Title: Fly reel, a study in integrated system design.

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Thesis submitted to the faculty of Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Master of Science Architecture concentration Industrial Design.

Accepted by:

William Green, Chairman

Robert Schubert

Mario Cortes

Abstract

Roby S. Williams

While enjoying a passion for outdoor related sports, I had taken an interest in the equipment I used while hunting and fishing. I was fascinated by the precision of the instruments I used to optimize my time spent in the field. This curiosity led to some preliminary designs to further enhance my outings. The joy I received from these projects led me to pursue industrial design as a profession.

As a student, I chose to design a product that related to the fishing industry. I selected to design a fly reel for its links to other fishing reels and man's interaction with water. This required a critical analysis of current fly reels and how to enhance its current design. To accomplish this I modified select mechanical elements of the reel. This involved, in some instances, new materials and incorporating different processes to achieve my goal. The innovations I incorporated allowed the reel to be used while fishing for a wider spectrum of fish than the typical fly reel. This flexibility reduces the need to purchase additional reels to pursue different size fish. This has the potential to provide a savings to the consumer and encourage them to fish for a species of fish they would otherwise neglect. In addition to my primary objective, I want to contribute a product that will be an asset to the fishing industry with attention to aesthetics, value and ease of use.

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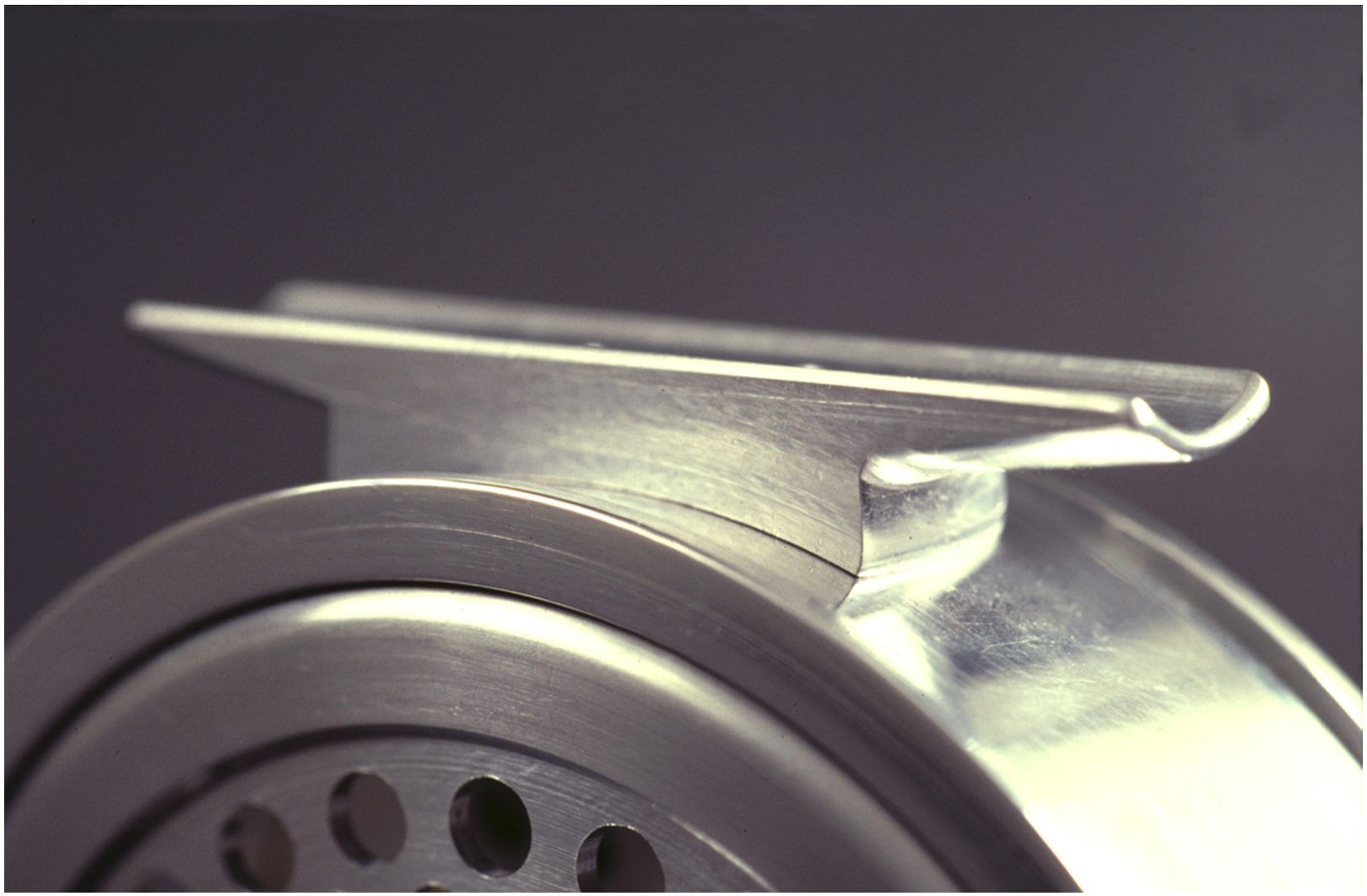
Acknowledgments

I am thankful to my family and friends who allowed me the latitude to investigate my own dreams and interests. Having grown up in Radford, Virginia I was drawn to the natural beauty the New River Valley offers its residents and visitors. My explorations into nature led to many wonderful discoveries on the New River. The result of my experiences is reflected in this thesis paper.

Introduction

Before I was aware of the existence of the industrial design profession, I began designing equipment for my personal use while enjoying the outdoors. Years later, as time approached for me to choose a subject for a thesis research project, I employed the advice of my academic instructors who encouraged my classmates and me to choose something we loved when selecting a thesis project. After considerable thought, I followed what was a natural path for me; this was to design a sports related product that could be used in the outdoors. I was compelled to explore a product relating to the fishing industry because it reflected my love for fishing as a means of recreation and sport.



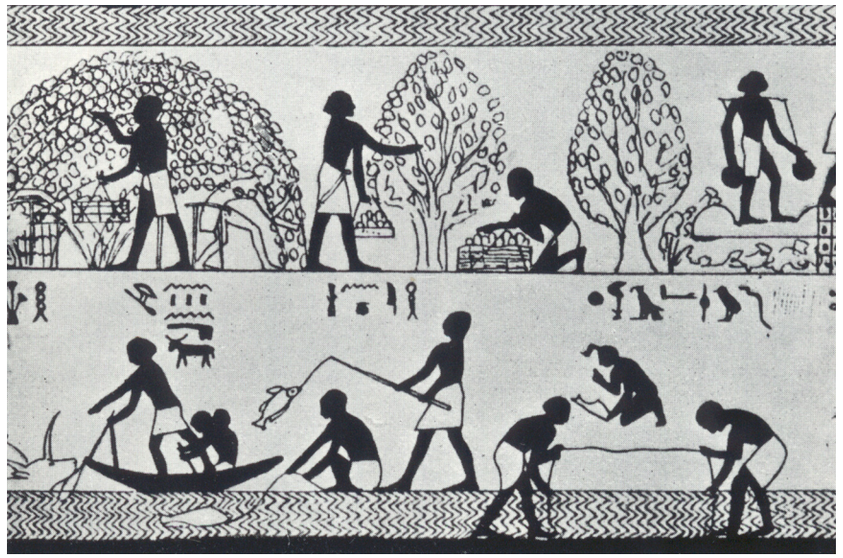
Design Intent

It is the goal of my thesis project to substantiate my past activities and ideas as a viable direction within the industrial design field. This objective has led to an original fly reel design. The project incorporates several new features allowing anglers to pursue wider varieties of fish while reducing the need to purchase additional reels.

