AD-A060 989 YOUNG LABS VAN HORNESVILLE NY F/G 13/10
DEVELOPMENT OF LINE RANGING EQUIPMENT.(U)
MAY 78 W A STRAUSS, N O YOUNG DOT-CG-73597-B

UNCLASSIFIED USCG-D-40-78 NL

1 OF 1
ADA
060989

END
DATE
FILMED
1 79
DDC

Report No. CG-D-40-78

LEVEL II

DEVELOPMENT OF LINE RANGING EQUIPMENT

NIELS O. YOUNG
WILLIAM A. STRAUSS

FINAL REPORT

MAY 1978

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
United States Coast Guard

12
NW

NOTICE

This document is disseminated under the sponsorship of the Department of Transportation in the interest of information exchange. The United States Government assumes no liability for its contents or use thereof.

The contents of this report do not necessarily reflect the official view or policy of the Coast Guard; and they do not constitute a standard, specification, or regulation.

This report, or portions thereof may not be used for advertising or sales promotion purposes. Citation of trade names and manufacturers does not constitute endorsement or approval of such products.

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
18 19 USCG-D-40-78		

4. Title and Subtitle

6 DEVELOPMENT OF LINE RANGING EQUIPMENT

5. Report Date

11 31 May 1978

6. Performing Organization Code

7. Author(s)

10 William A. Strauss, Niels O. Young

8. Performing Organization Report No.

12 20p.

9. Performing Organization Name and Address

Wm. A. Strauss, Niels O. Young
YOUNG LABORATORIES New
Box 13 Van Hornesville, N. Y. 13475

410 930

10. Work Unit No. (TRAIS)

11. Contract or Grant No.

15 DOT-CG-73597-B dgc new

12. Sponsoring Agency Name and Address

U. S. DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD
OFFICE OF RESEARCH AND DEVELOPMENT
WASHINGTON, D. C. 20590

13. Type of Report and Period Covered

9 FINAL rept.,

14. Sponsoring Agency Code

G-DSA-3

15. Supplementary Notes

The equipment described herein is manufactured under one or more of the following U. S. Patents: 3,374,933 3,330,557 3,398,949 3,408,967.

16. Abstract

Equipment has been developed and demonstrated capable of extending and directing a moving loop of line and maintaining it standing essentially horizontally over variable ranges as though it were a rigid structure.

Theoretical data were confirmed by tests indicating that line can be deployed and precisely directed with a power requirement of one horsepower per one hundred feet of range at any angle to the vertical.

With further development the equipment is expected to be useful where line-throwing guns are now used and in salvage, life-saving and rescue operations.

17. Key Words	18. Distribution Statement
Line ranging, Line throwing, Search and Rescue, Life-saving, Docking Systems, Salvage.	UNLIMITED. Document is available to the U. S. Public through the National Technical Information Service, Springfield, Virginia, 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
None	None 410 930	18	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

78 11 06 116

METRIC CONVERSION FACTORS

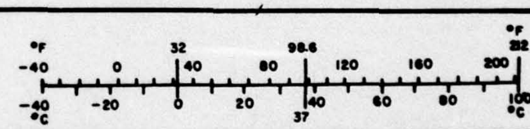
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



METRIC CONVERSION FACTORS

INTRODUCTION

Line throwing guns are seldom used unless absolutely necessary and rarely if ever in rescue operations because of the personnel hazards involved.

Even hand thrown lines have often been the cause of personnel injuries and property damage.

The use of throwing guns requires skilled operators and the careful attention of everyone in the area, both on the launching and receiving vessels. If a shot is a "miss", not only is the line lost, but valuable time and occasionally lives may be lost as well.

Ten years ago a series of U.S. patents issued to Niels O. Young, an author of this report, on systems for causing line to behave as though it were rigid, allowing it to be precisely directed to a target at varying ranges and maintained literally standing in air until seized or caught by a boat hook or a swimmer or simply dropped over a bollard, piling or cleat under the control of the operator.

This phenomom is achieved by driving a closed loop of line at a high speed (greater than its terminal velocity). The line leaves its drive pulley at a tangent and follows a ballistic curve to the end of its trajectory at which point it becomes limp and returns to the Line Ranging device, generally describing the shape of a huge paper clip or chain saw chain.

In contrast to the thrown messenger or shot line the standing loop can be carefully, slowly maneuvered into position with the operator compensating for the effects of wind and roll. Once dropped onto a bollard or other appropriate feature of the target, the continuous loop acts as messenger for heaving heavier line by the operator without the need for help from personnel on the target.

This equipment was brought to the attention of the U.S. Coast Guard Office of Research and Development in 1976. A fixed range demonstration unit was constructed at the R & D center in Groton, Conn. from drawings prepared by Mr. Young. This unit served to demonstrate that the principles involved were indeed sound and led to the decision to proceed with the work which is the subject of this report.

