HYDRAULIC DRAG FORCES ON SUCKER ROD STRINGS

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Introduction

Analytical procedures and techniques used to predict downhole forces for beam pumped wells are constantly evolving. Many individuals have contributed to this base of knowledge which has been instrumental in improving artificial lift equipment. It is the objective of this presentation to add to this pool of information which will, hopefully, result in bringing the industry a step closer to the optimization of lifting costs.

The objective of the following study was to quantify the hydraulic resistance acting on reciprocating rod strings--particularly on rod guides which are an important component of rod string designs. This resistance or drag force which occurs as production fluid flows around components of a rod string increases exponentially with pumping speeds. It was determined these drag forces can be a significant factor in proper rod string design.

Maximum hydraulic resistance occurs midway through the downstroke. In extreme cases, the effects of the fluid dynamics can become so great rod strings will "stack out" or float off the carrier bar.

The need to pump at higher rates is frequently associated with increasing water-oil ratios. As a result, the lubricating quality of the production fluid declines. Poor lubrication, coupled with greater rod string velocities, increase wear on rods and tubing which results in greater maintenance and repair costs.

Problems associated with increasing pumping speeds are compounded in wells with crooked holes and in wells with corrosive production fluids. Well bore deviation causes greater side loads and, subsequently, greater wear rates. Corrosion is accelerated as fluid turbulence increases around the components of a rod string.

One way to control M & R costs is to use rod guides and rod rotators. However, conventional rod guide designs, particularly the designs installed in the field, have a high resistance to flow which limits pumping speeds and reduces production efficiency.

As the speed and stroke length of conventional pumping units are increased, the forces resisting the downward motion of the rod strings can become the limiting factor in the amount of fluid that can be pumped. As the limit is approached, the minimum and maximum carrier bar loads diverge at an increasingly greater rate making it difficult, if not impossible, to effectively counterbalance the pumping unit. As a result, the overall efficiency of the production system declines - Figure 1.

Research

In analyzing the problem, it was recognized total resistance on the downstroke was caused by a combination of forces:

1. Mechanical friction resulting from contact between the rod string and tubing - (Figure 2)

2. "Hydraulic friction" or drag resulting from fluid flowing around the rod guides, sucker rods, and couplings - (Figure 6-11)

3. Buoyancy caused by the displacement of fluid by the rod string - (Figure 18-19)

In reviewing these forces, we began to realize very little was known about the hydraulic resistance associated with a rod string. We concluded it might be possible to reduce the overall resistance of the rod string by developing rod guides with lower drag. Therefore, it should be emphasized that the primary objective of this project was to quantify hydraulic resistance. The project did not address the mechanical friction which is a totally independent force.

We rationalized that the maximum hydraulic resistance should occur at the point of maximum velocity halfway through the downstroke on conventional pumping units. The equation to determine maximum velocity is developed in Figure 3.

A series of tests were conducted to measure the drag of various rod guide designs. Research was eventually extended to measure the drag generated by rod bodies and couplings, including the upsets and wrenching squares. The project culminated in the development of a new series of rod guides with significantly improved fluid dynamic properties.

The test apparatus used to conduct the flow tests is shown in Figure 5. The rod guide to be tested was mounted on aluminum tubing and held stationary. Water was pumped upward through the test stand to simulate a rod string's downward travel through the tubing. Flow rates were varied to cover a wide range of rod string velocities in 2", 2 1/2", and 3" tubing. However, only tests conducted in 2 1/2" tubing are included in this discussion.

The resulting forces were measured with a scale mounted on top of the test stand. Prior to each test, the test rod and rod guide were weighed at zero flow to compensate for buoyancy.

Once tests were completed, the drag coefficients for each rod guide were calculated using the equation in Figure 4. The test data was recorded and a drag force equation was tailored for each component of the rod string as shown in Figures 6-11. Drag force measurements were also plotted as shown in Figures 12 through 15.

Measurements were slightly greater than the actual drag of each rod string component by an amount equal to the pressure and frictional drag introduced by the tapered end and length of the test rod. This error was not corrected because the profile drag on the test rod proved to be very small relative to the induced drag generated by the rod guides, couplings, and upsets.

Drag measurements for steel rod couplings, rod bodies, and roller guides, were more difficult to obtain. Actual sucker rods, couplings, and roller guides were too heavy to test. Scales with enough capacity to weigh these components were not sensitive enough to accurately measure the incremental changes in weight. This problem was overcome by testing models machined from plastic.

Design and Development

The primary function of a rod guide is to prevent metal-to-metal contact between sucker rods and tubing. Design criteria for a rod guide are:

1. Maximum erodible wear volume (EWV)
2. Minimum total volume to EWV ratio
3. Minimum drag to EWV ratio
4. Minimum rate of wear
5. Minimum abrasion to metal
6. Maximum structural and impact strength
7. Maximum chemical and temperature resistance
8. Maximum bond to the sucker rod

Erodible wear volume (EWV) refers to the amount of rod guide material outside the O.D. of a rod coupling as illustrated in Figures 16-17. EWV represents the true investment in rod guides as it is all that prevents metal-to-metal contact. Once the volume outside the diameter of the largest metal part is eroded, the rod guide no longer offers the protection for which it was designed. To get the most from this investment, it is imperative the rod string be rotated to distribute wear evenly.

Selecting the design that would yield the minimum drag to EWV ratio became the objective. The equation in Figure 4 which predicts the drag of objects immersed in a flowing fluid was used as a primary design guide. Maximizing the area available for flow around the guide had obvious benefits because drag force varies directly with the square of the velocity. Rounding corners, coning the ends, and increasing the length to diameter ratio reduced cavitation and turbulence which produced a lower drag coefficient.

