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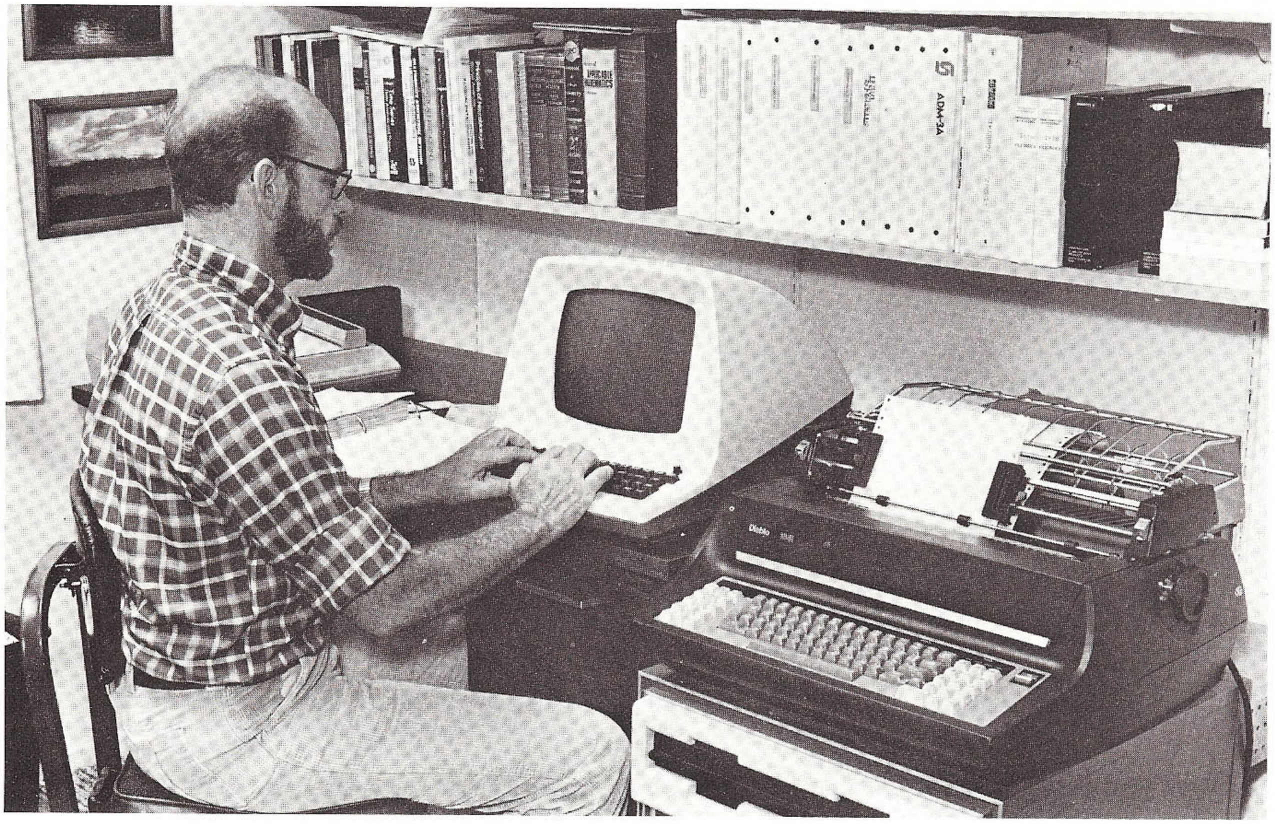
Author and the LSI-11 computer system used for the fly line analysis. Regrettably, few fish are impressed by computers.



Sink Rates of Sinking Lines

By James W. Havstad

I began to study the sink rates of sinking fly lines when I noted that some of my friends carried in their vests, and used, an astonishing number of types of sinking fly lines, and these same friends generally caught far more fish than I did. My study has provided experimental data about sink rates and a theoretical analysis to explain the experimental data, but it has not had all the hoped for effect on the problem of catching fish. Despite this disappointment, the study has provided certain benefits. I can now select the line types needed to cover a range of sink rates, even in the absence of any standards on sink rates. I no longer have to depend upon manufacturers' descriptions, which have previously caused me to buy near-duplicates of some lines and to leave large gaps between the sink rates of others. Another benefit is the realization that lines rarely sink as fast or as deep as I and many other fishermen have thought. And I have found the physics of the sinking process to be surprisingly complex and interesting, adding another aspect to my enjoyment of fly fishing.

A DEFINITION OF SINK RATE

It is difficult to define the sink rate of a tapered fly line, or of any line in moving water, or of a line being retrieved in still water. For any of these conditions, different parts of the line sink at different rates, and the sink rate of each part is constantly changing. There is a particular condition, however, in which the sink rate of at least a part of a line is stable so that it can be defined, measured and analyzed. This is when a horizontal level section of line is allowed to sink undisturbed in still water. If the level section is from the belly of a conventional sinking fly line, the sink rate in still water is the maximum rate any part of the line will have in any normal condition of use, such as when sinking in moving water or while being retrieved in still water.

Unless otherwise indicated, "sink rate" in this article means the maximum sink rate of a level section of line sinking undisturbed in still, fresh water. The sink rate of a particular part of a tapered line, such as the tip, is the sink rate of a long, level section of line having the same diameter and density as the specified part.