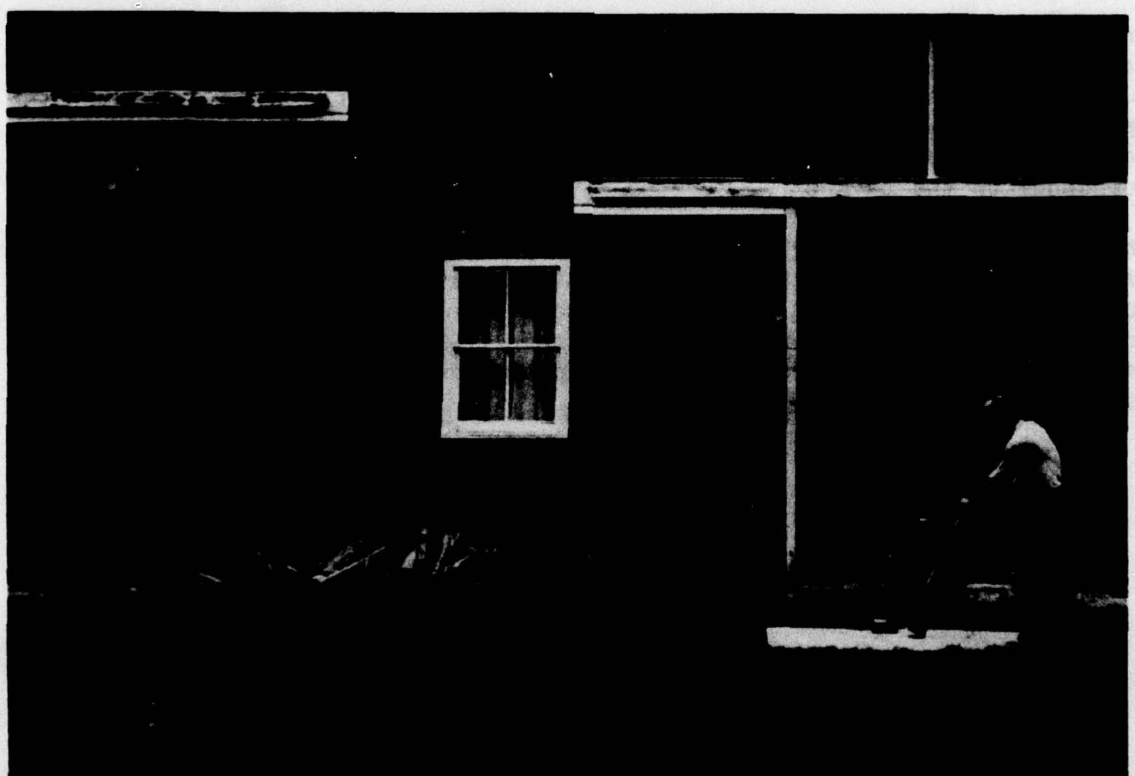
LINE RANGER DEVELOPMENT

The objective of this effort was to conduct exploratory development activities leading to the design of a prototype line transfer device that would be portable and have a controllable and continuously variable operating range, with linedeployed from and retrieved into an integral storage container.

Initial efforts were devoted to the development of the mathematics and theory in order that the performance of the equipment might be predictable with respect to power required, stability, drag coefficients, aspect ratios, length limits and the effect of sudden stops. These data are presented in the appendix.

The problem of obtaining suitable endless loops of line was addressed, it having been demonstrated that splices compatable with the drive system and high pulley speed were less than desirable. A source for endless braided nylon line was located and tests led to the selected line of .100", approximately 400lb. test. In the future it is planned to develop a line produced of a blend of polypropylene and nylon so that the line will float, using "dayglo" dyed filament for high visibility.

A protype device was constructed, tested and after several design modifications succesfully demonstrated. Figure 1.



DESCRIPTION OF THE LINE RANGER PROTOTYPE

The machine can be considered in three parts: the drive head, the storage and the line loop.

The drive head contains a high speed electric motor which moves the line loop along itself at about 120 feet per second, which requires about ½ horsepower mechanical input. The large diameter sheave shown in figure 2 is connected to the motor and the line is gripped by being pinched under an axial force. The drive head uses an outstream sheave and an instream sheave geared together at a fixed speed ratio. The ratio is such that when the instream sheave grips the line, the instream cannot return to storage as fast as it pays out. Consequently, the loop extends - typically at about ten feet per second. The instream sheave grips the line when the deploy trigger is squeezed with the left hand. Figure 3 shows the arrangement of the controls.