A review of fluid flow theory, coupled with trial and error testing, eventually led to the unavoidable conclusion that the length of conventional rod guides would have to be increased before significant improvements could be made in reducing the drag without sacrificing EWV. Increased length also meant increased manufacturing cost because the total volume of the rod guide had to be increased. It also meant significant investments in new molds and injection molding machines.

The test stand was modified and equipped with acrylic tubing which permitted observations and photographs of the flow tests. A small amount of compressed air injected into the water at the base of the test stand was very effective in making the streamlines visible. Inspection of the streamlines revealed separation points and subsequent cavitation on development models. This equipment was instrumental in the evolutionary process of selecting the optimum designs.

Comparisons of the drag forces generated by rod guides, rod bodies, and couplings are shown by graphs in Figures 12-15. Field installed guides, including roller guides, generate significantly more drag than rod guides that are molded directly to the sucker rods. These tests were conducted in water. In more viscous fluids, the magnitude of the drag forces would increase but the relative difference between components would remain the same.

Conclusions

Research is still in progress, but based on the studies which have been undertaken so far, it has been possible to produce an improved rod guide with lower drag and greater EWV. Much is still to be learned and we have only scratched the surface of organizing the work into a format that will hopefully aid in rod string design. However, some conclusions are already apparent.

1. Hydraulic resistance can be a significant factor as production volumes and fluid viscosity increase and should not be neglected in rod string design--particularly in the proper selection of rod guides.

2. Anything added to sucker rods, including couplings and rod guides increase drag. A continuous rod without connectors produces the lowest drag of all.

3. A low drag rod guide such as Huber's NETB will add less drag than a standard rod coupling.

4. A roller guide will add 4 to 5 times more drag than a NETB.

5. Field installed guides can add as much as 15 to 20 times more drag than a NETB.

6. Rod guides with the highest drag introduce the greatest amount of turbulence and increase the possibility of corrosion.

7. Depending on the pumping speed, sinker bars can generated large drag forces and their selection warrants careful analysis. The hydraulic resistance generated by sinker bars may be enough to significantly offset their weight. A better selection to prevent compression in a rod string on the downstroke may be conventional sucker rods with a high concentration of low drag rod guides.Also, sinker bars and roller guides have the obvious disadvantage of increasing the weight of a rod string which will increase the peak polished rod load on the upstroke.

Examples of how the information which has been developed by this project can be used are shown on the following pages. Work is still in progress to integrate these mathematical procedures into computer programs for the selection of rod guides. The illustrations contained here are only a sample of the tests Huber has conducted.

Example

Given:

12 SPM

120" Stroke Length

2 1/2", 6.5#/ft. Tubing

120 x 3/4" rods with Full Size (FS) couplings

Five (5) TB/rod

Three (3) DP/rod

Three (3) NETB/rod

One roller guide/rod

Required:

1. What is the maximum polished rod velocity?
2. What is the drag force for 100' of 3/4" sucker rods? For one 3/4" FS coupling? For one TB rod guide? For one DP rod guide? For one NETB rod guide? For one roller guide?
3. What is the total drag force generated by the sucker rods, rod guides, and couplings on the rod string with:
   (a) 120 sucker rods with 3/4" FS couplings and no guides
   (b) 5 - TB's/rod
   (c) 3 - DP's/rod
   (d) 3 - NETB's/rod
   (e) 120 - Roller guides
4. What is the erodible wear volume (EWV) for the rod string with:
   (a) 5 - TB's
   (b) 3 - DP's
   (c) 3 - NETB's
5. What is the drag force relative to the weight of the rod string with:
   (a) 120 - 3/4" FS couplings
   (b) 5 - TB's/rod
   (c) 3 - DP's/rod
   (d) 3 - NETB's/rod
   (e) 120 - Roller guides

Solution:

Maximum Velocity

$$V_{(MAX)} = \frac{\pi\,(SPM)\,(SL)}{12}$$

$$V_{(MAX)} = \frac{\pi\,(12)\,(120)}{12}$$

$$\boxed{V_{(MAX)} = 377\ FT/MIN}$$

Example

Drag Force Per Rod String Component

100 Ft. of 3/4" Sucker Rods $F = \frac{(C_D)\ (V_{MAX})^2}{1003831}$

$F = \frac{(78)\ (377)^2}{1003831}$

F= 11.04 LB_F per/100'

One - 3/4" FS Cplg. (Including upset and wrenching squares)

