# HIGH VOLUME SUCKER ROD LIFT – HOW HIGH IS HIGH?

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## ABTRACT

Sucker rod lift (SRL) has been used in a majority of artificially lift wells for many decades. The many attributes of SRL for maximizing drawdown and providing the most ultimate recovery continues to make this the method used the most on any lifted well provided the lifted volumes at the installed depth is within the equipment capabilities. This paper will provide a look back of published graphs showing net effect lift versus well depth. Additionally, new considerations of pumping unit types, configurations, and available pump sizes will be included in new rod string designs to determine the current high volume lift capabilities with well depths to 20,000 ft.

## INTRODUCTION

The first parameter to consider when selecting an artificial lift method for a well or field development is the amount of produced fluid that will have to be lifted from the net effective depth. This is somewhat different than considering just the pump setting depth since the net effective depth includes the energy remaining in the well being able to help lift some fluid. However, to be conservative in design for sucker rod lift, since this method is the only method that can draw a well down the greatest, is to consider no benefit from the well. Also, it should be considered for design that the pump setting depth is at or even below the lowest perforations. This will provide the most work necessary to lift the desired fluid to the surface and have sufficient pressure to overcome the surface flowline and surface separator or tanks back pressure. In design, this is known as using H = L, or the pump depth is at the perfs and there is no fluid above the pump after the well is shut in.

There are a few traditional, high volume lift methods. These include gas lift, electric submersible pump (ESP), and hydraulic jet pump. The traditional lower volume lift methods include plunger lift, intermittent gas lift, progressing cavity pump, hydraulic reciprocating pump, and sucker rod lift.  The difficulty comes in determining the true lift capabilities for each method in order to then consider the other selection criteria parameters to ultimately determine the best method to use.

## LIFT METHOD GRAPHS

Weatherford has published a lift method comparison chart for the traditional lift methods which has long been used as a starting point for selection considerations[1]. The best graphs to consider normally split the lift methods into high volume and lower volume capabilities. Figures 1and 2 provide these graphs. One of the problems with these graphs is that there is no record of the design considerations for each method to determine the maximum lift volume at depth.

Previously, Mr. J. Clegg published comparisons of high rate lift[2]. This included comparing gas lift to ESP and SRL. The graph for sucker rod lift is shown in Figure 3. In this paper, the design limitations for SRL were listed. These included:

- 4,000 bfpd from 1500’
- 1,000 bfpd from 4000’
- Largest conventional ~1988 was C912-365-168
- Rod grades: C, D, & E (extra high strength, non API )
- Taper: 86

While this list of design assumptions is useful to compare current equipment capabilities, not all of the major design parameters are listed.

## SUCKER ROD LIFT EQUIPMENT CONSIDERATION

The major design consideration for SRL includes:

- Casing size
- Tubing size
- L = Pump seating depth
- H = Net Effective Lift
- PD (S, N, & D)
- Pump plunger diameter
- Pump stresses (Hein & Loudermilk SPE 24552, 1992)
- Sucker rod diameter & grade
- Pumping unit load ratings (gear box & beam)
- Others (fluid type, temperature, viscosity, dog leg, etc.)

Harbison-Fischer have presented a table comparing the casing size versus maximum tubing size that can fit inside along with the maximum rod that can fit n the tubing and the maximum pump sizes that cold be used for these configureations.[3] This information is shown in Table i.

Other SRL design equipment configuration extending this table includes:

- Pump plunger diameters: 1.06 to 5.75" with one manufacture producing a pump of 7.5"
- Sucker Rod diameter: 5/8 to 1 1/8"
- Sucker Rod Grades:
  - API: C or K (tensile strength 90 to 115 k.s.i) & D (tensile strength 115 to 140 k.s.i)
  - Non-API: extra high strength (135 to 150 to 160 k.s.i)
- Sinker Bars: 1.25 to 2.0"

The maximum pumping unit sizes available include:

- Conventional:
  - 1824-305-240 (S = 240, 202, 179, 151") {N max 11.0}
  - 1824-365-216 (S = 216, 185, 155, 126") {N max 11.5}
- Air Balance: 2560-470-240 (S = 240, 200) {N max 10.0}
- Mark II: 1824-427-216 (S = 216, 192, 167) {N max 9.3}
- Rotaflex™: Reducer (420) Max P.R. (500) Stroke (366")
  {N max 3.75}
- DynaPump™: Hydraulic pressure (1800psi) Structure (800) Stroke (360") {N max 3.0 w/150Hp motor)

The theoretical lift volume capabilities using the maximum deign limitations for the various pumping units is found by assuming the pump displacement (PD) = $0.1166*S*N*D^2$.