FIGURE 2

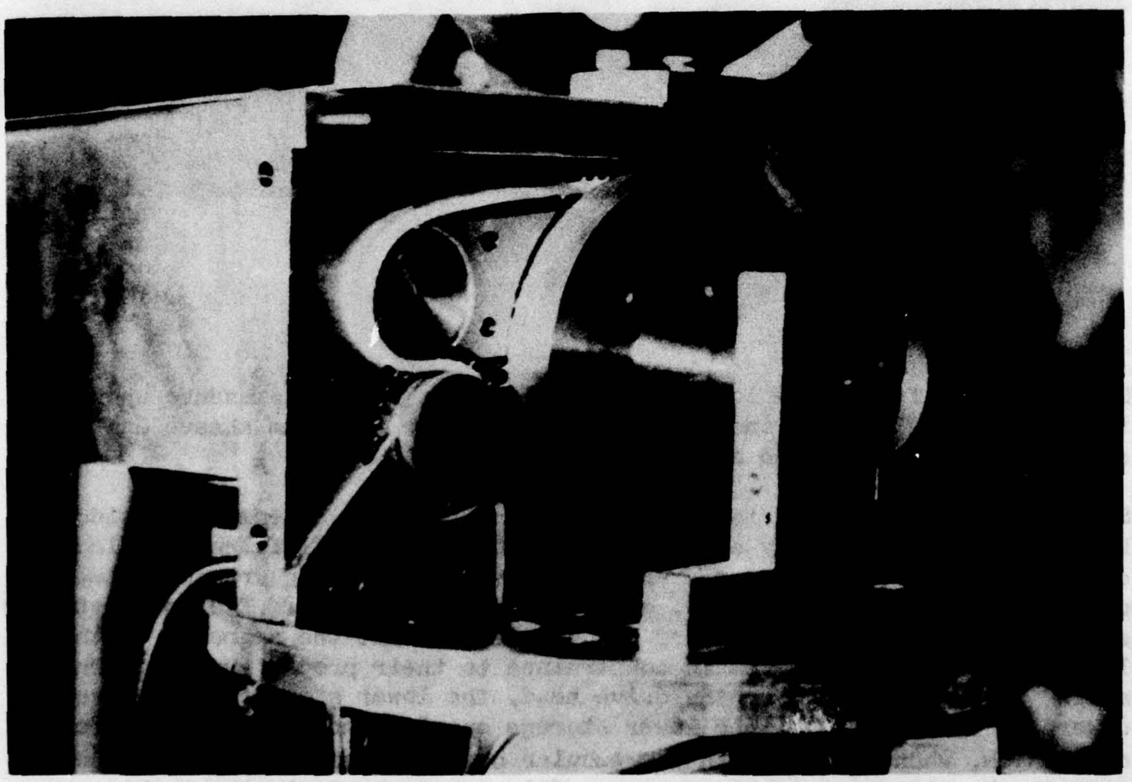
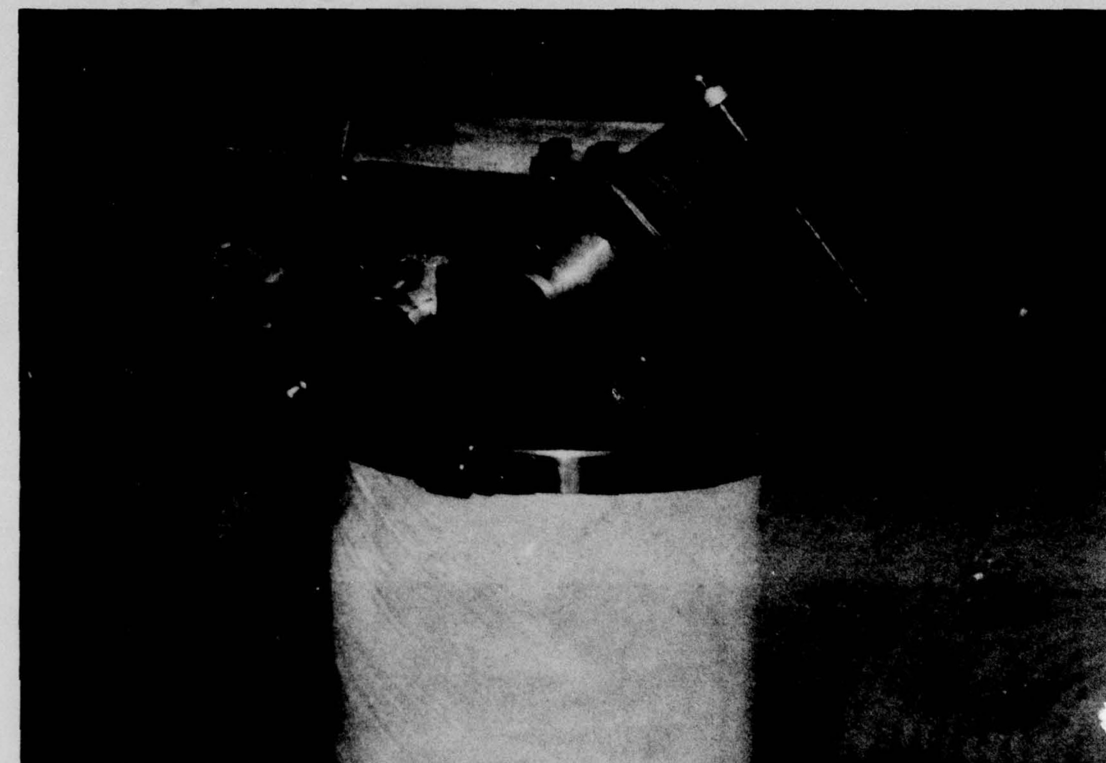