$F = \frac{(C_D)\ (V_{MAX})^2}{110575}$

$F = \frac{(1.10)\ (377)^2}{110575}$

F= 1.41 LB_F per Cplg

One - 2 1/2" TB

$F = \frac{(C_D)\ (V_{MAX})^2}{44220}$

$F = \frac{(0.75)\ (377)^2}{44220}$

F= 2.41 LB_F per TB

One - 2 1/2" DP

$F = \frac{(C_D)\ (V_{MAX})^2}{59477}$

$F = \frac{(0.84)\ (377)^2}{59477}$

F= 2.01 LB_F per DP

One - 2 1/2" NETB

$F = \frac{(C_D)\ (V_{MAX})^2}{69444}$

$F = \frac{(0.65)\ (377)^2}{69444}$

F= 1.33 LB_F per NETB

Example

One Roller Guide

$$F = \frac{(C_D)\ (V_{MAX})^2}{91926}$$

$$F = \frac{(2.67)\ \ (377)^2}{91926}$$

$F = 4.13\ LB_F$ per Guide

Total Drag Per Rod String

3/4" Sucker Rods w/FS couplings and no guides →	(120 cplgs) (1.41 LB_F/Cplg)	=	169 LB_F
	(120 rods) (25 Ft/ rod) (11.04 LB_F/100 Ft)	=	331 LB_F
	Total	=	500 LB_F
5 - TB's/rod →	(120 rods) (5 TB/rod) (2.41 LB_F/TB)	=	1446 LB_F
	(120 cplgs) (1.41 LB_F/Cplg)	=	169 LB_F
	(120 rods) (25 Ft/ rod) (11.04 LB_F/100 Ft)	=	331 LB_F
	Total	=	1946 LB_F
3 - DP's/rod →	(120 rods) (3 DP/rod) (2.01 LB_F/DP)	=	724 LB_F
	(120 cplgs) (1.41 LB_F/Cplg)	=	169 LB_F
	(120 rods) (25 Ft/ rod) (11.04 LB_F/100 Ft)	=	331 LB_F
	Total	=	1224 LB_F
3 - NETB's/rod →	(120 rods) (3 NETB/rod) (1.33 LB_F/NETB)	=	479 LB_F
	(120 cplgs) (1.41 LB_F/Cplg)	=	169 LB_F
	(120 rods) (25 Ft/ rod) (11.04 LB_F/100 Ft)	=	331 LB_F
	Total	=	979 LB_F
120 - Roller Guides →	(120 RG's) (4.13 LB_F/RG)	=	496 LB_F
	(120 rods) (25 Ft/ rod) (11.04 LB_F/100 Ft)	=	331 LB_F
	Total	=	827 LB_F

Example

Erodible Wear Volume (EWV)

5 - TB's/rod	→	(120 rods) (5 TB/rod) (37.53 cc/TB)	= 22518 cc
3 - DP's/rod	→	(120 rods) (3 DP/rod) (62.34 cc/DP)	= 22442 cc
3 - NETB's/rod	→	(120 rods) (3 NETB/rod) (67.68 cc/ NETB)	= 24365 cc

Weight of Rod Strings in Water

3/4" Sucker Rods w/FS Couplings and no guides	→	(120 rods) (25 Ft/ rod) (1.429 LB_F/Ft)	=	4287 LB_F
5 - TB's/rod	→	(120 rods) (25 Ft/rod) (1.429 LB_F/Ft)	=	4287 LB_F
		(120 rods) (5 TB/rod) (0.14 LB_F/TB)	=	84 LB_F
		Total	=	4371 LB_F
3 - DP's/rod	→	(120 rods) (25 Ft/rod) (1.429 LB_F/Ft)	=	4287 LB_F
		(120 rods) (3 DP/rod) (0.22 LB_F/DP)	=	79 LB_F
		Total	=	4366 LB_F
3 - NETB's/rod	→	(120 rods) (25 Ft/rod) (1.429 LB_F/Ft)	=	4287 LB_F
		(120 rods) (3 NETB/rod) (0.29 LB_F/NETB)	=	104 LB_F
		Total	=	4391 LB_F
120 - Roller Guides	→	(120 rods) (25 Ft/Rod) (1.429 LB_F/Ft)	=	4287 LB_F
		(120 RG's) (9.18 LB_F/RG)	=	1102 LB_F
		Less (120 Cplgs) (1.22 LB_F/Cplg)	=	(146)LB_F
		Total	=	5243 LB_F

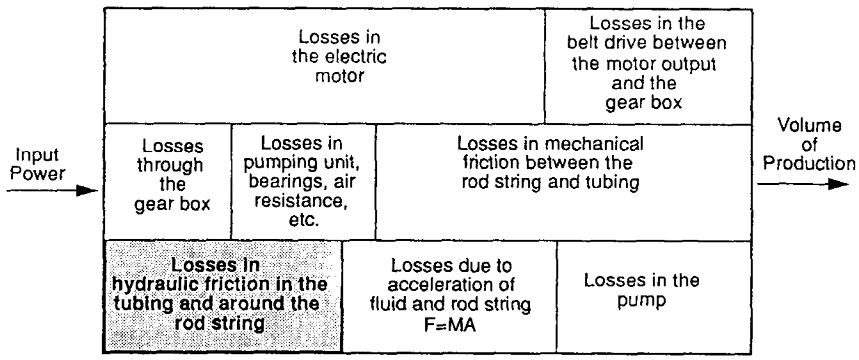
Example

Cost to Install Polyphenylene Sulfide (PPS) Rod Guides

5 TB's/rod	→	(120 rods) ($24.70/rod)	= $ 2,964
3 DP's/rod	→	(120 rods) ($24.50/rod)	= $ 2,940
3 NETB's/rod	→	(120 rods) ($24.50/rod)	= $ 2,940
120 - Roller Guides	→	(120 rods) ($160.00/rod)	= $ 19,200

Total Drag Relative to Weight of Rod String

3/4" FS Cplg only	→	500/4287 x 100	= 11.7%
5 TB's/rod	→	1946/4371 x 100	= 44.5%
3 DP's/rod	→	1224/4366 x 100	= 28.0%
3 NETB's/rod	→	979/4391 x 100	= 22.3%
120 - Roller Guides	→	827/5243 x 100	= 15.8%



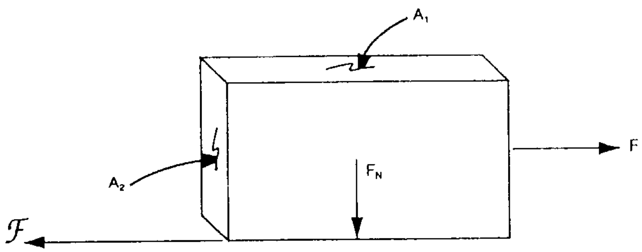
1. Hydraulic friction is developed as fluid flows around components of the rod string.

2. Mechanical friction is independent of hydraulic friction.

3. Hydraulic friction is most pronounced on the downstroke of the rod string.

Note: Chart similar to a diagram presented by Sam Gibbs, Nabla Corporation, at the July, 1991, SPE Forum in Crested Butte, Colorado.