Historical Information

Through the course of researching and collecting information on the ancient subject of fishing, I found numerous volumes covering this topic and it's diverse methods. My main objective was to approach this mountain of data from a historical perspective. I was seeking information focusing on ancient methods, techniques and artifacts. This greatly assisted me in sorting a vast amount of material, which did not directly relate to the scope of my research.

1-3 **Ebisu a Chineese diety always shown holding a fishing rod**



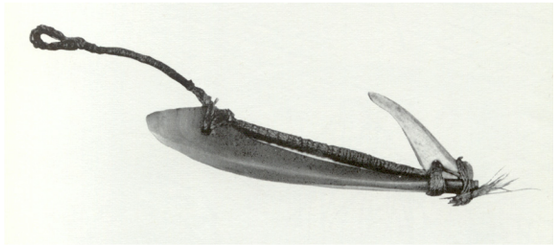
1-1 **Earliest representation of rod used for fishing painting by Beni Hassan 2000 B.C.**

1-2 **Earliest representation of a rod and reel combination painting by MaYan c 1195**

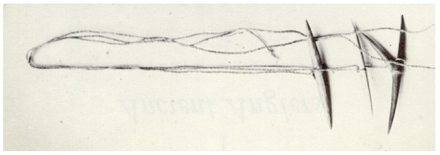
As these historical studies continued, I observed a trend. As I became closer to the historical origins of fishing, there were limited quantities of information, which had survived the ravages of time. This became evident as noted sources began covering the same material. Similar to those who are waiting on the discovery of Atlantis, curious fishermen and I must wait to see the treasures and links to our past uncovered by archaeologists in the future.

The significance of fishing has been well documented through the ages. The desire to catch fish for sustenance or leisure has created a need for the tools required to effectively optimize time spent to catch fish. Today this endeavor has generated a multi billion dollar commercial industry.

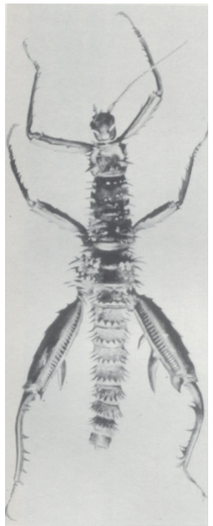
2-1. Early Egtptians using fish hooks for barter

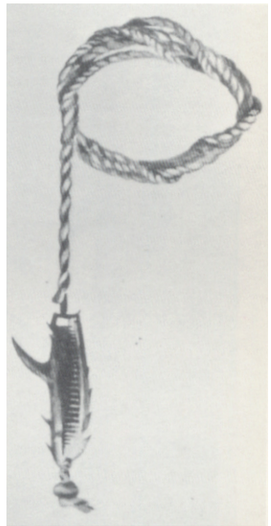


2-2. **Flint fish hook**



2-3. **Gorges made from bone, close up view**





2-4, 2-5. **Fish hook made from insect leg segment**

2-6. **Neolithic fish hook found in Normandy, France**

Fish Fact:

According to the latest U. S. Fish and Wildlife Service survey conducted in 2001.

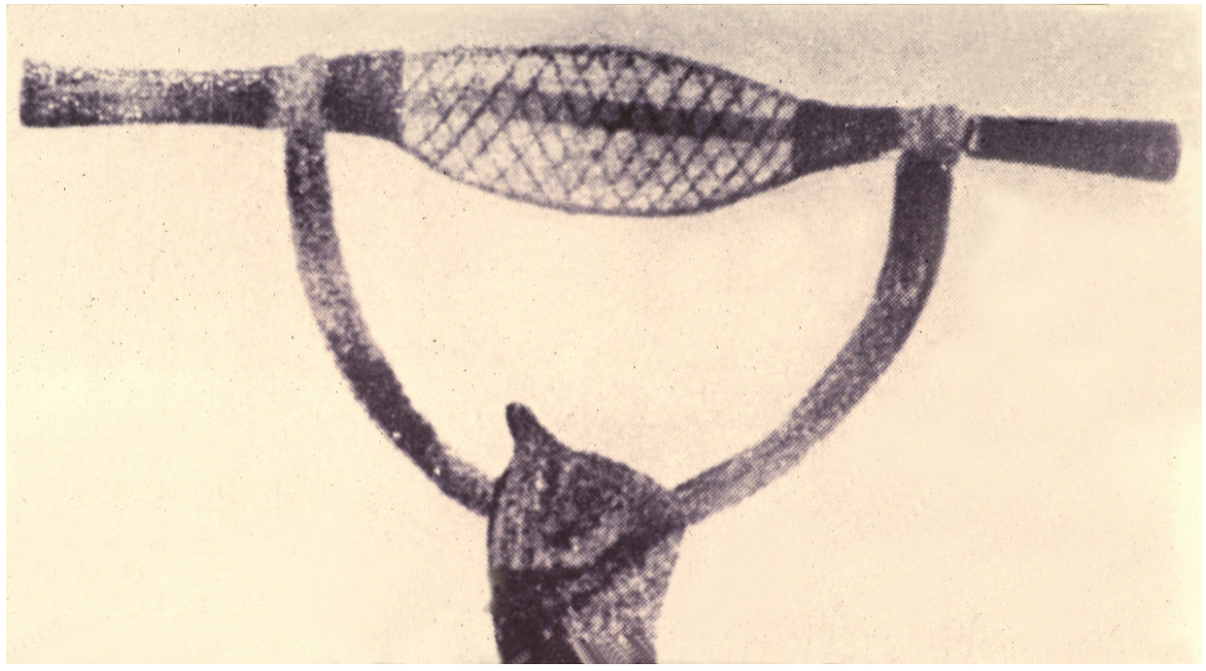
Over 34 million people go fishing annually.

Anglers spent $14.7 billion for fishing trips and $17.0 billion on equipment; $4.0 billion is spent on license fees stamps and tags.

Each participant spends an average $1,046 per year.

28.4 million anglers prefer freshwater fishing and 9.1 million people choose saltwater fishing.

During the process of filtering this historical material, one discovery proved to be a pivotal point in my research: the oldest representation of a reel. This reel was used by Egyptians 3,500 years before the earliest known representation of a rod and reel combination.

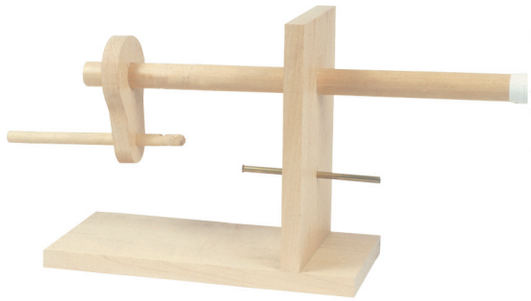


3-1. **Egyptian reel image**

Spinning Reel

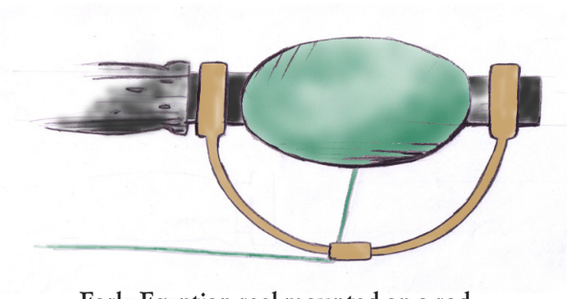
From the moment I made the decision to design a fishing reel I began to gravitate toward my own experiences within this subject. Being familiar with contemporary fishing reel styles, such as spin casting, spinning, bait casting and fly reels, I felt compelled to design one of these types of reels. My understanding of these different reels allowed me to see a connection between their defining elements and the ancient Egyptian reel. This connection inspired me to begin the initial ideation.

These sketches highlight the design evolution, with respect to the similarities of an ancient and modern fishing technology. This study also illustrates a direct correlation between the ancient Egyptian reel and the current spinning reel. I began to focus on the spinning reel as a viable thesis project. This led to some interesting preliminary designs and study models.