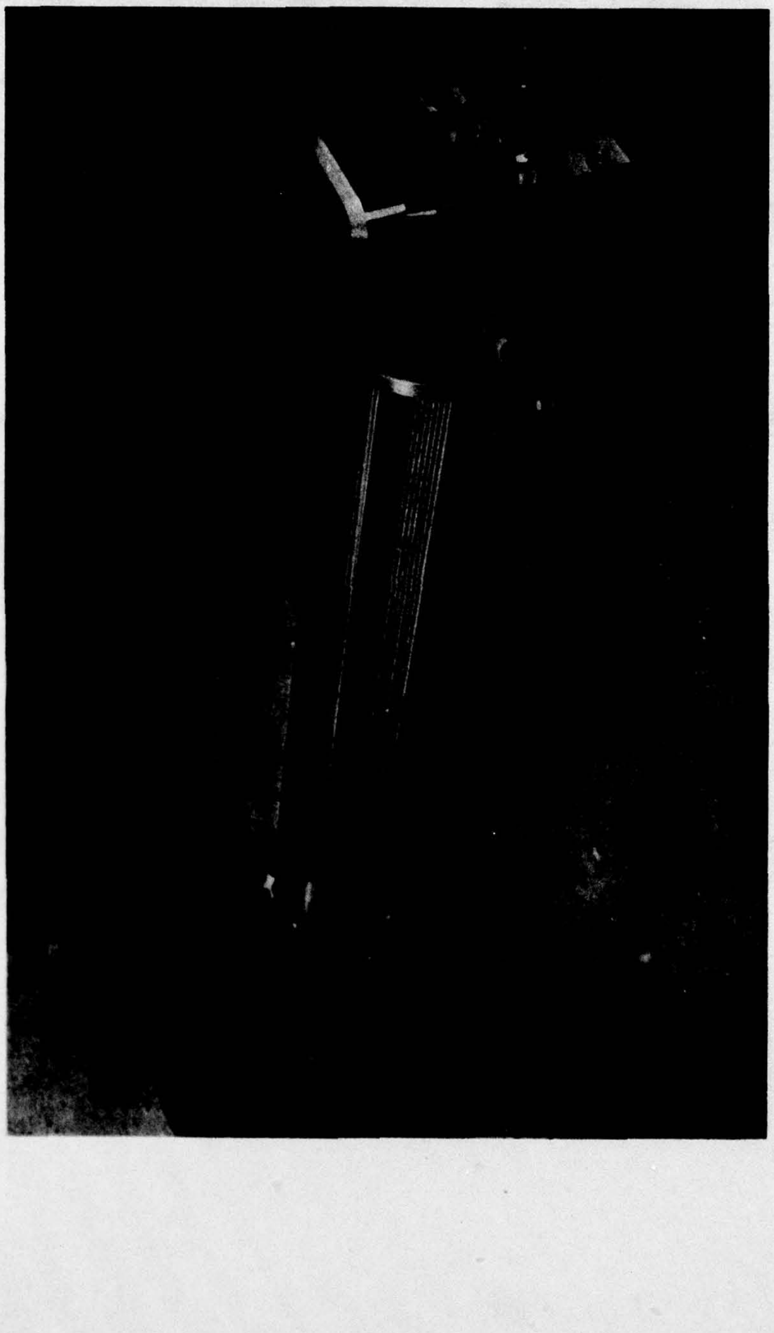
FIGURE 3



Maintaining a fixed line loop extension requires gentler pressure upon this trigger so to allow the instream to slip over the instream sheave and enter storage at the same speed as it pays out.

Storage of the line loop is required so that the loop extension outside the Line Ranger can be freely adjusted and also for stowage of the line loop during speed run up. Figure 4 shows line stored by being wrapped between upper and lower storage spools, much as in a block hoist. The lower storage spool is heavily pulled downward by springs, so that the segments of the loop between the spools remain constrained to their proper grooves. When a line loop is extended by the drive head, the lower storage spool moves upward in compensation. The lower storage spool is mounted upon a circular disc which, when installed in the tubular housing seen in earlier figures, acts as the piston of an air damper. This damper protects the machinery in case of a broken loop.

FIGURE 4



CONCLUSIONS AND RECOMMENDATIONS

Additional units should be constructed increasing the effective range to 100 feet and incorporating design changes to overcome the limitations observed in the prototype.

The following factors should be considered:

1. Loop extension should be proportional to the position of a twist grip. At present, loop extension velocity is proportional to a trigger pressure.