Figure 1 - Beam pumping - production system efficiency

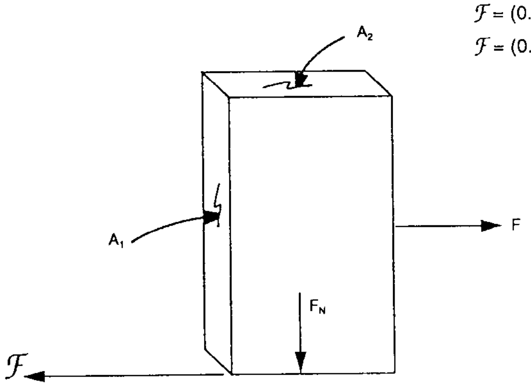


$\mathcal{F} = \mu F_N$

$A_1 > A_2$

Nylon/Steel in Water μ=0.16
Nylon/Steel in Oil μ=0.07

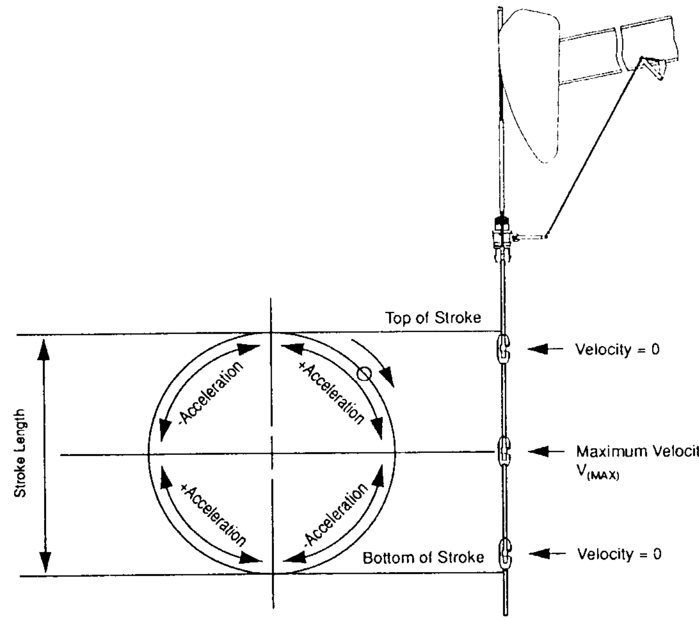
If F_N = 15LBF*
Then
$\mathcal{F} = (0.16)(15) = 2.4$LBF
$\mathcal{F} = (0.07)(15) = 1.1$LBF



$\mathcal{F} = \mu F_N$

* 15LBF is a value that was arbitrarily selected but that could be typical in wells with relatively straight and vertical holes. F_N values can easily exceed 200LBF in deviated wells

Figure 2 - Forces from mechanical friction are independent of the contact area between the rubbing surfaces



SL = Stroke Length, Inches
SPM = Number of Strokes Per Minute
T = Time in minutes for the pumping unit to make one stroke length down and one stroke length up or time to go (2) (SL).

$$V_{(AVG)} = \frac{\text{Distance}}{\text{Time}} \quad \begin{cases} \text{Distance} = \dfrac{(2)\,(SL)}{12}\ \text{FT} \\ \text{Time - Minute/Stroke} = \dfrac{1}{SPM} \end{cases}$$

$$V_{(AVG)} = \frac{(SL)\,(SPM)}{6}\ \text{Ft/Min}$$

$$V_{(MAX)} = \frac{\text{Distance}}{\text{Time}} \quad \begin{cases} \text{Distance} = \pi D = \dfrac{\pi\,(SL)}{12}\ \text{FT} \\ \text{Time - Minute/Stroke} = \dfrac{1}{SPM} \end{cases}$$

$$V_{(MAX)} = \frac{\pi\,(SL)\,(SPM)}{12}\ \text{Ft/Min}$$

Figure 3

$$F = \frac{1/2\ C_D\ \rho A V_G^2}{g_c}$$

Where:

F = Drag Force, LB_F

C_D = Drag Coefficient

ρ = Fluid Density, LB_M/FT^3

A = Projected area of the rod guide on a plane or the area the flowing fluid sees as it approaches the rod guide, FT^2

g_c = 32.2 $\frac{LB_M}{LB_F}$ Ft/SEC ^{2}

= 115,920 $\frac{LB_M}{LB_F}$ Ft/MIN^2

V_G = Velocity in the cross sectional area available for flow between the rod guide and inside of the tubing, FPM