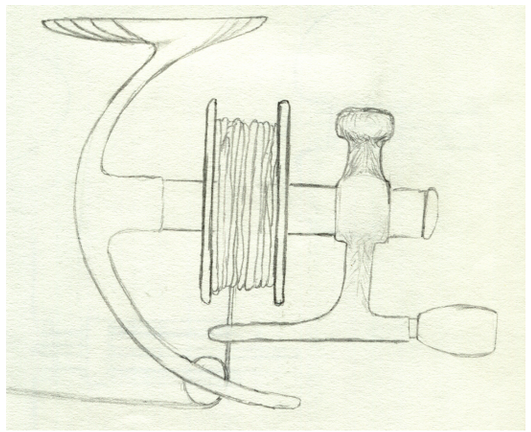


Wooden model proving failure of fixed spool concept

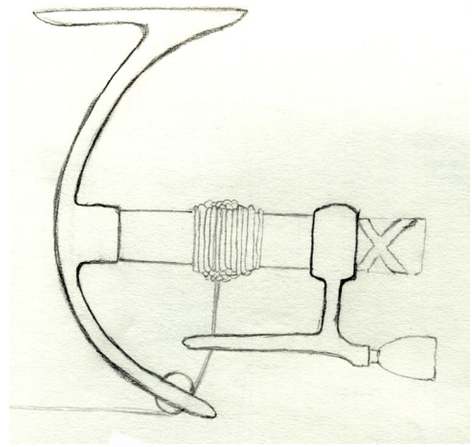
Photoshop renderings of reel concepts



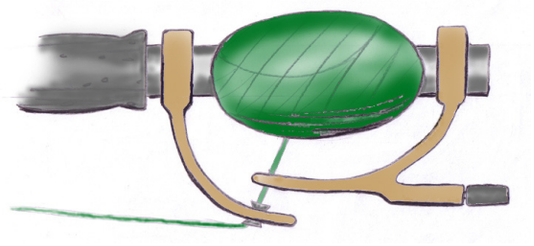
Early Egyptian reel mounted on a rod



Fixed spool concept 1

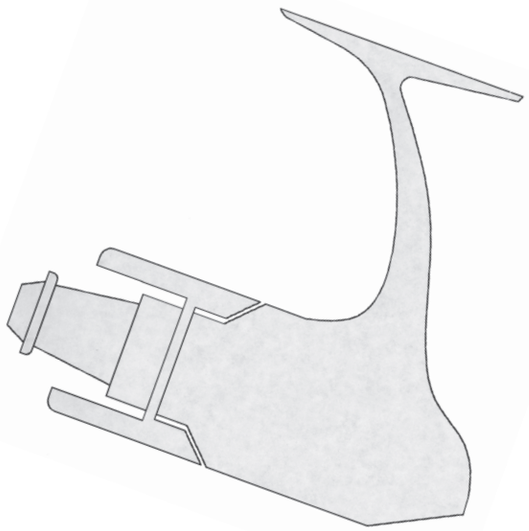


Fixed spool concept 2

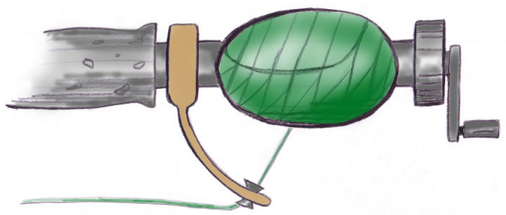


Modified Egyptian reel

Sketch exploring ergonomic possibilities



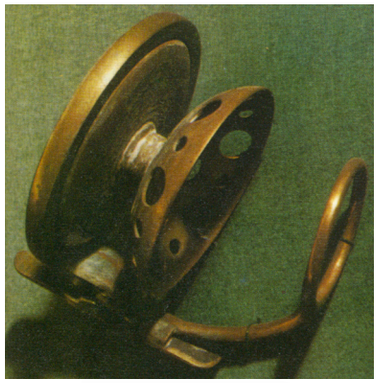
AutoCad drawing of spinning reel concept



Sketch progression towards modern fishing reel

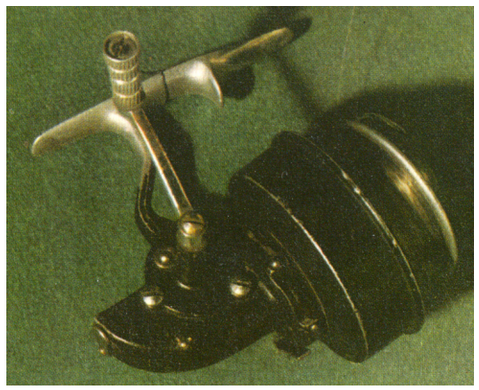
One of the goals of this thesis project was to achieve a design which could be constructed with the tools available to me as a student. As an industrial designer my main objective was to create an effective design; this would include ergonomic and aesthetic qualities such as form, fit and finish of the chosen materials. I would also be required to make decisions about feature levels and the price range of a proposed design in the market place. The more I studied my design of the spinning reel, the more I realized my design was better suited as a fly reel. This led me to narrow the focus of the thesis towards the design of a fly reel.