2. The instream should have a tension sensor so that automatic stops are possible if the line is caught.

3. The outstream should be aimed upward at an angle of about 20 degrees.

4. To eliminate a tendency for the line to twist, the storage should be designed with four sheaves with drive sheaves and idlers symmetrical.

5. To reduce internal shaft speeds, all sheaves, especially in the drive, should be of the largest practical diameter.

6. Means of eliminating jams at the intake should be devised.

7. Consideration should be given to adapting the unit for use on standard deck gun mounts.

APPENDIX

Theoretical

1.1 Power Required

Experience with line ranging devices shows that the faster the line moves, the stiffer it gets. Experience also shows that there is a lower limit of line velocity at which the standing loop is just able to lift itself free of solid support. The standing loop appears as shown in Fig. 1 when runnning at this lower velocity limit.

With the loop in this configuration, the air drag which acts parallel to the line, must have equal upward and downward components. Therefore the weight of the line must be supported by the drive mechanism. The drive mechanism therefore urges the line along with a drive force equal to the weight of the line. The line must therefore be moving with a velocity equal to its terminal velocity, called U_t. For at this terminal velocity the air drag force acting along the line equals the weight of the line.

The terminal configuration shown in Fig. 1 is useful as a means to measure U_t experimentally,

The behaviour of erected loops of line is crucially dependent upon the line velocity U. But it is more convenient to relate this velocity to the terminal velocity U_t so to define a speed parameter S:

$$S = U/U_t \qquad (1)$$

The power required for a line moving at its terminal velocity U_t is obviously equal to the weight of the line multiplied by its velocity:

$$P_t = W\,U_t \cdot 10^{-7} \quad \text{, Watts, where} \qquad (2)$$

W = line weight,

$$W = Mg\text{, where} \qquad (3)$$

M = line mass, grams,

$g = 981$ cm sec^{-2}

When the line moves at some velocity given by any speed parameter S which is greater than one, we get for the power P:

$$P = W\,U_t\,S^3 \cdot 10^{-7} \quad \text{Watts.} \qquad (4)$$

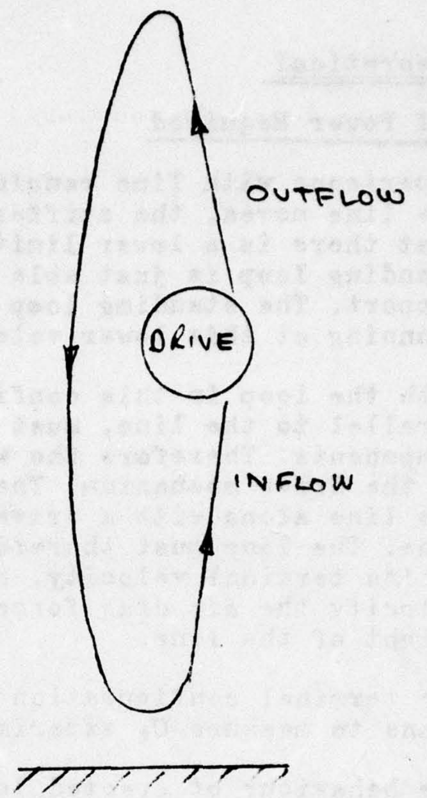
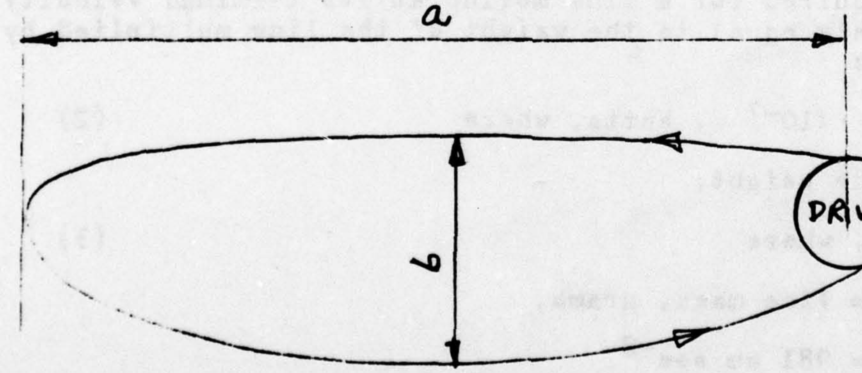