Figure 4 - Equation used to determine drag force

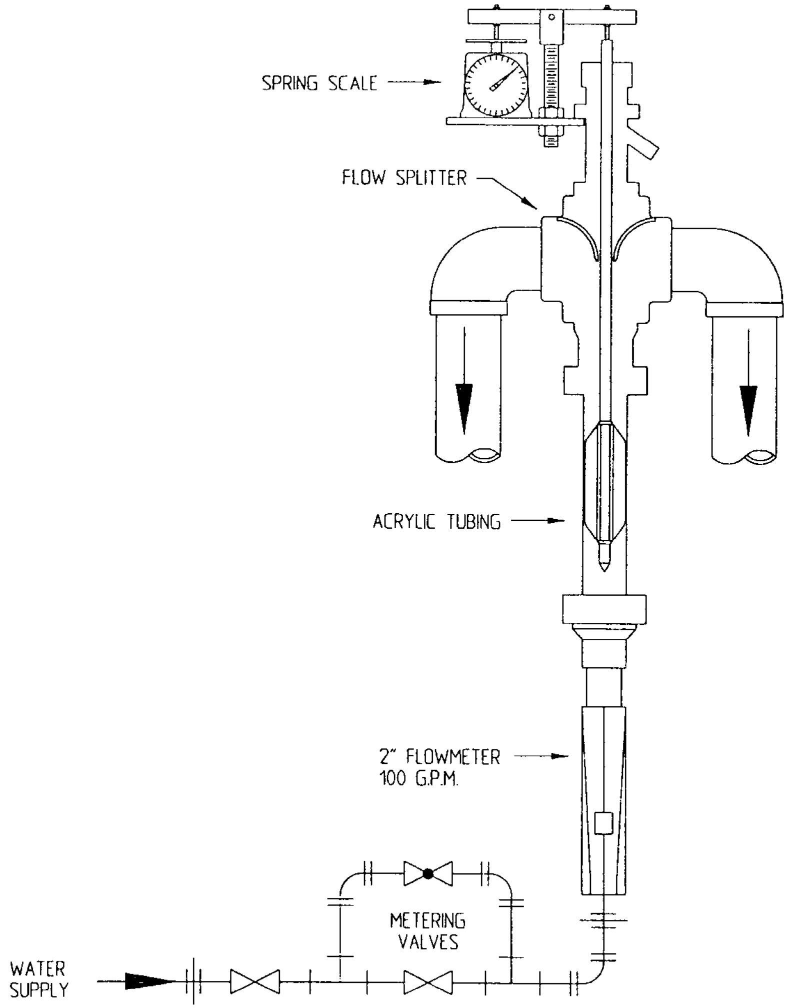
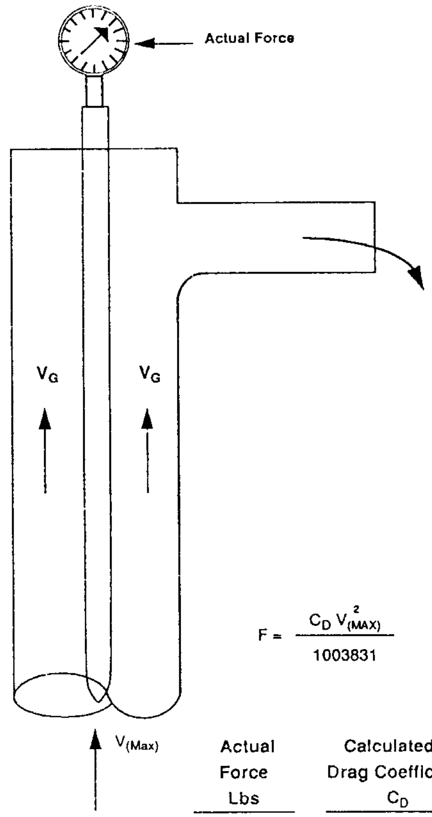


Figure 5 - Rod guide drag test apparatus

100 Ft. of 3/4" Sucker Rod Inside 2 1/2" Tubing

Note: Test results in water at ≈ 70° F



$$F = \frac{C_D V^2_{(MAX)}}{1003831}$$

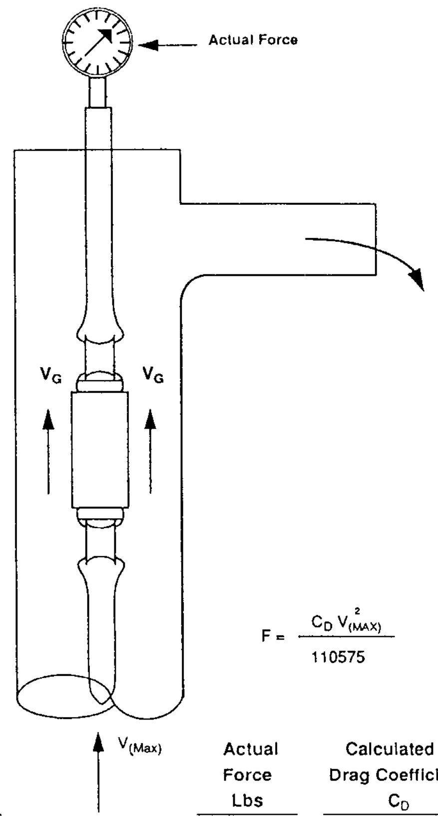
$V_{(MAX)}$ Ft/Min	V_G Ft/Min	Actual Force Lbs	Calculated Drag Coefficient C_D
195	214	2.29	60
233	256	3.44	63
272	299	4.59	62
311	342	7.27	75
350	384	9.56	78
389	427	11.86	79

Figure 6 - Test apparatus which simulates rods falling at various velocities in tubing filled with water

3/4" Rod w/Full Size Coupling* Inside 2 1/2" Tubing

* Coupling OD = 1 5/8"

Note: Test results in water at ≈ 70° F



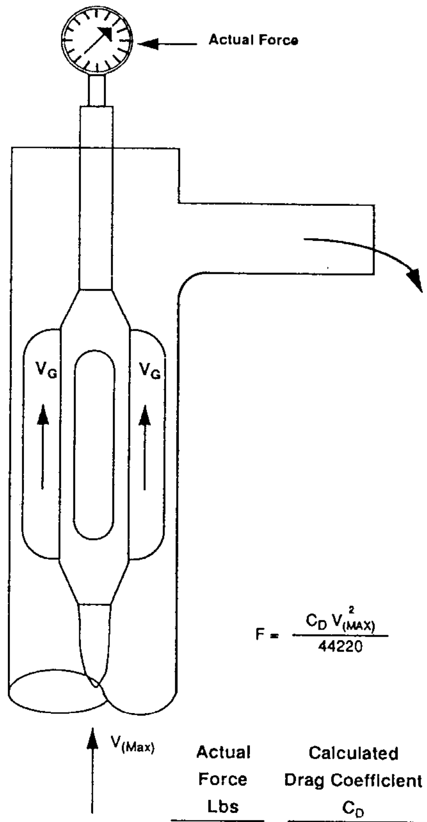
$$F = \frac{C_D V^2_{(MAX)}}{110575}$$

$V_{(MAX)}$ Ft/Min	V_G Ft/Min	Actual Force Lbs	Calculated Drag Coefficient C_D
78	134	-	-
117	201	0.19	1.53
156	268	0.31	1.41
195	335	0.45	1.31
233	402	0.61	1.24
272	469	0.80	1.20
311	536	1.00	1.14
350	603	1.20	1.08
389	670	1.53	1.12