Earliest Fixed Spool Reel

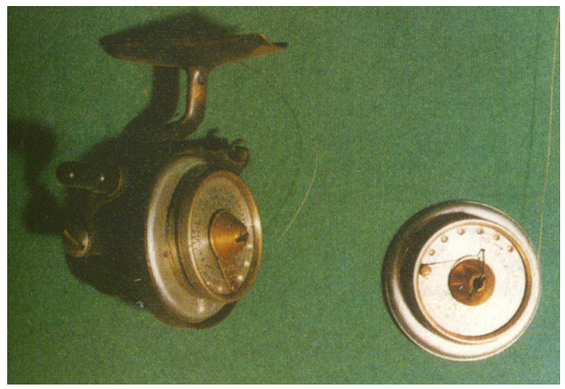


5-1. Malloch fixed spool reel, casting position

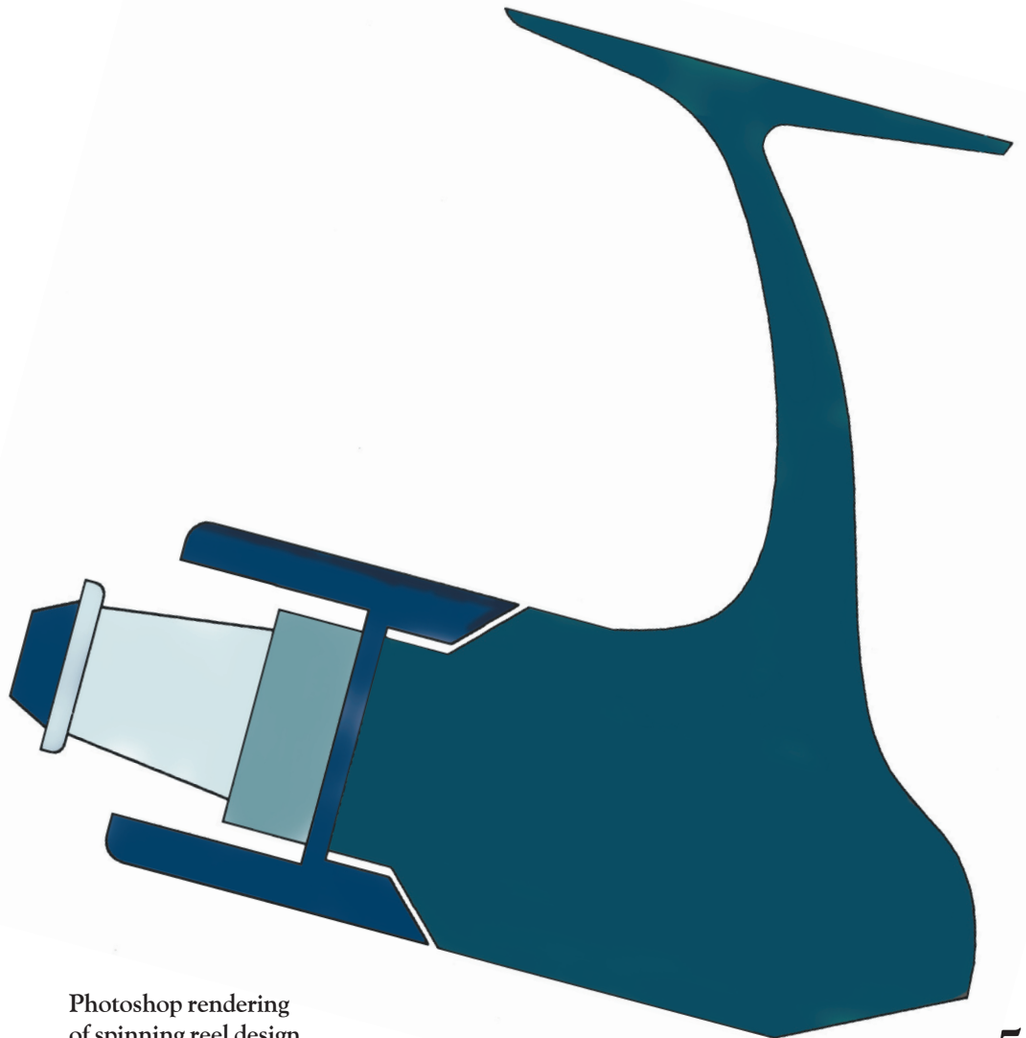
5-2. Malloch reel, reeling position



5-3. Early spinning reel, with ergonomic reel seat



5-4. Spining reel, note addition of spare spool and hook for winding line



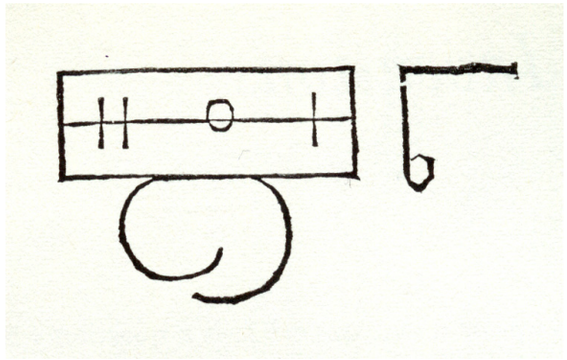
Photoshop rendering of spinning reel design

Fish Fact:

The first book written on the subject of entomology for trout fishing The Fly Fishers Entomology was written by Alfred Ronald in 1836.

Observation

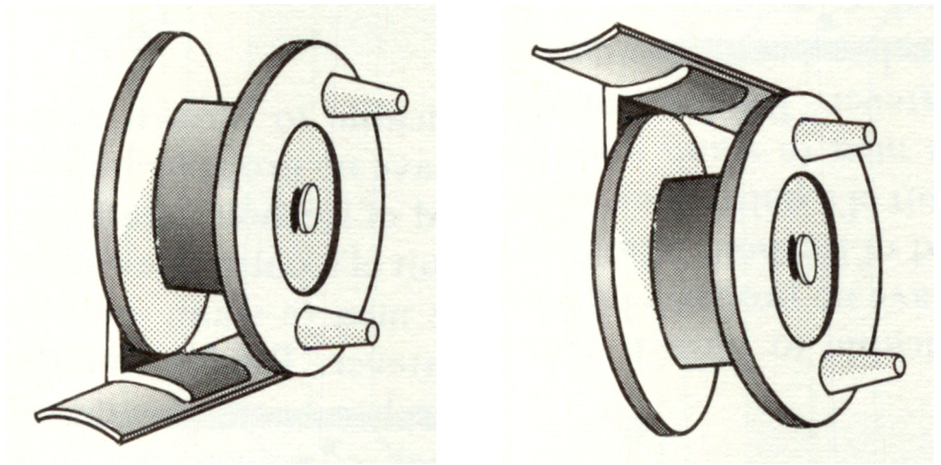
Examination of fly reels both old and new revealed characteristics, which have been maintained as basic elements since the fly reel was first invented. Recent advancements have occurred with the incorporation of an ever-changing mix of materials and technologies previously unavailable. These advancements include complex drag systems, ultra lightweight metals and precision bearings. The research of historical and modern fly reels inspired several decisions concerning the design of my fly reel.



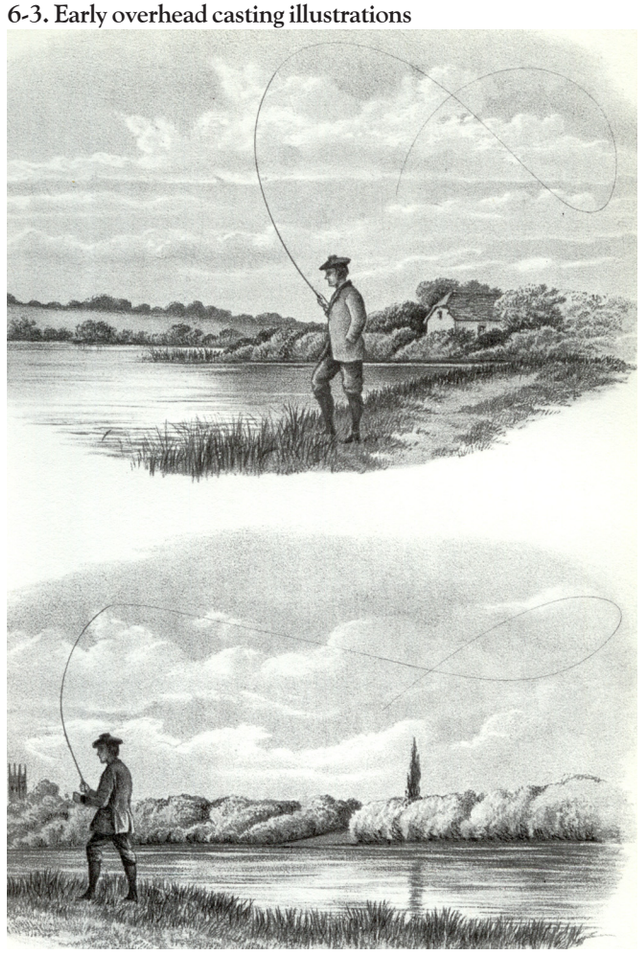
6-1. **Winder reel, first illustrated in 1657 in Thomas Barker's "the Art of Angling"**

6-6. Old fly reel made of wood

6-2. **Multiplier reel, early centerpin reel. Note same image on right when mounted on bottom side of rod the reel has the same appearance as a fly reel**



6-3. **Early overhead casting illustrations**



6-4. Modern casting techniques

6-5. Modern overhead casting

Design Analysis

The following is a critical analysis of the fly reel. I observed three distinct regions within the fly reel: the body of the reel, the shaft on which the spool rotates, and the spool itself. These three elements comprise a common denominator of a simple reel. Another element such as the drag system is not a necessity; however, it dramatically improves the performance of the reel. The next step was to study each of these elements separately by observing their functions and exploring their possibilities. Through the exploration of these key elements, I was able to see the fly reel on a rudimentary level. Once I was able to examine the fly reel on such a basic level, I began to view it as a simple reservoir of fly line supported by a main reel body.