SINK RATES OF COMMON SINKING LINES

The sink rates for many standard sinking fly lines are listed in Table 1. In Table 2 are sink rates for several lead-core lines. These rates are for level sections of line from the belly of the line, unless otherwise noted, in still, fresh water. The sink rates are in inches per second, calculated from measurements of line density and diameter, as described later in this article in a section on measurement. Statistical procedures have been used to minimize the effects of normal variability among particular samples of lines, so that the sink rates of typical lines in each weight of each type can be estimated.

The sink rates given in these tables do not specify the line taper. For tapered lines, the sink rates are for level sections from the bellies of the lines, except as noted. Since there is very little difference in the bellies of different tapers of a given line weight and type, there is also very little difference in sink rate. Most of the data are from level sections cut from the bellies of shooting heads or double-tapered lines.

TABLE 1.* Maximum sink rates in inches per second of level sections from bellies of tapered lines in still, fresh water.

	AFTMA** Line Weight							
Line	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
BERKLEY								
Qwik Sink	2.88	3.09	3.10	3.34	3.57	3.72	4.02	—
CORTLAND								
Type 1	1.35	1.42	1.49	1.59	1.67	1.77	1.88	1.94
Type 2	2.24	2.40	2.55	2.74	2.91	3.11	3.32	3.44
Type 3	2.63	2.84	3.02	3.26	3.47	3.72	3.98	4.12
Type 4	—	—	3.69	3.82	3.98	4.14	4.33	4.54
SCIENTIFIC ANGLERS								
Fisherman	0.96	1.09	1.15	1.18	1.32	1.41	—	—
Wet Cell I	—	1.53	1.68	1.87	1.99	2.18	2.28	—
Wet Cell II	—	1.97	2.16	2.39	2.55	2.80	2.92	—
Hi-D	—	—	3.15	3.46	3.70	4.04	4.22	—
High Speed	—	—	4.50	4.70	4.93	5.13	5.37	5.58
SUNSET								
Formula MS	1.82	1.87	2.03	2.16	2.30	2.48	2.61	—
Formula XS	2.66	2.75	2.98	3.18	3.40	3.64	3.91	—

* Not included in the tables are the Masterline sinking lines, due to insufficient reliable data. The Masterline medium sinking and Don VFS lines appear to be very much like the Sunset Formula MS and Formula XS lines respectively, and a series of lines with fine lead cores appear to sink a little more slowly than do the Don VFS lines.

** American Fishing Tackle Manufacturers Association members generally conform to standards adopted by the AFTMA in 1961 for fly line weights. Weight standards used by Scientific Anglers differ: heavy lines and all weights of High Speed lines are heavier. No AFTMA standards exist for lines heavier than number 12.

TABLE 2. Maximum sink rates, weights, specific gravities and diameters of level sections of lead-core lines in still, fresh water.

Line	**Weight gr./ft.**	**Diameter inches**	**Specific Gravity**	**Sink Rate in./sec.**
CORTLAND				
Kerplunk	8.9	0.0277	4.85	6.80
Super Kerplunk	14.1	0.0429	3.21	6.64
GLADDING				
Mark Five	12.3	0.0338	4.50	7.33
SUNSET				
Cannonball, belly	18.9	0.0585	2.32	6.08
Cannonball, tip	14.2	0.0430	3.23	6.68
0.020 lead	12.2	0.0313	5.22	7.73
0.023 lead	17.1	0.0366	5.34	8.66
0.027 lead	20.2	0.0388	5.64	9.30
0.033 lead	31.2	0.0441	6.75	11.26

The sink rates of conventional lines lie between the limits of about 1 and 6 inches per second. Usual types of lead-core lines do not sink faster than 8 inches per second, and the most extreme type of lead core sinks at only a little more than 11 inches per second.

Table 1 shows that all weights of a given line do not sink at the same rate. Heavy lines always sink faster than light lines of the same type. A line type is characterized not by a uniform sink rate, but by the densities of the materials from which the different weights of the line type are made. The ratio of core volume to coating volume can be maintained nearly constant, so that the densities of all weights of a line type are nearly the same, as in the Berkley Qwik Sink lines, but the heavy lines still sink faster than the light lines. This indicates that diameter, as well as density, contributes to sink rate.

In order to show more clearly the relationships between sink rates and weights for different types of lines, the data from Table 1 are shown in graphic form in Figure 1 (see page 37). Sink rates in inches per second are shown as the vertical axis, and line weights in grains are given as the horizontal axis. American Fishing Tackle Manufacturers Association weight categories are also shown along the top of the graph. Both axes are logarithmic, in order that equal percentage differences appear as equal distances. The AFTMA weights have approximately equal spacing on this logarithmic basis, since the differences in grains between successive weights are greater for heavy lines than for light ones. The choice of a logarithmic rather than linear sink rate axis is based on the opinion that a 20-percent difference in sink rate between two slow-sinking lines, for example, has the same significance as a 20-percent difference between two fast-sinking lines, even though this difference might be ¼ inch per second for the slow lines and four times that amount for the fast lines.

