MEASURED ROD STRING/TUBING WEAR AND ASSOCIATED SIDE LOADING

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Abstract

The Petroleum Industry has been aware of rod string and tubing wear ever since the first installation of steel sucker rods in production tubing. The associated rod string and tubing wear from this lift system continues to impact the ability of the Industry to economically produce oil and gas.

The downstroke phenomenon of sucker rod string compression, buckling, sucker rod and tubing contact and associated sucker rod and tubing wear is becoming more clearly defined. (1,2,3)

This paper will provide the Petroleum Industry with a more accurate understanding of sucker rod and tubing wear resulting from sucker rod side loading initiated by downstroke sucker rod buckling. This paper will present a description of test equipment and test parameters resulting in the following;

1. Calculated cycles to 100% tubing wall loss vs. side loading.
2. Calculated cycles to 100% sucker rod diameter loss vs. side loading.
3. Calculated cycles to 100% sinkerbar diameter loss vs. side loading.

A better understanding of sucker rod and tubing wear will provide the Industry with better sucker rod string design guidelines. Use of these guidelines can reduce costly sucker rod and tubing wear and failures that impact the ability of the Petroleum Industry to economically produce oil and gas.

Test Equipment

The test equipment designed for this experiment simulated vertical sucker rod and tubing wear in a horizontal configuration. The tubing reciprocated in a horizontal plane, while the rods and sinkerbars were loaded during the full stroke with various static loads. These static loads were selected to simulate side loads acting on the interior wall of production tubing during lift operations. This test equipment was designed to handle four (4) separate test configurations of rods and sinkerbars in tubing. All four (4) test configurations were submerged in two (2) separate containment vessels to simulate rod string and tubing wear in liquid environments.

Test Parameters

The test parameters for this experiment were selected to simulate as close as possible rod string and tubing wear experienced by rod strings operating in compression in tubing. The selected test parameters are listed as follows;

1.	Tubing;	2-7/8" OD, 6.50#, J-55 Normal, 0.217 Wall API 5CT Normalized J55, Electric Resistance Weld	
2.	Rods;	0.75" OD, 1.634#, API Grade-C 1.00" OD, 2.904#, API Grade-C	
	Sinkerbars;	1.50" OD, 6.000#, API Grade-C 1.75" OD, 8.200#, API Grade-C	
3.	Average Tubing Velocity;	1,044 Inch./Min. Stokes per Minute; Stroke Length;	 43.5 Spm 12.0 Inch.
4.	Side Loads;	250 lbs. 200 lbs. 150 lbs. 100 lbs. 50 lbs.	
5.	Test Fluid;	Fresh Water - Odessa, Texas	
6.	Testing Period;	0 - 90,000 Cycles	

Measurement Equipment;

1.	Wall and Diameter;	Micrometer Caliper, 0 - 4 Inch. with 0.002 Inch. ball point for curvature measurements L.S. Starrett, +/- 0.001 Inch.
2.	Weight;	Electronic Scale, 0 - 10,000 Gram Ohaus Manufacturing, +/- 0.1 Gram

Test Procedure;

The following test procedure was repeated with 50 lbs. incremental side loads, beginning with 250 lbs. and ending at 50 lbs.

Test Procedure; - Continued

1. Initial tubing wall thickness was measured at five (5) points along the bottom of four (4) samples of 2-7/8" tubing. These five (5) points were averaged to establish an average, initial wall thickness.

2. Initial rod and sinkerbar diameters were measured at four (4) points and averaged to establish average, initial rod and sinkerbar diameters. A 0.750" rod, 1.00" rod, 1.50" sinkerbar and 1.75" sinkerbar were tested for each side load.

3. The initial tubing, rod and sinkerbar weights were measured to assist in validation of wall thickness and diameter measurements.

4. Testing was repeated and compared at intervals of 15, 30, 45, 60, 75, and 90,000 cycles.

5. An independent, third party engineering laboratory was utilized to measure and record all data gathered throughout this test procedure.

Calculation Of Test Results;

1. Tubing wall loss was calculated and reported as percent of average, original wall thickness.

2. Rod and sinkerbar diameter loss was calculated and reported as percent of average, original rod and sinkerbar diameter.