Shaft located in reel body

Stainless Steel Shaft

Final drag mechanism with bearing

Design Goal

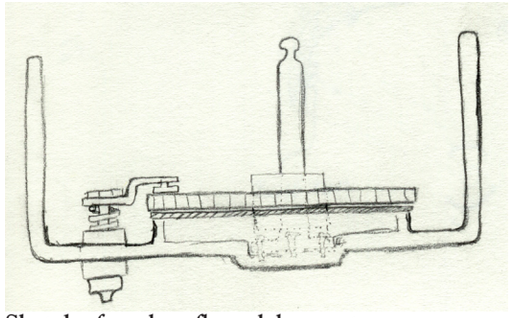
Through the exploration of the many configurations a fly reel can assume, I found a direction the fly fishing industry has yet to examine. This is the diversification of the fly reel that I chose to explore as the goal of my thesis paper. The objective of designing a fly reel which has multiple spools that attach to the same reel body is, to enable the angler to pursue different sizes of fish while using the same reel. The advantage of multiple spools is eliminating the need of different reels in order to adapt to diverse fishing conditions. Though this option is currently available, I believe this feature may be enhanced by my design. In order to accomplish this goal, I have chosen to manipulate the size of select mechanical members, which are crucial to the function of the reel. These changes will allow the reel to meet the demands that a larger fish places on a fly reel. This will be done while maintaining a respectable weight and size for smaller fish.

Drag System

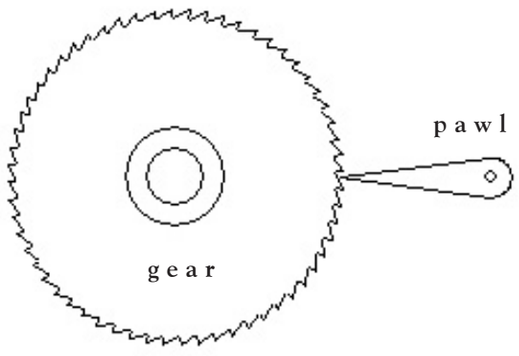
During the course of my research, the study of different fly reel mechanisms became necessary. Through this research I observed the trend of using the drag system as a means to define quality among fly reels. The higher the quality of the reel, the more involved the drag system became. These drag systems not only differ in the way they operate, but also in the type of material used within this system.

One common method of making this drag system operate is a clicker and pawl mechanism. In this system, a gear is attached to the spool, and a pawl is attached to the reel body. The pawl allows the spool and gear to revolve with minimal resistance until the direction of the spool is reversed. At this point, the pawl is engaged in the gear. The amount of tension placed upon the pawl determines the amount of drag on the spool. This system is referred to as a clicker because the gear and pawl make a clicking noise as they come in contact with each other. A different clicking sound is heard as the spool changes direction.

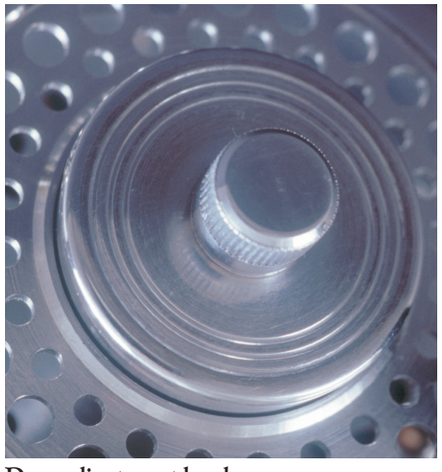
More complex drag systems do not rely on the clicker and pawl system to activate their drag. These systems use components, which are more technically advanced and accurate, such as precision bearings, and use advanced anti-friction materials in their braking mechanism. While creating a drag that operates smoother and more efficiently than their predecessors, the use of technologically advanced components has resulted in a marked increase in the performance and price of fly reels.



Sketch of modern fly reel drag system



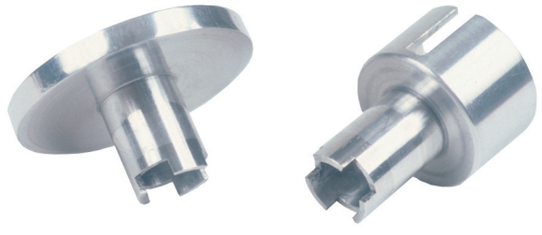
Clicker and pawl system
expanded view



Drag adjustment knob

Early two pronged
drag mechanism

Two pronged drag
mechanism assembly



Final three pronged drag
activator

Designing the drag system for this project was a difficult and time consuming process. There was a recurring problem that I felt was crucial to the function of a fly reel. How could the spool turn freely in one direction and then have drag on it when the rotation was reversed? To overcome this problem, I focused on a basic requirement which I used as a design parameter: free spool when reeling, and drag when the spool reverses direction. To solve this design problem, I studied anti-stop features and mechanisms in other types of fishing reels. I learned that clutch bearings provide this desired feature in spinning reels. I adopted the use of clutch bearings as a means to overcome this problem.

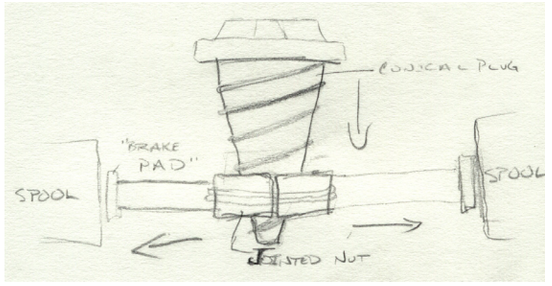
The drag system relies on a braking media to provide the friction to slow the turning of the spool. The angler can control the amount of tension on the drag by turning the drag adjustment knob. This reel has a wide range of drag tension available, which can easily be adjusted. I chose to use successive layers of teflon washers as the media at this point for its anti-friction properties. The amount of force needed to initiate the drag in a fly reel needs to be very low to prevent breakage of the fragile tippet line material.

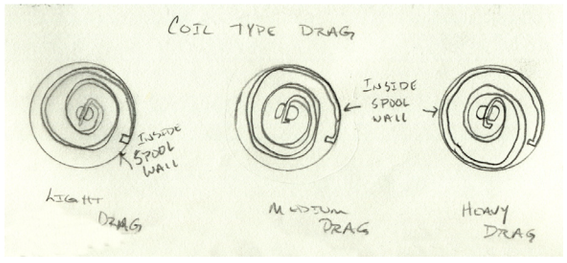
I was able to show my reel to several leading authorities in the fly fishing industry, most notably Lefty Kreh. He encouraged me to find a more advanced drag washer material like graphite impregnated teflon. After discussing my reel with professional fishing guide and fly reel designer Norm Bartlett, he agreed with Mr. Kreh and donated some of this drag material for me to use in my fly reel. Changing to this new drag material dramatically improved the performance of the drag system. It significantly lowered the force needed to initiate the operation of the drag.

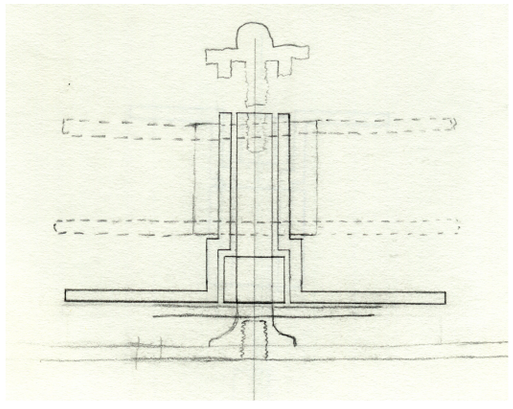
Fish fact:

After showing my reel to fly fishing authority, Lefty Kreh he stated "That's a pretty good idea, but don't get your hopes up kid."