FIG. 1



$A = a/b$

FIG. 2

To apply eq.(4) to a practical case requires information as to what speed parameter is required. The speed parameter S can be chosen by noting its relationship to the loop shape. Figure 2 shows how loop shape is defined here by an aspect ratio A, the ratio of the loop extension a to its height b, for a horizontal loop:

$$A = a/b \tag{5}$$

A theoretical effort was made to relate the aspect ratio A to the speed parameter S. It was based upon the observation that no moment is exerted upon the drive mechanism by the weight of the line acting at a lever arm equal to a/2. Thus the moment must be taken up by air drag acting upon the line. At higher speed parameters, the required moment can be produced at higher apsect ratios. The theoretical attempt involved integrating moment elements around the loop - whose shape was assumed to be eliptical. The result of this work was to show that there was an approximate relation of the form:

$$S - 1 = kA \text{ , where } k \cong 0.2 \tag{6}$$

In experiments reported later, the constant k was found to be equal to 0.184, therefore we get the empirical relation:

$$S = 1 + 0.184A \tag{7}$$

Combining this result with eq.(4) gives a means to find the line ranger drive power provided we know the terminal velocity of the line, U_t. The terminal velocity can be determined with reasonable precision from first principles, as we shall now show. First, it is defined in terms of known quantites but for a drag coefficient C_f:

$$U_t = (2 \, p_o \, g \, / \, \pi \, \phi \, p_a \, C_f \,)^{\frac{1}{2}} \text{, where} \tag{8}$$

p_o = the line linear density, gm cm^{-1}

ϕ = the line diameter, cm

p_a = the density of air, say 1.23×10^{-3} gm cm^{-3}

The drag coefficient C_f is given by an empirical relationship which has been established by experiments reported later:

$$C_f = 163/N_{re}^{\;0.665} \text{, where} \tag{9}$$

N_{re} = the Reynolds number characteristic for the line,

$$N_{re} = p_a \, U \cdot \phi \, /\mu \text{ , where} \tag{10}$$

μ= the viscosity of air, say 2×10^{-4} Poise.

The foregoing equations allow calculation of the drive power P as a function of simple parameters. The calculation is simple if U_t for the proposed line is known (at approximately the operating Reynolds number), otherwise one must iterate. The application of these equations will be shown in a later section.

1.2 Stability

We shall consider the tensile force in the line outside the drive mechanism, and show how it can limit the extension <u>a</u> of the line ranger. Tension in the line is primarily due to two effects: the dynamic tension F_d and a tension caused by air drag, F_a. The two tensions superimpose, so that the tension at any point along the arc length is the sum of F_d and F_a at that point.

The dynamic tension F_d is equal everywhere along the line,

$$F_d = p_o U^2 \tag{11}$$

The drag tension F_a is zero at the line ranger outlet, and increases linearly with distance along the line Z:

$$F_a = \pm Z \pi \phi C_f (p_a U^2 / 2) \quad \text{for } 0 < Z < a \tag{12}$$

It is useful to think of the dynamic tension, equal everywhere, as "inflating" the loop. Like an inflated structure, then, the loop would collapse at those regions where the tension went to zero. Since the tension in the line is the sum of the dynamic and the drag tensions, this is possible. The tension of the outflow increases with distance from the line ranger outlet, according to eq.(12), but has a negative sign. The outflow will therefore reach its maximum extension when the line tension goes to zero, or when

$$F_a + F_d = 0, \quad \text{at outflow collapse} \tag{13}$$

By inserting eqs.(11), (12), and (8) into this simple relationship, it turns out that the critical loop extension, a_{max}, is expressed with elegance:

$$a_{max} = U_t^2 / g \tag{14}$$

There are other contributions to the line tension which have not been considered. These are the effect of gravity, and the way that moments are taken up. While these may be large effects, it has been shown by experiment that eq. (14) is valid for a limited range of situations, within ± 30%. At this early stage in line ranger development, further refinements upon this result don't seem necessary.

Experimental

Measurements in support of eqs. (7), (9), and (14) were made. The results now make it more likely that a given design of line ranger will perform as expected.

The measurements were made using both ribbon and line, whose properties are listed in Table I. Note that a wide range of characteristics were included; loop mass M varied over 1000:1, and terminal velocities varied over 7:1.

2.1 Drag Coefficients

By using eq.(8) drag coefficients C_f were calculated from the measured properties of lines #1 through #6. The natural logarithms of the C_f's and the associated Reynolds numbers were then tabulated in Table II below:

Table II

Case	C_f	$\ln C_f$	$\ln N_{re}$
#1	.00462	-5.38	16.1
#2	.00953	-4.65	15.2
#3	.00953	-4.65	14.3
#4	.0199	-3.92	13.7
#5	.0311	-3.47	12.6
#6	.0644	-2.74	12.2

The last two columns of this table were graphed as shown in Fig. 3. The straight line running among the points represents eq.(9), and is seen to be a reasonable fit to the data.

2.2 Aspect Ratio

The loops of cases #1 through #6 were run horizontally at various speed parameters greater than one, and the aspect ratio A measured. The results are listed in Table III, which points are also graphed in Fig. 4.

The straight line running among the points represents eq. (7), and is seen to reasonably fit the data.