3. At each side load, cycles to 100% tubing wall loss were calculated by extrapolation using a sum of least squares linear equation for 0.75" rods, 1.00" rods, 1.50" sinkerbars and 1.75" sinkerbars.

   (Refer to figure 1.0 for percent tubing wall loss extrapolation)

4. At each side load, cycles to 100% rod and sinkerbar diameter loss were calculated by extrapolation using a sum of least squares linear equation for 0.75" rods, 1.00" rods, 1.50" sinkerbars and 1.75" sinkerbars.

   (Refer to figure 2.0 for sucker rod and sinkerbar diameter loss extrapolation)

5. At each side load, cycles to 100% tubing wall loss and cycles to 100% rod and sinkerbar diameter loss were plotted for 0.75" rods, 1.00" rods, 1.50" sinkerbars and 1.75" sinkerbars.

   (Refer to figure 3.0 for cycles to 100% tubing wall loss)

   (Refer to figure 4.0 for cycles to 100% rod and sinkerbar diameter loss)

Calculation Of Test Results; - Continued

6. A repeatability test was conducted with a 50 lbs. side load on each of the four (4) independent test arms. Tubing wall loss, rod and sinkerbar diameter loss was measured with each test arm containing a 1.50" sinkerbar loaded in 2-7/8" tubing.

   (Refer to figure 5.0 for repeatability of percent tubing wall loss at a standard deviation of 1.6)

   (Refer to figure 6.0 for repeatability of 1.5" sinkerbar diameter loss at a standard deviation of 1.1)

Results Of Testing;

1. The following changes in 2-7/8" tubing wall life resulted, when 1.75" sinkerbars, 1.50" sinkerbars and 1.00" sucker rods were compared to 0.75" sucker rods at various side loads. (Refer to figure 3.0)

50 lbs. Side Load	1.75" sinkerbars	-	297 % increase
	1.50" sinkerbars	-	217 % increase
	1.00" rods	-	18 % increase
100 lbs. Side Load	1.75" sinkerbars	-	46 % increase
	1.50" sinkerbars	-	94 % increase
	1.00" rods	-	36 % increase
150-250 lbs. Side Load	1.75" sinkerbars	-	48 % increase
	1.50" sinkerbars	-	28 % increase
	1.00" rods	-	17 % decrease

2. The following changes in sucker rod and sinkerbar life in 2-7/8" tubing resulted, when 1.75" sinkerbars, 1.50" sinkerbars and 1.00" sucker rods were compared to 0.75" sucker rods at various side loads. (Refer to figure 4.0)

50 lbs. Side Load	1.75" sinkerbars	-	467 % increase
	1.50" sinkerbars	-	555 % increase
	1.00" rods	-	19 % increase
100 lbs. Side Load	1.75" sinkerbars	-	232 % increase
	1.50" sinkerbars	-	232 % increase
	1.00" rods	-	24 % increase
150-250 Lbs. Side Load	1.75" sinkerbars	-	89 % increase
	1.50" sinkerbars	-	77 % increase
	1.00" rods	-	18 % decrease

Results Of Testing; - Continued

3. The following changes in average, 2-7/8" tubing wall life, regardless of sucker rod or sinkerbar diameter resulted, when average wall life at 50 lbs. and 100 lbs. side loads were compared to average wall life at 150-250 lbs. side load.

   Average Tubing Wall Life, 50 lbs. Side Load; 467 % increase

   Average Tubing Wall Life, 100 lbs. Side Load; 17 % increase

4. The following changes in average, sucker rod and sinkerbar life in 2-7/8" tubing, regardless of outside diameter resulted, when average rod and sinkerbar life at 50 lbs. and 100 lbs. side loads were compared to average sucker rod and sinkerbar life at 150-250 lbs. side load.

   Average Sucker Rod and Sinkerbar Life, 50 lbs. Side Load 544 % increase

   Average Sucker Rod and Sinkerbar life, 100 lbs. Side load 36 % increase

Conclusions;

1. Large diameter sinkerbars, when subject to side loading can be expected to maximize 2-7/8" tubing wall life, compared to smaller diameter sucker rods.