Figure 7 - Test apparatus which simulates rods falling at various velocities in tubing filled with water

2 1/2" Huber Turbulence Breaker Inside 2 1/2" Tubing

Note: Test results in water at ≈ 70° F



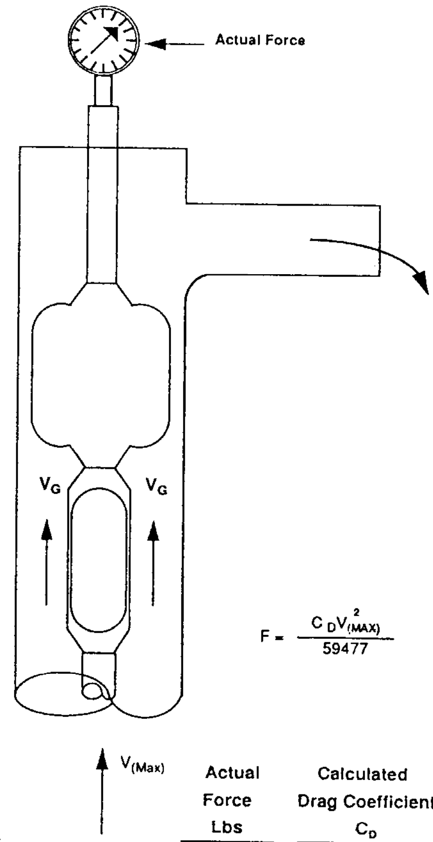
$$F = \frac{C_D V_{(MAX)}^2}{44220}$$

$V_{(MAX)}$ Ft/Min	V_G Ft/Min	Actual Force Lbs	Calculated Drag Coefficient C_D
156	354	0.50	0.91
195	443	0.69	0.80
233	532	0.88	0.71
272	620	1.25	0.75
311	709	1.69	0.77
350	797	2.19	0.79
389	886	2.56	0.75

Figure 8 - Test apparatus which simulates rods falling at various velocities in tubing filled with water

2 1/2" Patco Double Plus Inside 2 1/2" Tubing

Note: Test results in water at ≈ 70° F



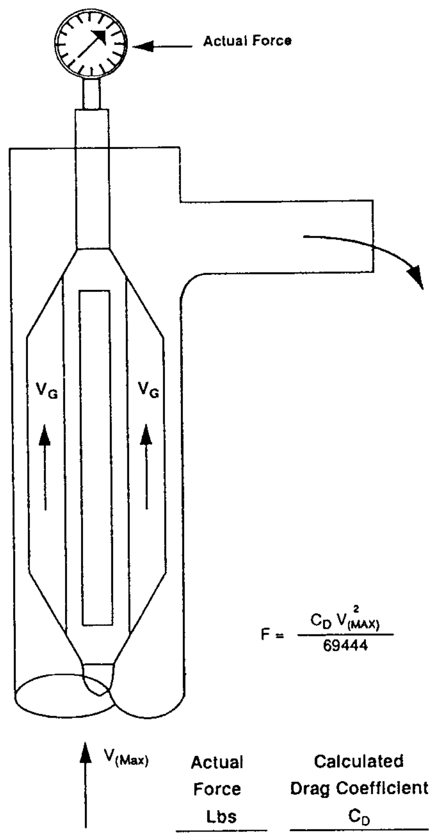
$$F = \frac{C_D V_{(MAX)}^2}{59477}$$

$V_{(MAX)}$ Ft/Min	V_G Ft/Min	Actual Force Lbs	Calculated Drag Coefficient C_D
156	275	0.38	0.92
195	344	0.56	0.88
233	413	0.75	0.82
272	482	1.06	0.85
311	550	1.38	0.84
350	619	1.75	0.85
389	688	2.19	0.86

Figure 9 - Test apparatus which simulates rods falling at various velocities in tubing filled with water

2 1/2" Huber NETB
Inside 2 1/2" Tubing

Note: Test results in water at ≈ 70° F



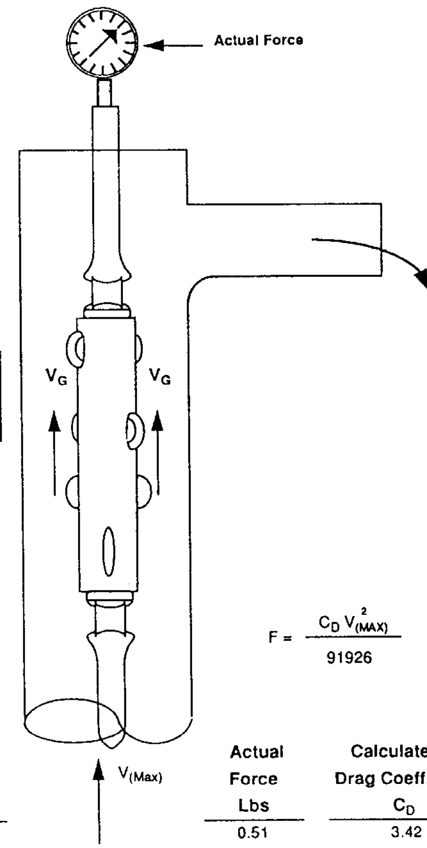
$$F = \frac{C_D V_{(MAX)}^2}{69444}$$

$V_{(MAX)}$ Ft/Min	V_G Ft/Min	Actual Force Lbs	Calculated Drag Coefficient C_D
156	306	0.22	0.63
195	383	0.31	0.57
233	460	0.49	0.62
272	536	0.69	0.65
311	613	0.94	0.67
350	689	1.16	0.66
389	766	1.43	0.66

Figure 10 - Test apparatus which simulates rods falling at various velocities in tubing filled with water