The figure indicates that except for one group of line types, lines presumably having similar sink rates, such as Cortland Type 1 and Scientific Anglers Wet Cell I, are not more alike than their presumably unrelated neighbors. The one group of similar lines might be called a type-3 group, con-

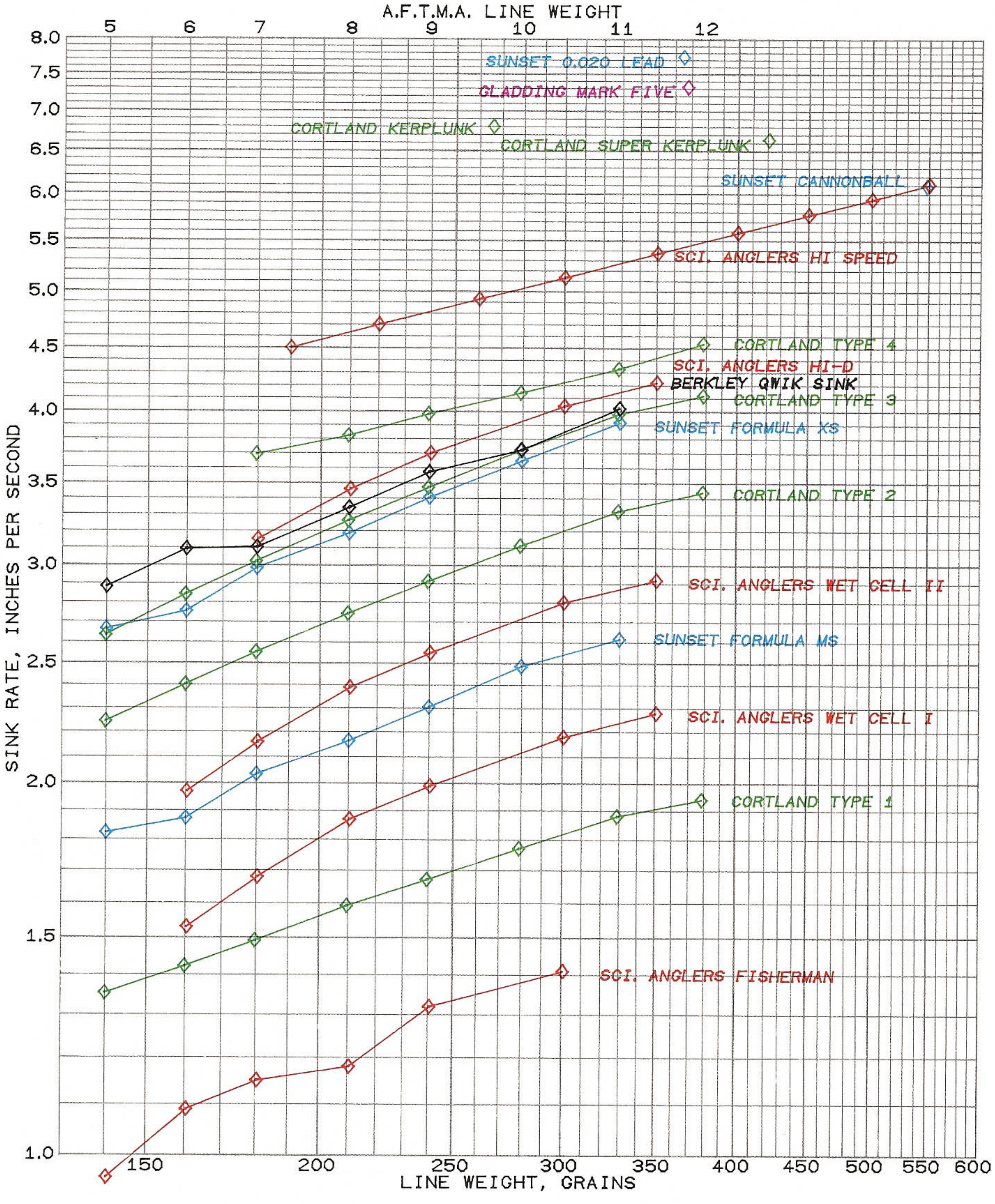


FIGURE 1. Typical maximum sink rates of level sections of sinking fly lines in still, fresh water. Sink rates from Table 1 are plotted with curves joining successive weights of each line type, in order to show the relationships among the line types. Very heavy Scientific Anglers High Speed and some lead-core lines from Table 2 are included. Both AFTMA line weight and weight in grains for the first 30 feet of line are shown.

sisting of the Berkley Qwik Sink, the Cortland Type 3, Scientific Anglers Hi-D and the Sunset XS.

The fastest sinking conventional line sinks about four times the rate of the slowest line of the same weight. A fisherman who needs lines that cover this entire range might wish to do so with five types of sinking lines, all the same weight. If the sink rates of these lines were to be evenly spaced on a logarithmic basis, each line would sink about 41 percent faster than the next slower line. (Photographers may note that this is the same ratio as successive f-stops.) Figure 1 shows that by including lines of several manufacturers, lines with these ratios can be selected. The line types of a particular manufacturer may not be uniformly spaced in sink rate. Of course, many factors in addition to sink rate should be considered in the selection of sinking lines.