2. Large diameter sinkerbars, when subject to side loading can be expected to maximize rod string life in those areas where side loading exists, compared smaller diameter sucker rods.

3. Side loads of less than 100 lbs. can increase the life of 2-7/8" tubing, sucker rods and sinkerbars.

(1) "Solving Rod Buckling" - Gregory L. Mendenhall, and Russ Ott.
(2) "Downhole Dynamometer Update" - Glenn Albert
(3) "Euler Loads and Measured Sucker Rod Buckling" - Scott W. Long, P.E., and Donald W. Bennett

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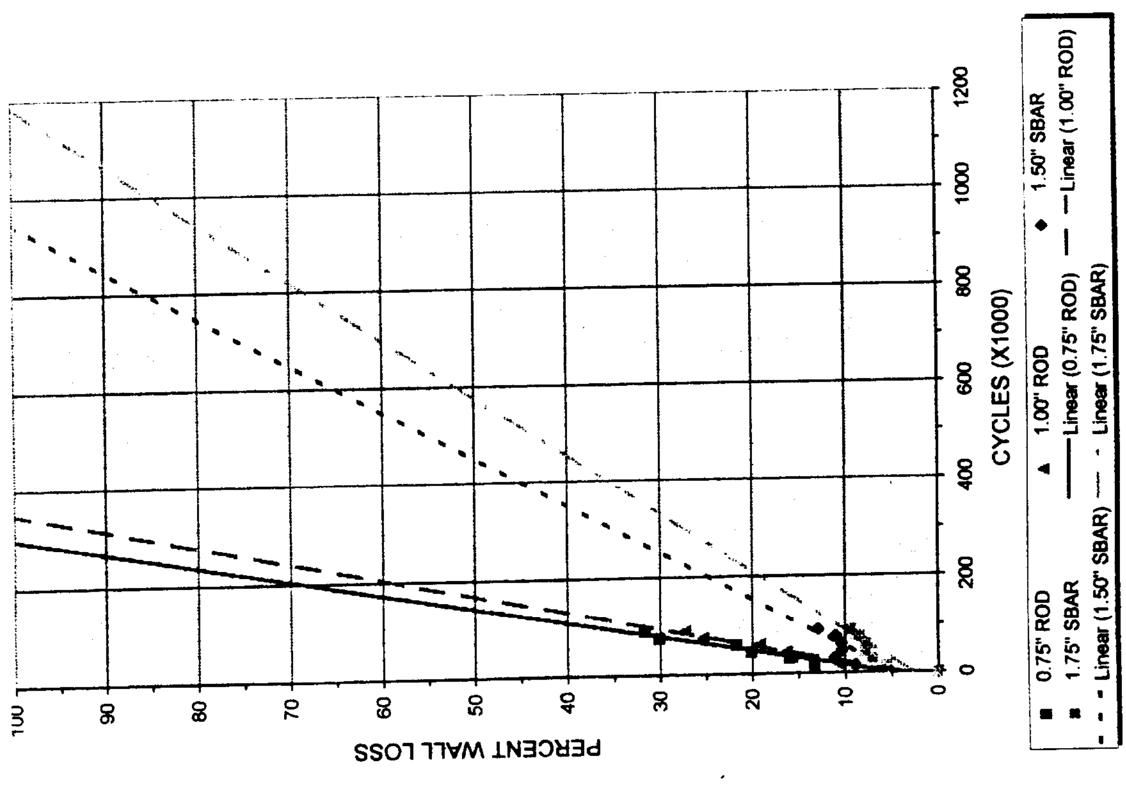

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Figure 1 - Per 2-7/8" Tubing Wall Loss at 50 Lbs. Side Load