27" Long, 4 Wheels, 1 1/2" O.D.
Roller Guide for 3/4" Rods
Inside 2 1/2" Tubing

Note: Test results in water at ≈ 70° F



$$F = \frac{C_D V_{(MAX)}^2}{91926}$$

$V_{(MAX)}$ Ft/Min	V_G Ft/Min	Actual Force Lbs	Calculated Drag Coefficient C_D
117	182	0.51	3.42
156	242	0.75	2.83
195	303	1.13	2.73
233	363	1.58	2.68
272	424	2.11	2.62
311	484	2.81	2.67
350	545	3.56	2.67
389	605	4.56	2.77

Figure 11 - Test apparatus which simulates rods falling at various velocities in tubing filled with water

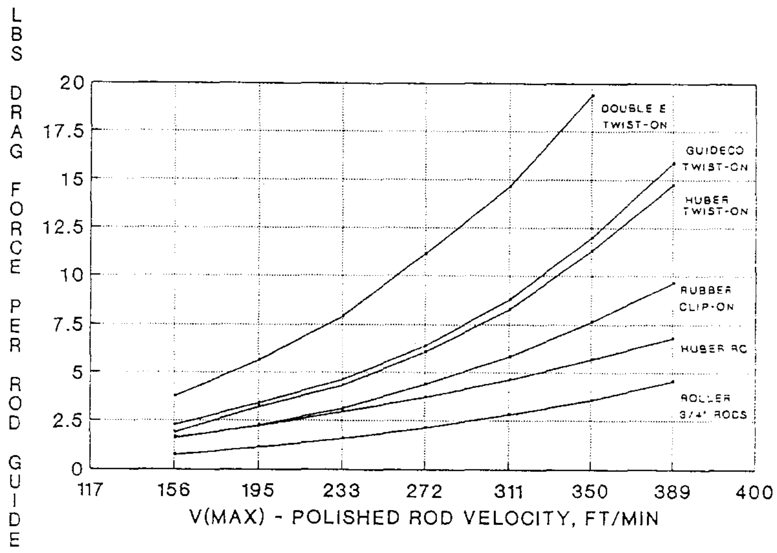


Figure 12 - Hydraulic drag forces for 2-1/2" field-installed rod guides inside water-filled 2-1/2" tubing

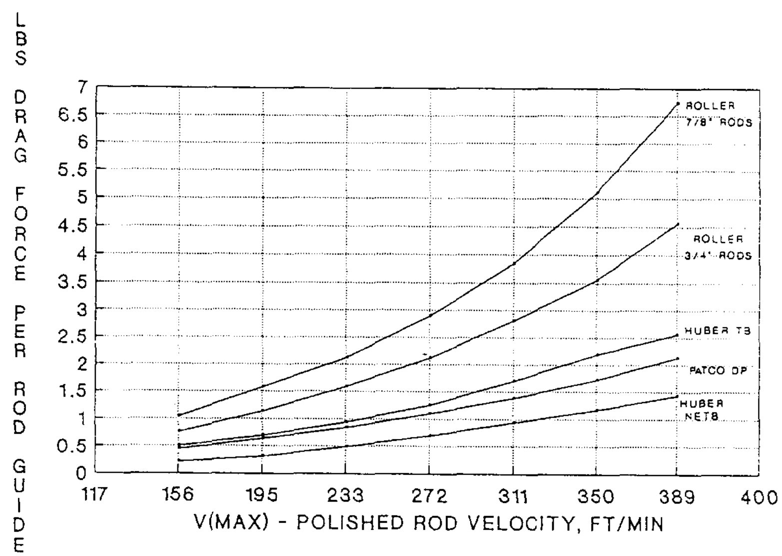


Figure 13 - Hydraulic drag forces for 2-1/2" mold-on and roller rod guides inside water-filled 2-1/2" tubing

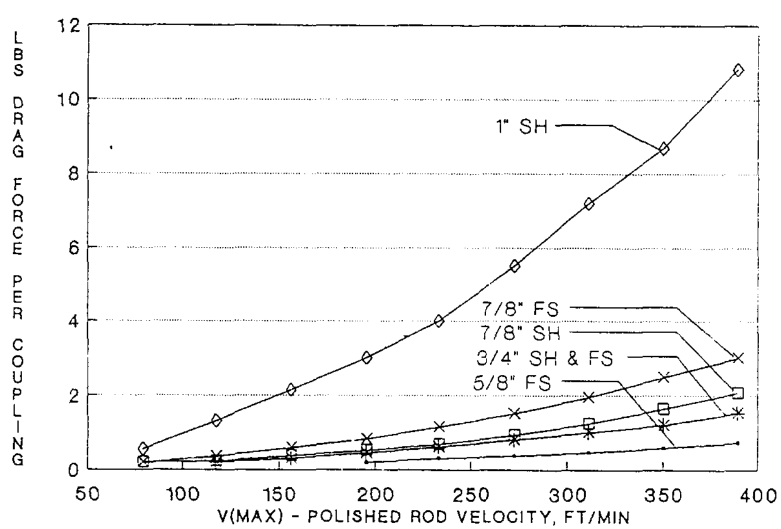


Figure 14 - Hydraulic drag forces for rod couplings inside water-filled 2-1/2" tubing

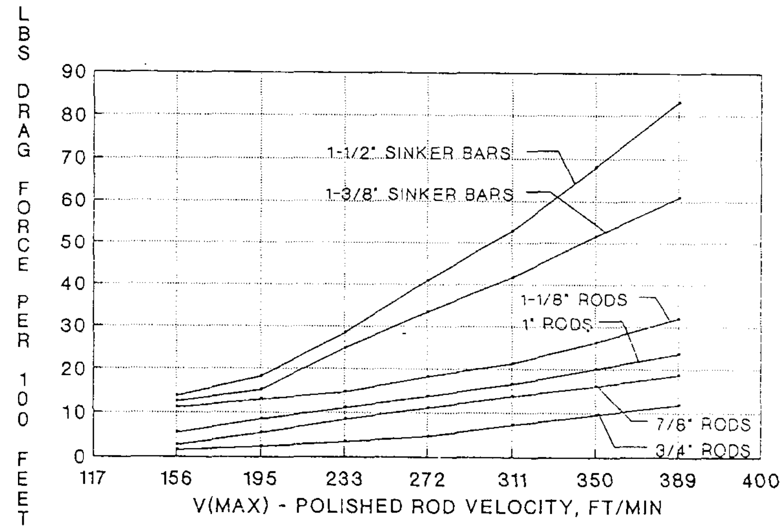


Figure 15 - Hydraulic drag forces for sucker rod and sinker bar bodies in water-filled 2-1/2" tubing