The upward slopes of the curves for the various line types show that for each type, heavier lines sink faster than light lines. The average weight increase for one step in AFTMA line weight is about 14.4 percent. From the slopes of the sink-rate curves, the corresponding increase in sink rate is about 5.5 percent. On the average, then, a number-8 line sinks 5.5 percent faster than a number-7 line of the same type, and a number-11 line sinks 24 percent faster than a number 7 (that is, 1.055 raised to the fourth power). On heavy lines, manufacturers generally use cores larger in diameter than those used on light lines, but several weights may use the same core. This results in the irregularities found in curves joining successive weights of a line type, as shown in Figure 1. The actual difference in sink rate between two lines may differ, therefore, from this average value.

The lead-core lines of Table 2 are level lines except for the Sunset Cannonball, which is a tapered shooting head. The taper of this line is formed by adding a coating that is less dense than the lead in the uniform core. This results in a belly that sinks slightly more slowly than the tip.

The Cortland Kerplunk and the level Sunset lead-core lines have bare braid over the lead core. The Gladding Mark Five has a thin plastic jacket over the braid, which decreases friction and reduces the tendency of the lead-core line to kink. The Cortland Super Kerplunk has a thicker plastic coating over the braid. The decrease in sink rate due to the reduction in line density by the plastic jacket is partially compensated for by the increase in diameter, which increases sink rate.

The mathematical analysis of sink rates, described later, allows calculation of a number of influences on sink rate not convenient to determine experimentally. Water temperature has a slight influence on sink rate, primarily due to changes in water viscosity. Lines sink faster in warmer water, and the effect is slightly greater for slow-sinking lines. At 70 degrees Fahrenheit, lines sink about 4 percent faster than at 50 degrees.

Sink rates are less in salt water than in fresh water, but the effect is not as great as might be expected. The reduction in sink rate is greatest for slow-sinking lines. For an 8-weight Cortland Type 1 line, the reduction is about 18 percent, while for a Scientific Anglers High Speed of the same weight, the reduction is about 4 percent. The decreased sink rate is due to the greater density and greater viscosity of salt water.

The time required for a line to reach its maximum sink rate can be calculated also. This depends on the particular line, but the time required to reach within 1 percent of the final, maximum sink rate is less than a quarter of a second for level line sections sinking in still water.

It is said that a line of the type-3 group is useful in fishing at depths of up to 20 feet when it is necessary to reach such depths rapidly. The sink rate of a number-8 line of this group is about 3.3 inches per second, so that if this line were allowed to sink slackly in still water, without any retrieve, it would require over 1 minute 12 seconds to sink to 20 feet. Many fishermen may find such a line unsuitable for fishing at these depths.

If a line is cast into running water and allowed sufficient slack to drift freely, it will sink much as it would if it were in still water. The depth it will reach in a particular current if allowed to drift a specified distance can be calculated. For example, if a number-8 line of the type-3 group with a maximum sink rate of 3.3 inches per second is cast into a moderate current of 3 miles per hour and allowed to drift freely for 50 feet, it will have sunk no more than 38 inches at the end of the drift. If, as is usual, the line is held against the current, the depth will be much less.

VARIABILITY OF SINK RATES

When several lines are tested whose labels indicate that they are the same type and the same weight, the sink rates may vary. Most of these variations are small and not important to the fisherman, but more serious deviations are not uncommon.

Manufacturing tolerances in both line diameter and density of line materials cause variations in sink rate that are small as long as the line weight is within the weight tolerances specified by the AFTMA. The formula for calculating sink rate, which is given in a later section, shows that sink rate is dependent upon about the 0.7 power of diameter, while weight is proportional approximately to the square of the diameter, depending upon relative densities and diameters of core and coating materials. Sink rate is thus much less sensitive than weight to diameter variations.

Density variations affect the sink rates of fast- and slow-sinking lines differently. The sink rate is dependent upon about the 0.6 power of the difference between line density and water density, whereas weight is proportional to line density. As a result, in fast-sinking lines (those with a density much greater than that of water) the sink rate is not as sensitive as is the weight to variations in line density. In very slow-sinking lines (those with a density slightly greater than that of water) there is a much greater variation in sink rate when there is a small variation in line density.

Changes in the design of a line, generally in order to improve some aspect of the line, may result in changes in the sink rate. Various changes made to the Scientific Anglers High Speed lines since their introduction have caused variations in their sink rate. This very complex line has been much more difficult to analyze than other lines, and the sink rates given in the table are estimates for lines now on dealers' shelves. The design of the Cortland Type 1 line was changed about 2 years ago, and current lines sink more slowly than older lines. It can be seen from Figure 1 that this change makes the new lines more interesting.