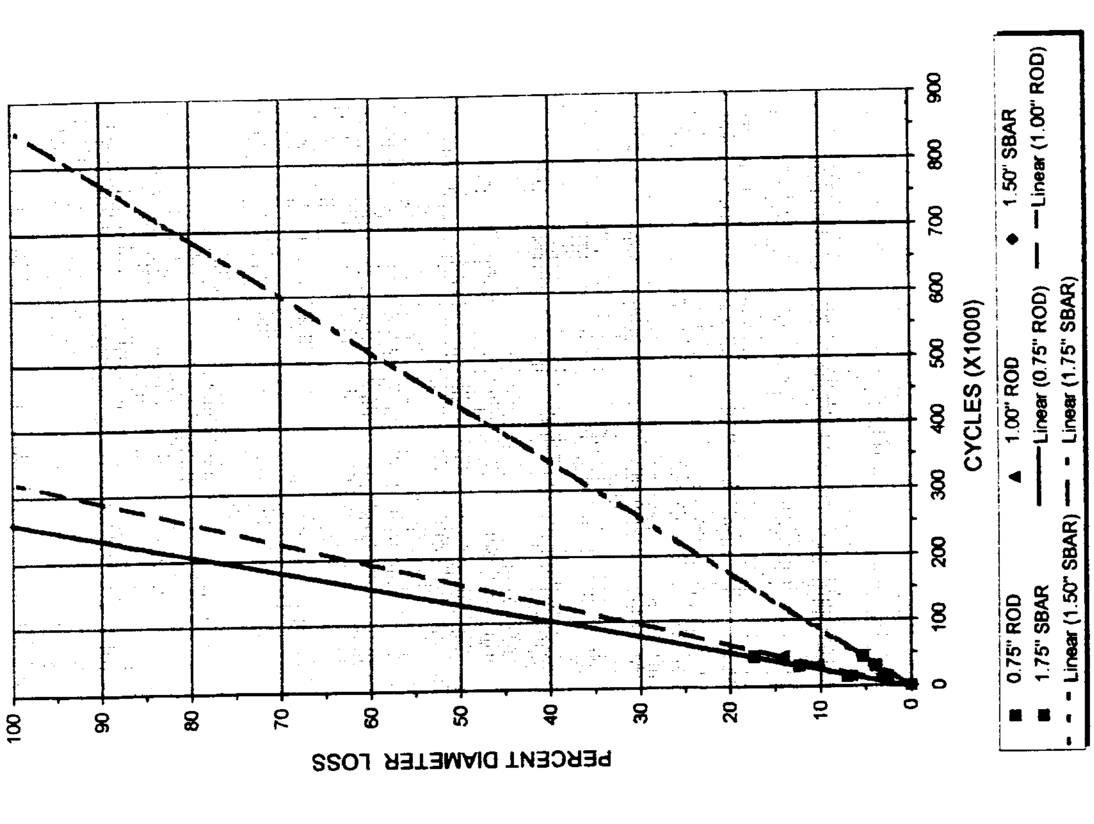

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Figure 2 - Percent Rod/Sinkerbar Diameter Loss at 100 Lbs. Side Load