Table I

Loop length 2a, cm (#)	Loop mass, M in grams	Mat'l.	Cross section x / y inches	Diam., ϕ, cm. (§)	Density ρ_o, gm cm^{-1}	Term. veloc., U_t, cm sec^{-1}	Loop N_{re} at U_t (*)
1000. #1	71.7	white nylon	.035 .424	.742	7.17×10^{-2}	3258	1.00×10^{7}
1000 #2	26.2	rayon cotton	.014 .473	.788	2.61×10^{-2}	1329	4.09×10^{6}
400 #3	10.42	"	"	"	"	"	1.64×10^{6}
400 #4	6.72	acetate rayon	.008 .490	.805	1.68×10^{-2}	729	8.97×10^{5}
225 #5	.490	nylon yarn	-	.191	2.18×10^{-3}	432	2.99×10^{5}
193 #6	.045	nylon suture	-	.018	2.33×10^{-4}	322	1.91×10^{5}

(§) The diameter for ribbons is taken to be that cylinder whose perimeter is equal to the perimeter of the tape, thus:

$$\phi = 2(x + y)/\pi$$

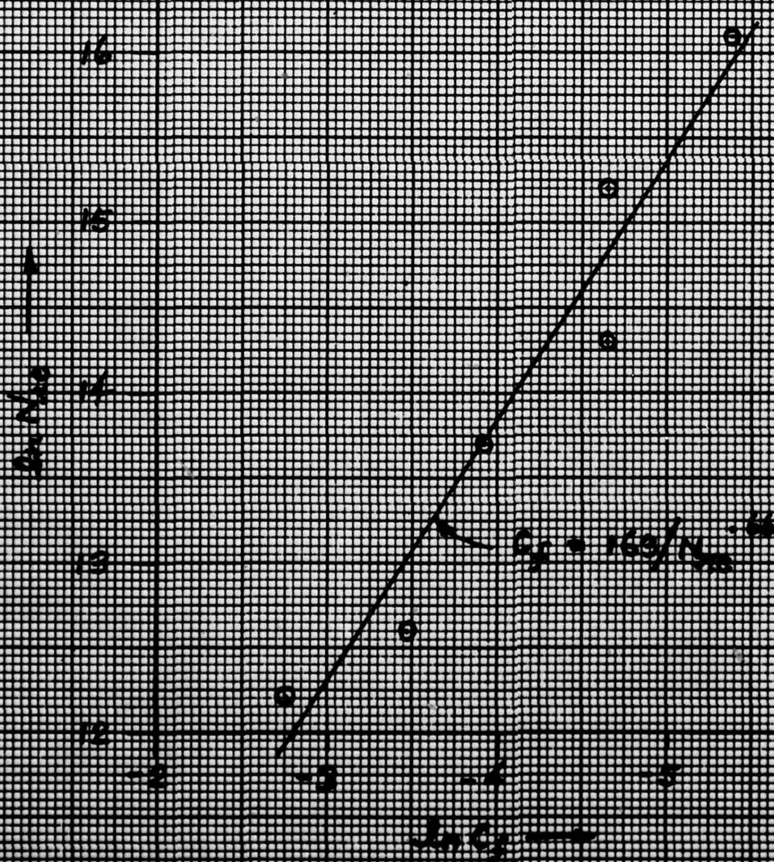
(*) The Reynolds number is found according to eq. (10) at the measured terminal velocity U_t as listed here.

(#) The loops are identified in later tables by the # number.

Table III

Case	S	A	Case	S	A
#1	1.30	2.18	#4	1.39	2.39
	1.68	4.02		1.68	3.67
	1.91	5.32		2.04	4.93
				2.57	7.88
#2	1.30	2.17		3.09	12.1
	1.70	3.58			
	2.31	7.04			
	2.82	10.7	#5	1.45	3.69
				1.90	5.53
#3	1.38	2.72		2.44	11.6
	1.59	3.84			
	1.96	5.63			
	2.31	7.51	#6	1.62	3.17
	2.86	9.85		2.40	9.50