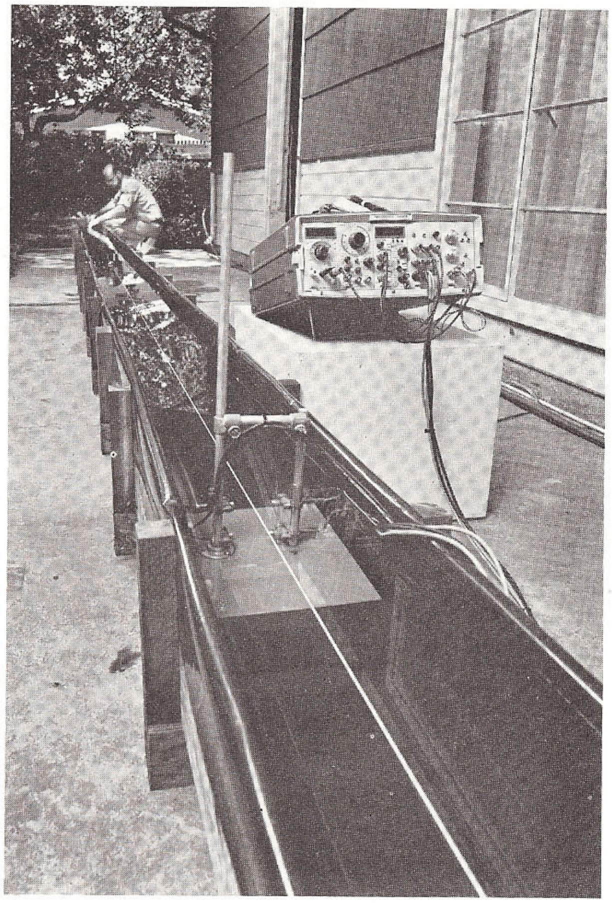
The most serious causes of sink rate variations are mislabeling of lines and use of wrong materials in making them. Lines are labeled with the wrong weight with disturbing frequency, although this is much more of a problem with some manufacturers than for others. Errors in line type labeling also occur, which may not be simply a problem of putting a line in the wrong box. Where line type is identified by a characteristic color, color is not necessarily a reliable means for identifying line type. The fisherman who suspects that a line is not what the package says it is should verify both weight and sink rate. The methods described in the next section should be helpful.

MEASUREMENT OF SINK RATES

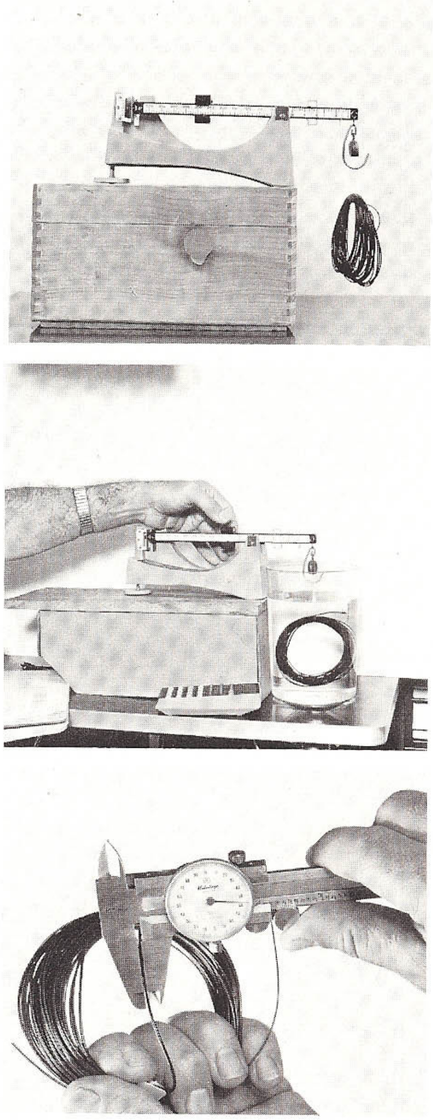
Sink rates are most directly determined from the time required by lines to sink known distances. A peculiarity of this method is that the result depends upon the length of line used. Very short pieces of line sink faster than do long sections.

The water-filled trough and electronic instruments shown in the photograph and described in the caption give precise measurements of sink rate. It is difficult, however, to control the measurement conditions sufficiently to give reproducibility of better than a few percent for successive trials. Slight variations in the way the line is held beneath the water surface and then released produce variable, although slight, lengthwise movements of the line, altering sink rate. Vortex shedding, described in a later section, causes side-to-side movements of the line that are not uniform along the length of the line, adding to the lengthwise movements. Controlling the tension on the line before release by use of an electronic transducer, or preventing tension on the line by use of a mechanical device that holds and then releases the line along its entire length, reduces but does not eliminate significant variability. It is necessary to statistically analyze a long series of measurements for each line in order to get reliable results. This method has been invaluable in providing data for comparison with other methods, and for testing the adequacy of a theoretical analysis of sink rate. Because of the considerable effort involved, it is not generally a practical method for routine use.

Sink rates are measured by the author with this shallow trough and electronic instruments. Time is measured for the line to sink a few inches, from one photoelectric sensor to another. By allowing the line to sink only a short distance, the sink rate of the belly of a tapered line can be measured without interference from the different sink rates of the tapered parts of the line.



Photo/Jack Clark



Photo/Jack Clark

Photo/Christine Fong

Photo/Jack Clark

The sink rate of a line can be calculated from measured values of specific gravity and diameter. Specific gravity can be found from two weight measurements, using a simple reloading scale. The coiled line is first weighed as in the first photograph, and the apparent weight of the line when suspended in water is then found, as in the second photograph. The line is suspended from the scale with a fine thread, and care is taken to remove air bubbles trapped when the coil is immersed in water. The difference between the two measurements is the buoyancy of the line, and the specific gravity is the weight divided by this buoyancy. Diameter is measured with calipers, a micrometer or a thickness gauge, with care taken not to compress the line and by using the average of several measurements to avoid errors from non-uniformities in the line. Sink rate can either be calculated using the formula given in the text of this article or be found from Figure 2.

