position either at one of them or midway between them. But this would require accurate measurement of angles and logarithmic computation—activities not easily carried on in the excitement and confusion of a tournament. Besides, we had already ruled out surveying instruments at the outset; and the only excuse for mentioning them once more is to clinch the idea that they have no place in the flight shooter's equipment.

INDEX