FIG. 9



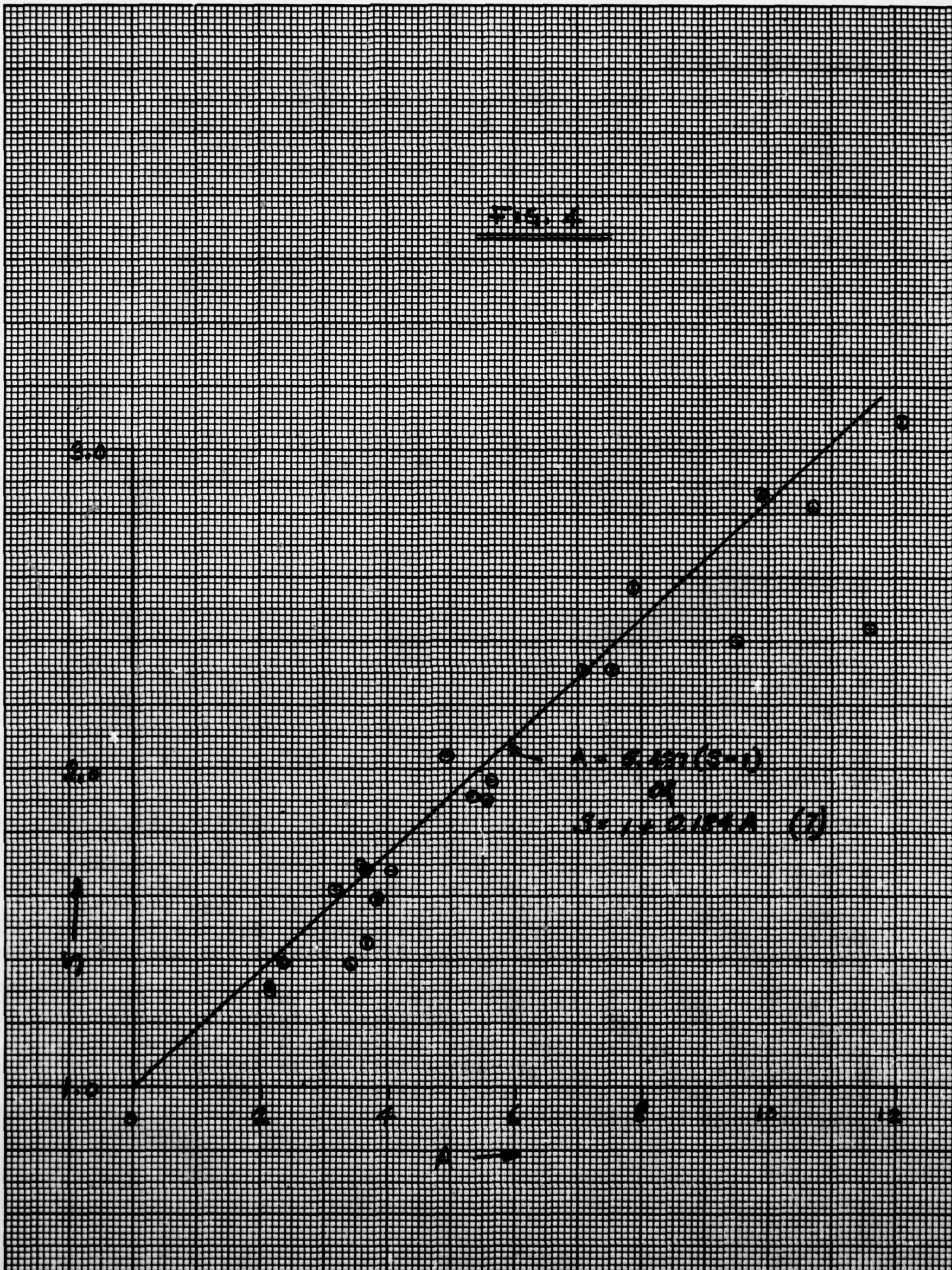


FIG. 4
3.0
2.0
1.0
S
0
2
4
6
8
10
12
A
A = 5.437(S−1)
or
S = 1 + 0.184A (7)

2.3 Length Limit

The experimental notes concerning cases #5 and #6 have remarks about the difficulty of avoiding loop collapse, or chaotic line flow near the tip of the extension. The notes comment that the suture of case #6 was practically impossible to erect stably.

A measure of how close to collapse a loop is can be formed as the ratio of the actual extension **a** over the maximum possible extension a_{max} given by eq. (14). This number has no dimensions, and is a measure of how close to chaotic line flow an erected loop is. We shall call it the chaos number, N_{ch}:

$$N_{ch} = a/a_{max} = a\left(U_t^2/\ g\right)^{-1} \tag{15}$$

The erected loops of cases #5 and #6 were operating at a chaos number of 0.59 and 0.92, respectively. Since collapse can be expected for $N_{ch} \gg 1$, it is easy to appreciate why these loops were difficult to erect.

2.4 Sudden Steps

The experiments reported here were carried out with two very different line throwing machines. One is adapted to throw ribbons, and has a vacuum sheave driven by a high speed motor. The other consists of an annular adjustable air orfice through which line is ejected by compressed air. These two machines are both well adapted to take a variety of lines, in contrast to the machine at the U.S.C.G. which can take only round line of limited range of diameter.

Further, these two experiment machines allow suddenly stopping the line inflow. By doing this maneouvre, the line outflow is also stopped, and consistent behaviour is seen. The outgoing line stops, but the incoming line jumps behind the machine retracting the far end of the loop. The impulse from stopping the outgoing line is absorbed by the machine. But the incoming line preserves its momentum and so flies behind the machine.

In the line ranger design given here, the inflow will be stopped but the outflow will decellerate relatively slowly as the storage sheaves lose their momentum. A purpose of building the line ranger prototype will be to investigate whether the outflow should stop this way, or whether some other program would be preferable.