Short, level pieces of line can be allowed to sink greater distances in a glass container, and the time can be measured with a stop watch. Pieces more than about 2 inches long, or less than 1 inch, tend not to remain horizontal as they sink, and so do not sink uniformly. Pieces from 1 to 2 inches long tend to sink in a stable manner, but the sink rate depends upon the ratio of diameter to length and on the line density. One-inch pieces of very fast-sinking lines may sink more than 10 percent faster than long sections of the same lines. The error is less for slow-sinking lines.

Sink rates can be indirectly determined by calculation from measured line density and diameter. This method is fast, uses only inexpensive equipment that many fly fishermen already have and gives excellent agreement with the most careful

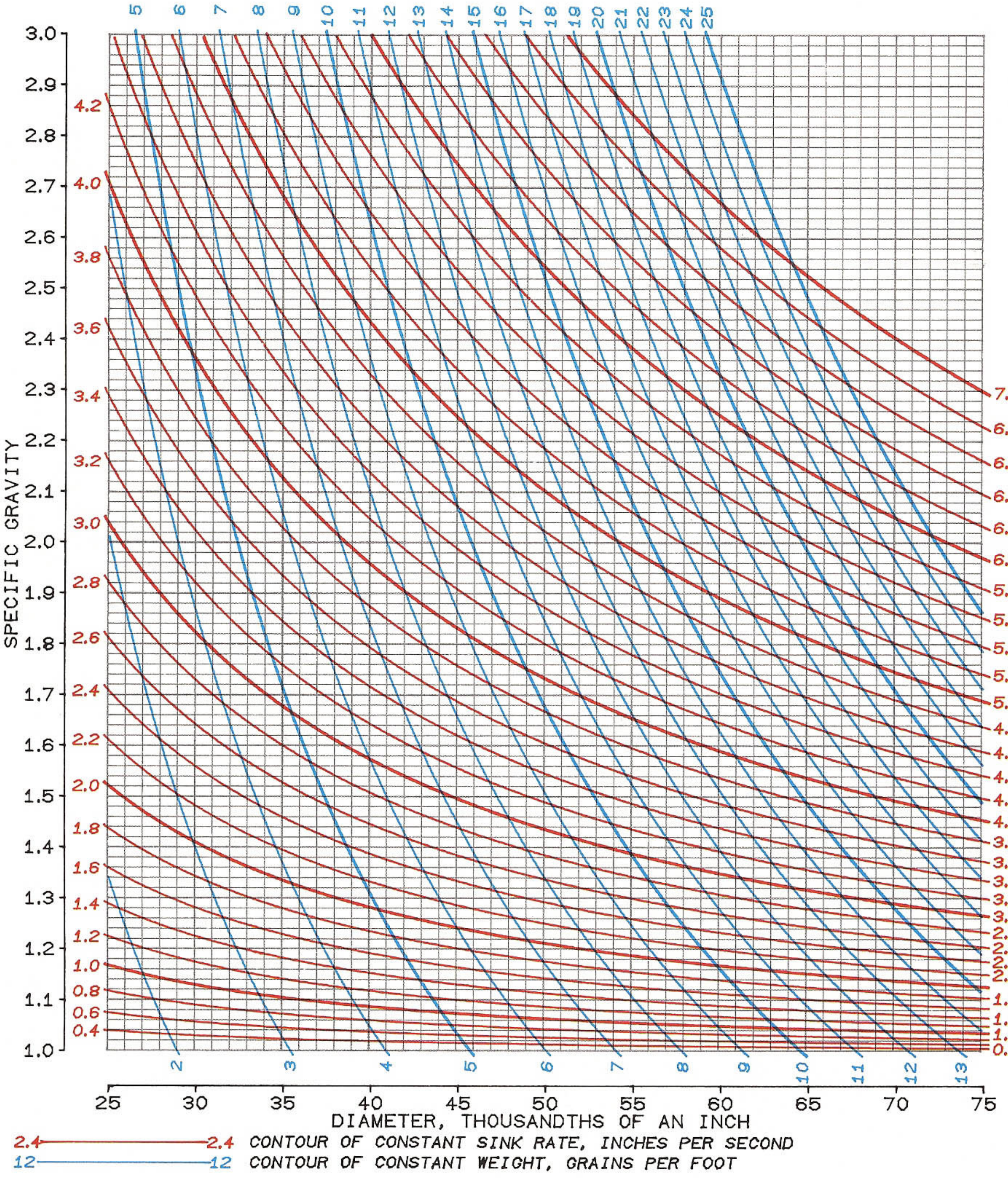


FIGURE 2. Maximum sink rates in still, fresh water, and weights of level sections of sinking fly lines as functions of line diameter and specific gravity. Each point on the graph corresponds to a particular combination of diameter and specific gravity. Each sink rate contour passes through all the combinations of diameter and specific gravity that give the sink rate of the contour. Weight contours pass through all points giving the indicated weights, which are not AFTMA weight numbers, but grains per foot. The sink rate of a particular line can be found from the graph, if the diameter and specific gravity are known, by locating the point corresponding to these values and interpolating between the sink rate contours at that point.

direct measurements using long line sections. The mathematical formula for this is given later in the article. Unless a computer or programmable calculator is available for the calculations, it may be convenient to use Figure 2 to find the sink rate corresponding to the measured specific gravity and diameter.