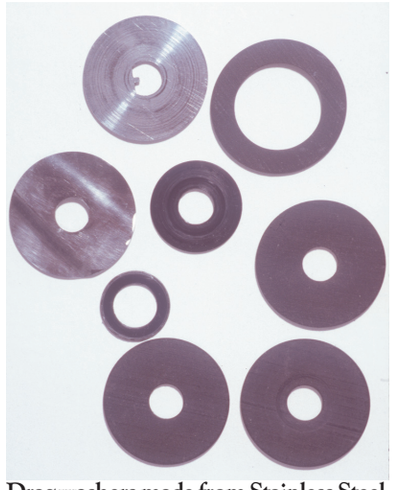
Early drag sketchs







10-1. Lefty Kreh



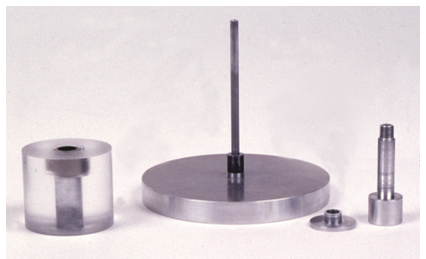
Drag washers made from Stainless Steel and Graphite impregnated Teflon

Early prototype bearing sleeve with clutch bearing

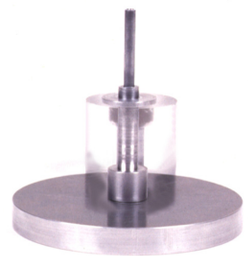
Final bearing sleeve with clutch bearing

Bearing System

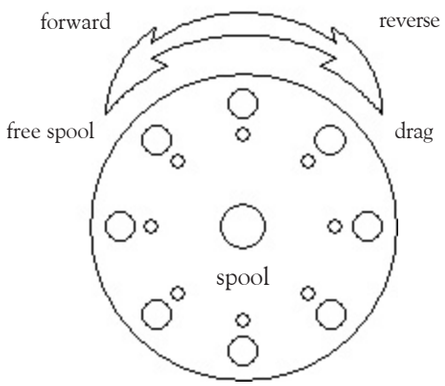
The integral part of this reel is the bearing system. This system allows the reel to operate efficiently and smoothly. The incorporation of two clutch bearings creates a seamless interchange from reeling to the activation of the drag system. This interchange takes place by having the two clutch bearings working against each other. When one bearing is in a locked position the other bearing is in the unlocked or turning position. By having one clutch bearing mounted into the drag mechanism, it allows the drag to operate or turn in one direction. The other clutch bearing is press fit into the spool. While winding in line, the bearing inside the spool is unlocked, and the spool rotates without drag resistance. When a fish takes out the line, the rotation of the spool is reversed, and the clutch bearing inside the spool will instantly lock. At the same moment this locking occurs in the spool, the clutch bearing inside the drag mechanism instantly disengages. This allows the spool to reverse directions, activating the drag system. This dual-clutch system allows the angler to reel in line without having to overcome the resistance in the drag system.



Prototype model to test bearing system

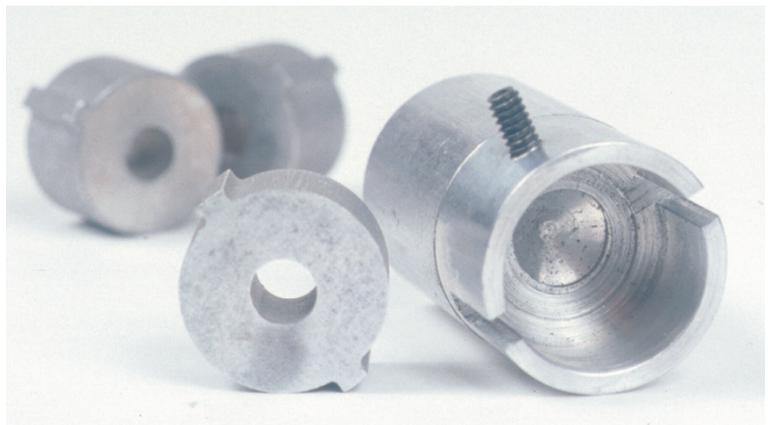


Prototype assmebly with clear acrylic spool

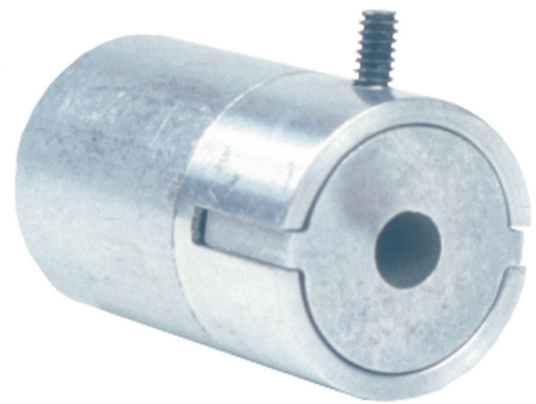


Spool diagram

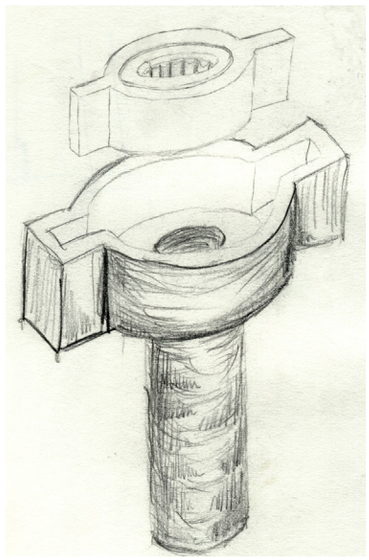
Torrington clutch bearings



Fixture for machining bearing sleeves and inserts



Bearing fixture



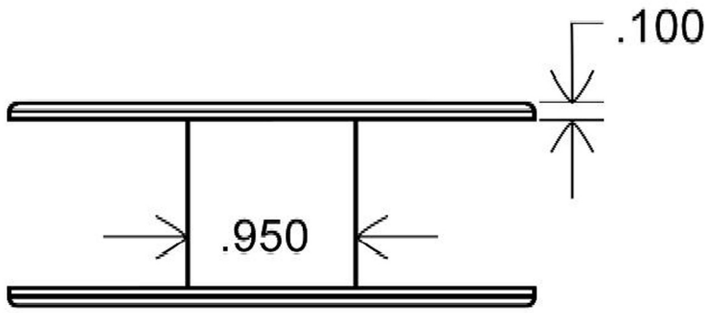
Concept drawing of bearing sleeve and drag activator

The Spool

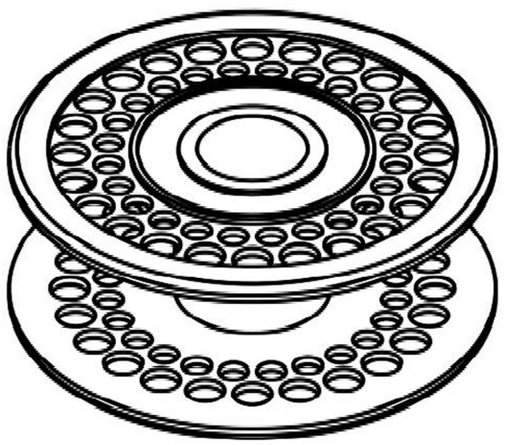
When viewed strictly as a reservoir of line, the fly reel has requirements placed upon it by the size of the fish one desires to catch. A large fish can make long powerful runs that remove large amounts of line, thus requiring a large spool. A small fish that only removes a small amount of line will only require a small spool. This illustrates the relationship between the size of the spool and the size of the fish that is desired. The reel I have designed has the capability to accommodate these requirements by changing spools as the circumstances dictate.