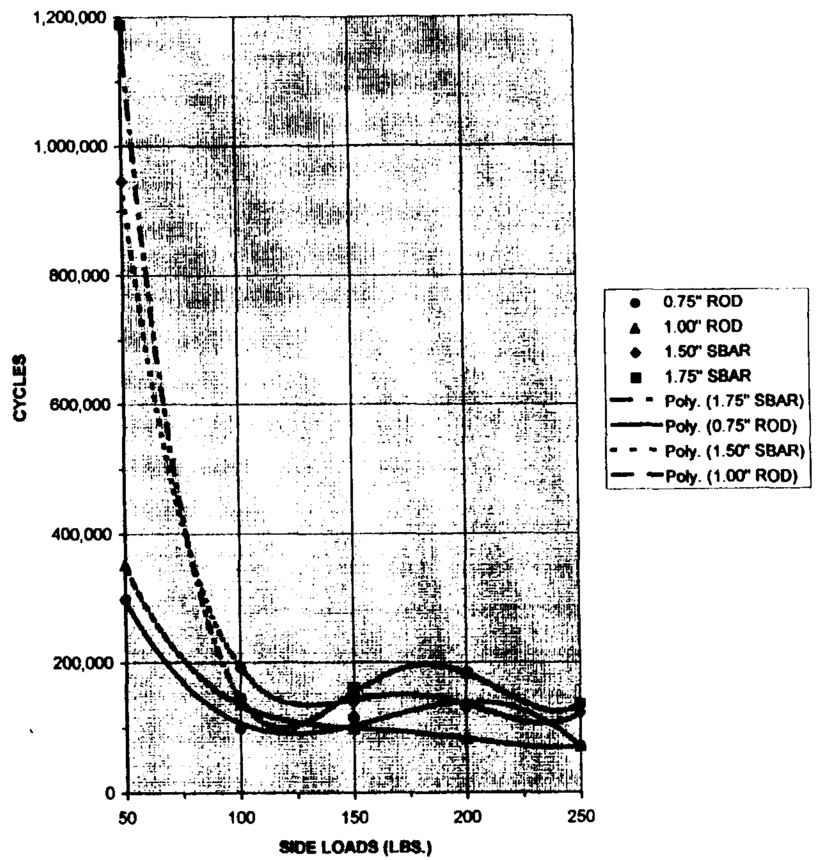

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Figure 3 - Cycles to 100% Tubing Wall Loss at Various Side Loads in 2-7/8" Tubing

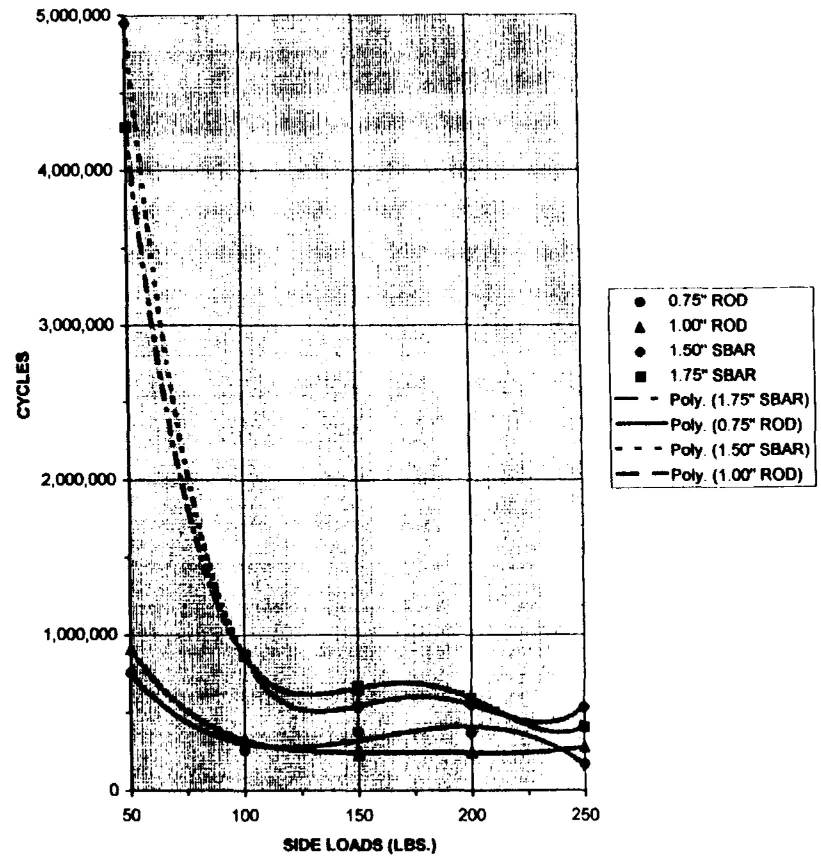

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Figure 4 - Cycles to 100% Rod/Sinkerbar Diameter Loss at Various Side Loads