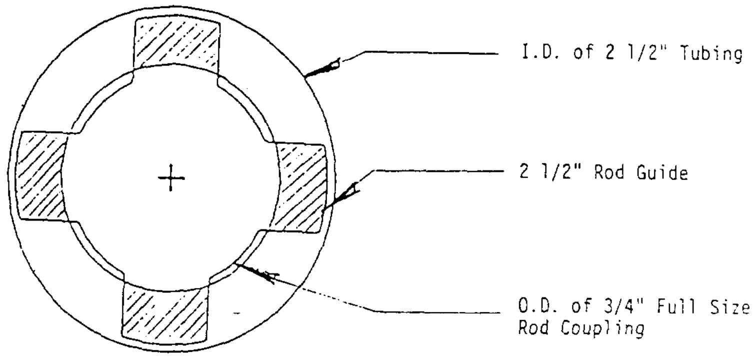


Figure 16

Comparison Chart
Cubic Centimeters
(Cubic Inches)

Rod x Tubing	TB	DP*	NETB
5/8" FS x 2"	17.37 (1.06)	33.81 (2.063)	35.17 (2.146)
3/4" FS x 2"	11.96 (0.73)	22.96 (1.401)	23.86 (1.456)
7/8" SH x 2"	11.96 (0.73)	22.96 (1.401)	23.86 (1.456)
3/4" FS x 2 1/2"	37.53 (2.29)	62.34 (3.804)	67.68 (4.13)
7/8" FS x 2 1/2"	26.06 (1.59)	45.11 (2.753)	47.85 (2.92)
1" SH x 2 1/2"	13.60 (0.83)	28.42 (1.734)	29.17 (1.78)
7/8" FS x 3"	64.73 (3.95)	158.30 (9.66)	161.90 (9.88)
1" FS x 3"	37.85 (2.31)	99.31 (6.06)	99.81 (6.06)
1" SH x 3"	50.80 (3.10)	128.15** (7.82)	133.06 (8.12)

* *Published by Patco*
** Calculated

Figure 17 - Erodible wear volume (EWV) - comparison chart

Displacement Volumes for Sucker Rods Including Upsets and Full Size (FS) Couplings

25 Ft. Rods

Rod Size	Gallons/100'
5/8	1.733
3/4	2.459
7/8	3.312
1	4.352
1 1/8	5.589

30 Ft. Rods

Rod Size	Gallons/90'
5/8	N/A
3/4	2.193
7/8	2.955
1	3.879
1 1/8	4.993

Weight of Sucker Rods and Full Size (FS) Couplings in Air

Rod Size	Lbs/Ft
5/8	1.142
3/4	1.634
7/8	2.224
1	2.904
1 1/8	3.670

Rod Size	Lbs/Ft
5/8	N/A
3/4	1.615
7/8	2.198
1	2.870
1 1/8	3.628

Weight of Sucker Rods and Full Size (FS) Couplings In Fresh Water

(Density = 8.33 lb/gal or specific gravity = 1.0)

Rod Size	Lbs/Ft
5/8	0.998
3/4	1.429
7/8	1.948
1	2.541
1 1/8	3.204

Rod Size	Lbs/Ft
5/8	N/A
3/4	1.412
7/8	1.924
1	2.511
1 1/8	3.166

Figure 18 - Sucker rod weights with full size couplings

Sucker Rod Full Size (FS) Coupling Dimensional and Weight Data

Rod Size	O.D. Inches	Length Inches	Wt. In Air Lbs.	Displacement Volume (1) In^3	Weight In Water (2) Lbs.
5/8	1 1/2	4	1.27	4.4328	1.11
3/4	1 5/8	4	1.39	4.8517	1.22
7/8	$1\frac{13}{16}$	4	1.72	6.0035	1.50
1	2 (3)	4	2.71	9.4590	2.37
1	2 3/16	4	3.42	11.9372	2.99

Roller Guide Dimensional and Weight Data for 2 7/8" Tubing

Rod Size	O.D. Inches	Length Inches	Wt. In Air (4) Lbs.	Displacement Volume (1) In^3	Weight In Water (2) Lbs.
5/8 x 2.25 (5)	1 1/2	27	10.13	35.3578	8.85
3/4 x 2.25 (5)	1 1/2	27	10.50	36.6492	9.18
7/8 x 2.25 (5)	1 5/8	27	11.31	39.4764	9.89

Injected Molded PPS(6) Rod Guide Dimensional and Weight Data for 2 7/8" Tubing and 3/4" Rods

Rod Guide	O.D. Inches	Length Inches	Wt. In Air Lbs.	Displacement Volume In^3	Weight In Water (2) Lbs.
Huber TB	2.300	4.25	0.39	6.8350	0.14
Huber NETB	2.325	8.50	0.77	13.3030	0.29
Patco DP	2.300	7.00	0.58	10.0690	0.22

(1) Based on density of steel = 0.2865 lbs/in^3
(2) Specific Gravity = 1.0...Density = 8.33 lbs/gal
(3) Slimhole (SH) Coupling
(4) Published by Oilfield Improvements
(5) Wheel diameter, inches
(6) Polyphenylene Sulfide (PPS) SG = 1.6

Figure 19