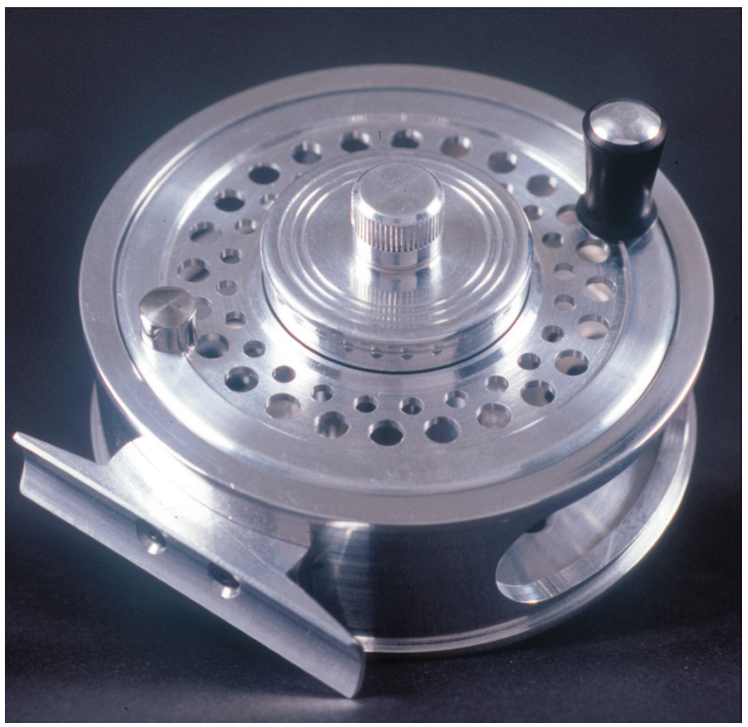
When the spool is first seen a pattern of holes machined into the spool is noticed. On this level, the holes provide aesthetic quality for the spool. Two more functions the holes provide that deal with the function of the reel are reducing the weight of the reel and providing a means for the line to dry. When combined, these three factors contribute to the overall appeal of the reel as a product.

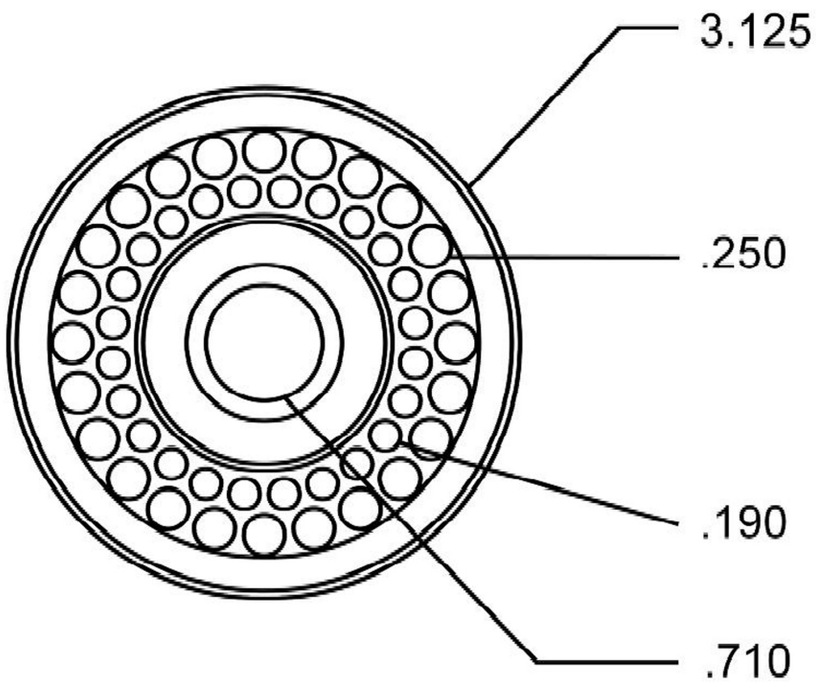
The spool for this fly reel contains many intricately machined holes located in exact positions. This contributes to the relationship between the spool and reel.



Drawings of spool created with SolidWorks







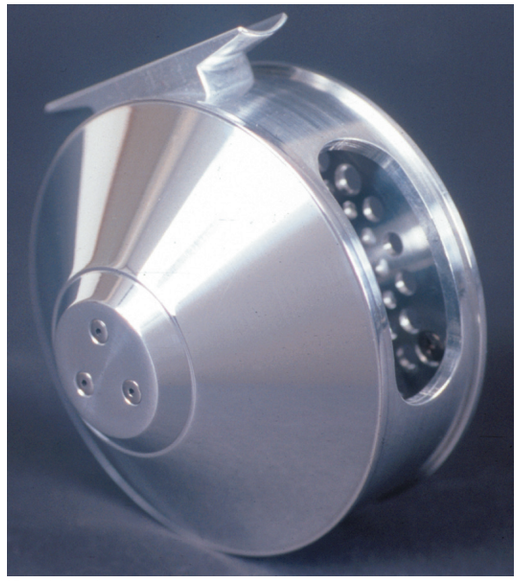
Reel Body

The form of the reel body provides a signature aesthetic for a reel. The body also defines the size and limits of the reel. I used the main design parameter to determine the size of this reel.

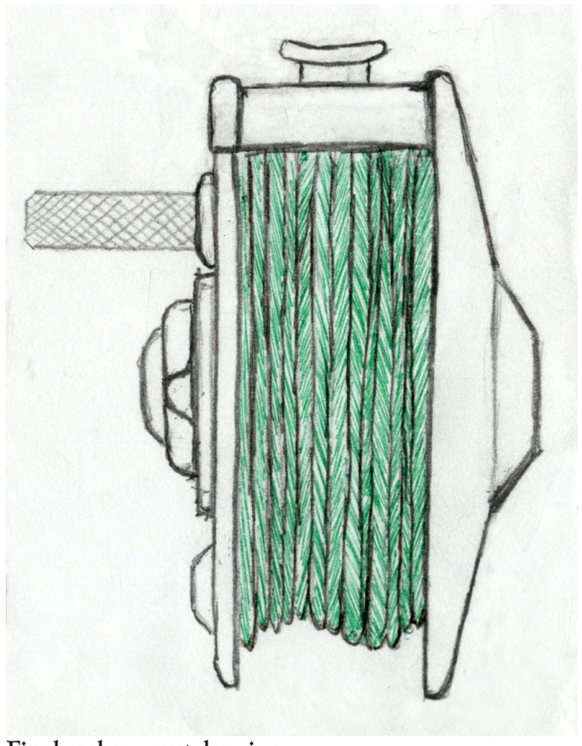
The design of the reel body is a combination of reflection and function. The body reflects the form of the spool in the two rings that surround the exterior of the body. The width of these rings is of the same thickness as the spool body. The height of the rings is also the same as the thickness of the body of the spool. The dimensions between the two rings and the width of the spool are the same. The conical formation on the backside of the reel body was designed to be an ergonomic and aesthetic means to functionally cover and protect a portion of the bearing system.

A common means of protecting aluminum fly reels is to anodize them. Anodization is a protective electro chemical process that provides a tough scratch resistant finish in a variety of colors. Removing as many blemishes as possible allowed me to attain the high level of finish. To accomplish this it was necessary to use a variety of abrasive grit sanding papers. These sanding papers become finer in grit throughout the sanding process. The final finish was attained by using a polishing compound for metals. This brought the shine to a near mirror finish.

Hand formed taper on reel seat



Reel back



Final reel concept drawing

Reel front

Fish fact:

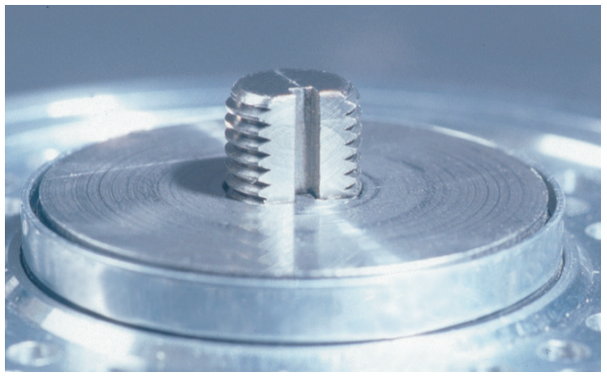
After viewing my reel Dale Karr, reel designer with fishing tackle manufacturer Shakespeare, he stated, "We can't make that, it is beyond our high end product."