The vertical axis of Figure 2 is line specific gravity (that is, the ratio of line density to the density of water), and the horizontal axis is line diameter in thousandths of an inch. A level section of line has a particular specific gravity and diameter, so that a particular line section corresponds to a single point on the graph. Four variables are represented: specific gravity, diameter, sink rate and weight. Any two of these can be determined from the graph for a particular line if the other two are known (see caption of Figure 2).

Specific gravity and diameter can be measured as described in the captions of the photographs. The average specific gravity of a conventional shooting head or double taper is only 1 or 2 percent less than that of a level section from the belly of the line, so that using the intact lines of these tapers results in only a small error in the sink rate calculation. The head and running line portions of weight forward lines should be separately coiled, and only the head section should be weighed for the specific gravity calculation.

The sink rates in Tables 1 and 2 used the indirect method of calculation from specific gravity and diameter for level sections cut from the lines. Because of the relatively large error in a direct measurement of diameter, the diameters were calculated from the weight, specific gravity and length of the level section. Direct measurement of diameter with a micrometer or thickness gauge tends to compress the line, giving a reading about one thousandth of an inch less than the calculated diameter.

DESCRIPTION OF THE PROCESS OF SINKING

The downward force of gravity on a sinking line in still water is opposed by the buoyancy of the line, by the drag forces of the line moving in the water and by the force from any downward acceleration. The line rapidly approaches its maximum sink rate so that the acceleration force becomes negligible after, at most, a few tenths of a second, and the gravitational force then equals the combined buoyant and drag forces.

Common sense has led writers to assume that sink rate is proportional to line density, or to a ratio of density to diameter. These assumptions are not correct because of the nature of the drag forces. The two notable aspects of the drag force for fly lines are: (1) that the friction-like effects are not between the line and the water, but between the surrounding water and a layer of water that moves with the line; and (2) for even very slowly sinking lines, the smooth flow of these layers of water past each other is disrupted by the formation of a turbulent wake behind the line.

Since the water does not move over the surface of the line, the smoothness of the line is not important in sink rate, unless the surface is extremely rough. It is the viscosity of the water rather than a coefficient of friction between line and water that is important in sink rate.

The direct effect of water viscosity on drag is significant for very slowly sinking lines, but a pressure difference between front and back of the line, resulting from the formation of a wake, is the main source of drag for faster sinking lines. This explains why the sink rate for very short pieces of line is greater than for long pieces. The movement of water around the cut ends of the short piece significantly reduces the pressure difference between front and back of the line, thus increasing the sink rate.

A notable feature of the wake behind sinking lines is that vortices are formed, first on one side and then on the other. After a vortex is formed, it separates from the line and drifts back in the wake. This vortex shedding results in lateral forces on the line, causing it to vibrate from side to side. Close inspection of sinking lines will show these movements at rates from about four to nearly twenty per second. The vortices are not uniform along the line, so that an initially straight but slack line will tend to take a serpentine form as it sinks. These movements complicate the direct measurement of sink rate.

The layers of water that move with the line are the boundary layers. These are thin at the leading surface of the line and increase toward the back of the line. Wake formation results when a boundary layer becomes unstable. A problem with measuring and analyzing sink rates in moving water is that the movement of water along the length of the line increases the boundary layer thickness around the entire line, altering the form of the wake and reducing the sink rate. Of course, if the line is not parallel to the direction of the water movement, additional lift forces will further complicate analysis.

A FORMULA FOR CALCULATING SINK RATES

The relationships among sink rate and properties of the line and water, for level sections of sinking fly lines in still water, can be derived by considering the forces acting on the line. The derivation of the mathematical formula is lengthy and outside the scope of this article. Details of the derivation are available by writing to the author in care of the editor of this magazine.

Within a few tenths of a second after the line is released below the surface of the water, the line will have reached virtually its maximum sink rate, which is given by

$$U = (A/D)\,(C^{1/3} + C^{-1/3} - 1)^{3/2}$$

where

$$A = v(10/3)^{3/2}$$
$$B = -1 + (84.823\ g\ D^3)\,(d_L - d_W)\ /\ (4{,}000\ v^2 d_W)$$
$$C = B + (B^2 - 1)^{1/2}$$

and

U = *sink rate*
v = *kinematic viscosity of water*
g = *gravitational acceleration*
d_W = *density of water*
d_L = *density of line*
D = *diameter of line*

For fresh water at 70 degrees F, the terms A and B are:

A = *0.00929 square inches per second*
$B = 3{,}512{,}000\ D^3(S-1) - 1$

where diameter is in inches and sink rate in inches per second, and

$S = d_L / d_W$ = *specific gravity of the line.*

For the benefit of nonmathematical readers, conventional Greek symbols for some of the quantities are not used.

For other conditions, such as for salt water or for other temperatures, the appropriate values of water density and kinematic viscosity are substituted in terms A and B. The system of units must be consistent with the other terms.

A least-squares-error procedure can be used to approximate this formula by a simpler one over a limited range. For a sink rate and line diameter product greater than 0.06 and less than 0.3 square inches per second, the error in sink rate will be not more than 1 percent for fresh water at 70 degrees F, with the following formula:

$$U = 37.5\,(S-1)^{0.563}D^{0.689} \text{ inches per second}$$

where D is in inches. This simplified equation shows more clearly the relative importance of line density and diameter. The range of applicability for this equation includes all the conventional lines listed in Table 1 and the lead-core lines of Table 2, except the Cannonball and the three heaviest Sunset level lead-core lines. For these and other large and very fast, or small and very slow lines, the exact equation should be used.