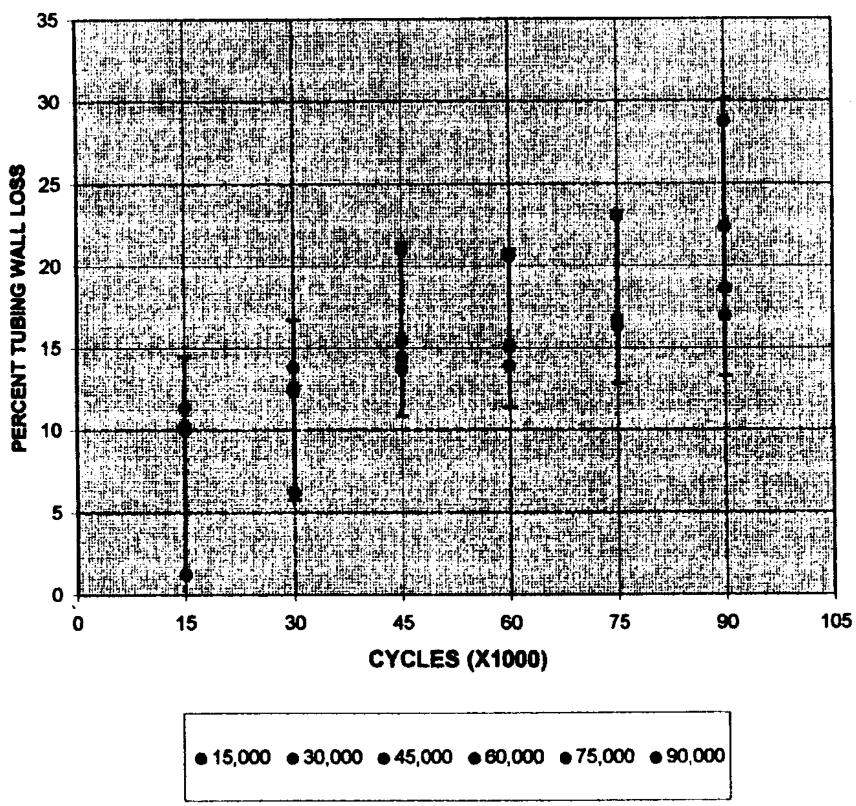

Figure 5 - Percent 2-7/8" Tubing Wall Loss 50 Lbs.
Validation Test 1.6 Standard Deviation

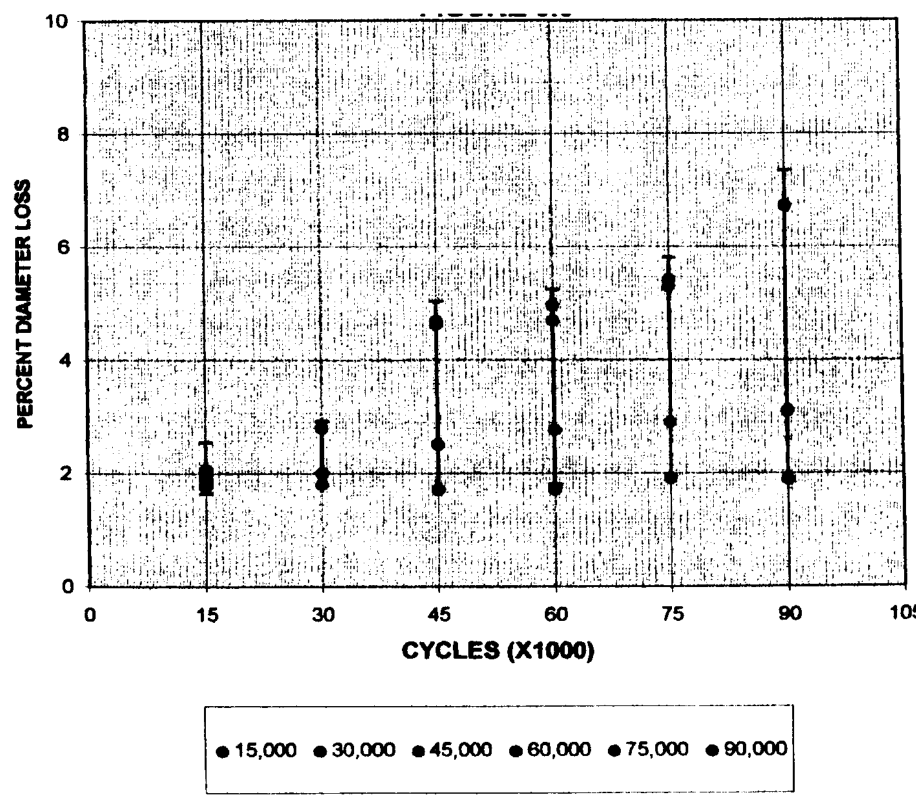

Figure 6 - Percent of 1.5" Sinkerbar Diameter Loss
50 Lbs. Validation Test 1.1 Standard Deviation