The Shaft

The shaft performs two important functions. It is both the central axis of the reel and the support for the spool. When first considering the design of the shaft, I was concerned with the strength requirements. The shaft needed to be as strong as the largest fish with which the reel could be matched. A diameter of .375" was chosen for the shaft because it could withstand the stress a large fish could place on a fly reel. The shaft was made of stainless steel to provide extra strength and protection against wear. It was attached to the reel body by three 2-56 flat head stainless steel screws. A small post was machined onto the base of the shaft to locate and seat the shaft on the body of the reel. Precise machining was needed to ensure the shaft would move as little as possible. This was necessary, due to the extremely tight tolerances maintained throughout the machining process. A tolerance of less than .0005" was attained here.

The threaded portion of the shaft continued to display the diversity needed to ensure the proper function of the reel. The threads provide a means to adjust the tension for the drag. The notch and flat on the machined section of the shaft allow the drag to operate smoothly. A problem became evident during the model building phase. As the spool turned the drag adjustment knob also turned. This caused the knob to tighten with each turn of the spool. The problem was solved by placing a non-rotating washer, matching the profile milled on the end of the shaft, between the drag adjustment knob and the drag material. The washer does not rotate as the spool rotates due to the washer being cut to match the shape of the shaft. This prevented the drag adjustment knob from turning as the spool turned, but it created another problem. How could a precise washer be made? A cutting machine that used a combination of water and an abrasive aggregate as its cutting medium presented a solution. A water jet cutter was used for this important part. A water jet has the capability to make intricate cuts in most materials in a cost effective manner. Stainless steel was chosen as the material for its strength properties. Such a washer would allow the drag adjustment knob to function independently from the rest of the reel.

Bottom view of shaft showing registration post



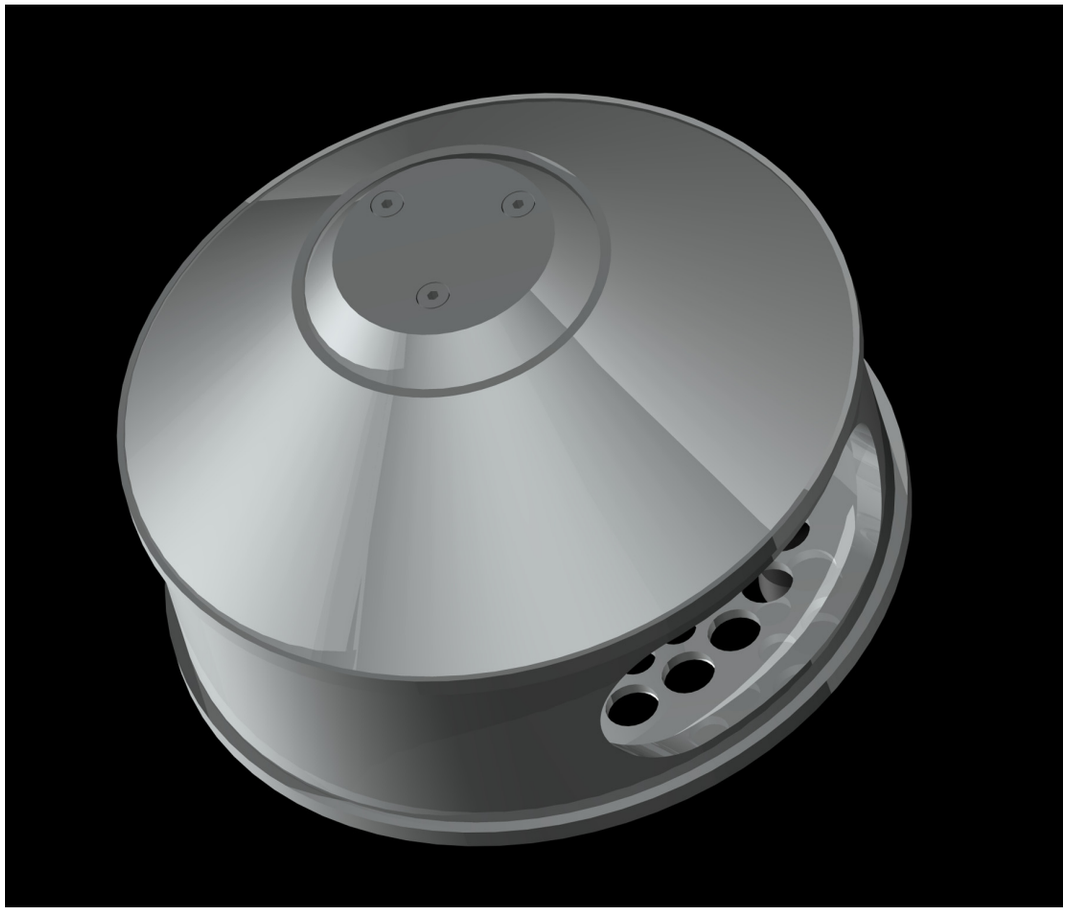
Machined keyway in shaft showing drag plate cut with a water jet cutter

Fly reel prototype mounted on fly rod

When the shaft and other periphery elements are assembled, they collectively create a fly reel. This reel, or self-contained system, has been a labor of love in both the design and building phases.

Renderings

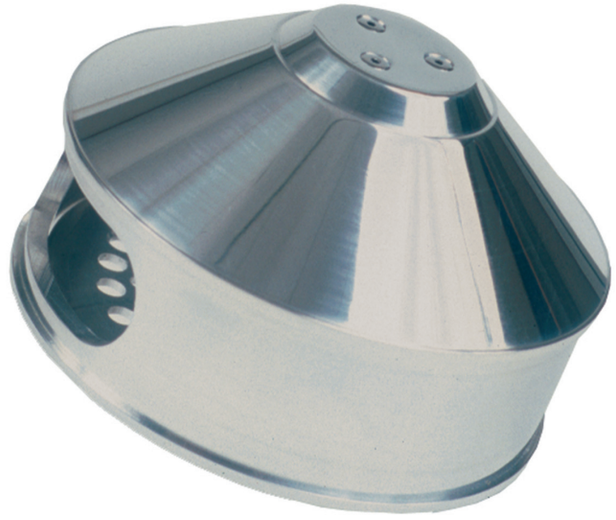
SolidWorks renderings



Conclusion

Contained within this fly reel are different elements that, when assembled, create a closed system. The elements in this system directly affect each other simultaneously. Making changes to one element was the most challenging task during the design phase of this project. When one element was altered, the reaction of this change had to be anticipated throughout the other elements in the reel. This reaction had to be judged on its level of functionality.

To visualize these characteristics, I needed to build a working prototype. I did not have the resources to have a rapid prototype constructed utilizing industry standards such as stereolithography, fused deposition modeling, or computer numeric control machining. I was left with the alternative of making the prototype in various metals via conventional machining techniques. The importance of this prototype proved to be immeasurable. It allowed me to critically analyze the reel and how its different subsystems operate together. By objectively testing the reel with regards to the main design goal, I was able to see the strengths and weaknesses in my design. The project as a whole was both rewarding and thought provoking.



The reel has received many kudos on its appearance and performance from fishing reel manufacturers, Penn Reels and Shakespeare, to fly fishing authorities, and enthusiasts. Professional machinists have made positive comments about the attention to detail and tight tolerances achieved and maintained throughout the reel. Building a prototype revealed facets of the design that warrant further study, which include the lack of additional spools, as well as, weight and minor ergonomic issues. The prototype also communicates positive elements such as the seamless transition between reeling and the activation of the drag system. The inclusion of clutch bearings in this system allows the reel to function smoothly and consistently.

Building upon the knowledge attained from this project, I have been driven to pursue more advanced fly reel designs. These designs would be available in the nation's largest fishing tackle retailers, such as Bass Pro Shops, fly fishing specialty shops, and retail outlets around the country. The ability to choose materials and manufacturing processes allows the products to be marketed in various price ranges and to anglers of various skill levels. This enhances the overall exposure of the product and permits anglers to advance to more technical equipment as they progress with additional skills. Through this design I have strived to maintain quality, without compromising affordability.

This project has been the culmination of my goal as a fisherman, student and practitioner of industrial design.

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