Note that sink rate is strongly dependent upon line diameter. Because of the greater diameter in heavy weights of a particular line type, heavy weights sink faster than light weights, even if all weights are made with the same specific gravity. This explains why it is difficult to make light but very fast-sinking lines.

A PROPOSAL FOR SINK RATE STANDARDS

As the variety of sinking lines increases and more of these lines are bought by fishermen who do not yet have great experience with them, the need for better identification of sinking lines becomes greater. The trade names or descriptive terms used by manufacturers are not adequate for comparing or selecting sinking lines, and these terms are sometimes even misleading.

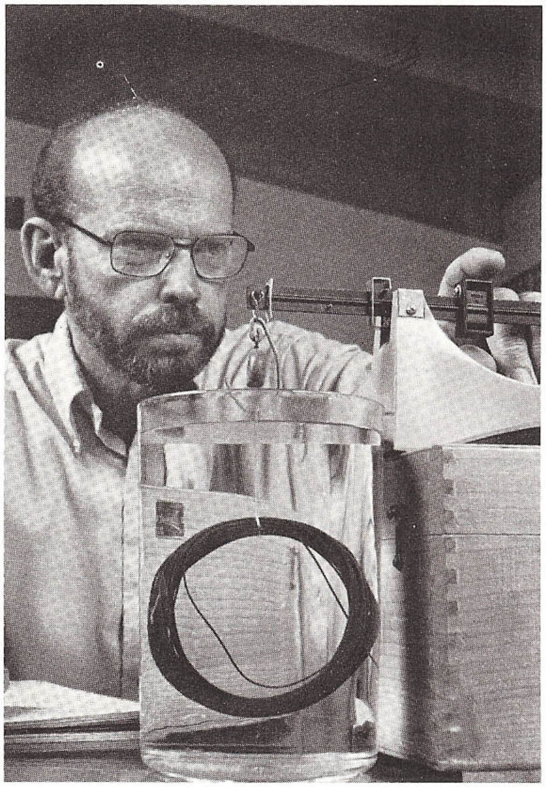
An obstacle to the adoption of sink rate standards has been the difficulty of defining, measuring and analyzing sink rates in ways that give consistent results. I think that now it has been shown that in still water with level line sections, and using my mathematical formula for calculating sink rate, it is possible to agree on the maximum sink rate of any particular line. There seems to be no technical reason now for not adopting some standard method of specifying sink rate.

There are differences of opinion as to the appropriate form of a sink rate standard. The late Myron Gregory advocated adoption of sink rate standards analogous to the AFTMA weight standards, of which he was a principal author. He felt that all sinking lines should conform to a limited number of categories of sink rates, and that all weights of a given type of line should sink at the same rate.

Many fly fishermen would regret the restriction of the rich variety of sinking line types, and the inhibition of valuable new developments, which would result from a standard which limited sinking lines to certain sink rate categories. I believe that such a standard would attack the wrong problem: it is not the number of different sinking line types that is the problem, but the lack of information about them. This problem can be solved, without limiting in any way the manufacture or the development of sinking lines, by labeling each line with its sink rate.

I propose that an industrywide standard be adopted to specify exactly what is meant by sink rate, how it should be determined, and with what accuracy it should be stated. In conformity with the standard, each line would be labeled with the sink rate in inches per second as determined by the manufacturer to be typical of that line weight and type.

It is understandable that some manufacturers would resist providing and ensuring the accuracy of more information than necessary about their products. The AFTMA has declined to consider proposals for sink rate standards. It is hoped that informed and thoughtful fly fishermen will debate this matter and urge manufacturers to adopt sink rate standards that will provide better information without restricting the manufacture or development of sinking fly lines. **FFF**



Determining apparent weight in water.

ACKNOWLEDGMENTS

The late Myron Gregory heaped encouragement and fly line lore on me in a valued series of letters of unforgettable vigor. In a recording found after his death, he summarized his views on sink rate standards and expressed his hope that some type of standard would be adopted. I hope this article will contribute to the fulfillment of his hopes.

Al Perryman of Sacramento, California, and Alaska helped inspire my study of sink rates with memorable demonstrations of the effectiveness of sinking lines.

My measurement procedures required that dozens of lines be sacrificed in gathering the sink rate data, so I am grateful to the fly line manufacturers for supplying many of the lines for these tests. These results were checked with simpler, nondestructive tests on other lines, many of which were borrowed. For the loan of lines, I particularly thank Bill Kiene of Fly Fishing Unlimited in Sacramento, California, and Andy Puyans of Creative Sports Enterprises in Walnut Creek, California.

Harry Bylsma of Scientific Anglers was helpful in comparing results of his careful methods of sink rate measurement with my methods and calculated sink rates, and in pointing out the instabilities in sinking that occur with certain short lengths of lines.

The phenomenon of vortex shedding was first brought to my attention by Daryl Davis, then president of the Fly Fishers of Davis, California.

I thank Bill King of Sacramento, California, for reading drafts of this article and for making many helpful suggestions.