Where:

- PD is in bfpd
- 0.1166 is volume conversion
- S = stroke length (in.) {should consider downhole plunger stroke (Sp)}
- N = pumping speed (strokes per minute)
- D = pump plunger diameter (in.)

Applying the above design maximums to the various SRL units shows the following pump displacements:

- DynaPump™:
  PD = $0.1166 * 360 * 3.0 * (5.75)^2$ = 4,163 bfpd
- RotaFlex™ (1115):
  PD = $0.1166 * 366 * 3.75 * (5.75)^2$ = 5, 291 bfpd
- Mark II:
  PD = $0.1166 * 216 * 9.3 * (5.75)^2$ = 7,724 bfpd

- Air Balance:
  $PD = 0.1166 * 240 * 10.0 * (5.75)^2 = 9{,}252$ bfpd
- Conventional:
  $PD = 0.1166 * 240 * 11.0 * (5.75)^2 = 10{,}177$ bfpd

This shows that SRL could be considered a high volume lift method, with produced rates up to over 10,000 bfpd. However, the theoretical have to be tempered by the above design parameters and being able to lift the desire production from depth.

In order to consider all the parameters, commercially available rod string design programs were used. Initially, Load Cal C, available from Harbison-Fischer. When limitations to the designs were discovered, the Theta Enterprises' XROD was used to relook at lift rate capabilities.

## ROD DESIGN PROGRAM RESULTS

The design parameters used included:

- HF equipment dimension table
- Specific gravity of mix fluid = 1.0
- H = L
- Tubing anchored at pump
- Conventional pumping unit rotating clockwise
- Pump VE = 100%
- Tubing pressure = 50 psi
- Changed parameters for PD, steel rod tapers w/SF = 1.0, extra high strength rod grade, and middle stroke length until pumping unit capacity or allowable rod stress was overloaded

Table II shows a summary comparing and interpolation of the prior published Weatherford and Clegg data with the new, conservative design considerations. These comparisons are shown graphically in Figure 4. The results show that for all depth except at 5,000 ft, there are higher rate capabilities than previously published.

One must remember that if there is some reservoir drive energy, there would be fluid above the pump and the SRL system design would not have to provide all the energy lifting the fluid to the surface. Thus, if there is some reservoir pressure, the production rates could be slightly higher since the lift system could produce more for the same, resultant loading.

Table III provides a summary of the equipment and operating considerations for the new design rates at depth. These data show that the neither the gear reducer nor high strength (Norris 97) rod string were overloaded in any configuration. However, the unit structure was overloaded for the cases at 5000 ft and below. The limitation for these designs is the walking beam. Shown above for the air balanced pumping unit, there are available larger beams (and then associated unit structure) of 427 and 470, these beams had not been requested nor designed for the conventional 1824 gear reducer size. Thus, if higher capacity structures could become available, even more fluid could be lifted using sucker rod lift for all depth considerations.

## CONCLUSIONS & RECOMMENDATONS

1. Currently available pumps and pumping units allow a dramatic increase in production rate for SRL, especially at shallow (<5000 ft) depths.
2. Weatherford’s graph, while showing much lower rates at shallow depths, may be optimistic or realistic in moderately deep wells (<10,000 ft).
3. Currently available graphs do not provide the production rate versus depth capabilities for very deep wells (>15,000 ft). This is becoming a production challenge, especially for gas well deliquification.
4. New designs using XROD resulted in greater lift capability for all depths except at 5,000 ft.
5. The gear reducer and sucker rod design were not overloaded for these designs.
6. The limitation on production lift rate at depth was the beam capacity and related unit structure.
7. It may be possible to lift even greater rates at all depths than shown here if larger structures could be designed and provided.

REFERENCES
1. Weatherford internal publication
2. J. Clegg, "High Rate Artificial Lift," SPE 17638; SPE Richardson, JPT 03/1988
3. Harbison-Fischer internal publication

Table I
Harbison-Fischer typical downhole equipment configuration (ref. 3).

**TABLE OF CASING / TUBING / SUCKER ROD PUMP SIZES**

| Casing Size | Tubing Size, Max | Sucker Rod Size, Max | RW Insert Pump, Max | RH Insert Pump, Max | TH Tubing Pump, Max | Oversize Tubing Pump, Max |
|---|---|---|---|---|---|---|
| 2-7/8" 6.5# | 1-1/2" Reg. | 5/8", Slim Hole Cplgs | 1-1/4" | | 1-1/2" | 2" |
| 3-1/2" 7.7-10.2# | 2-1/16" Integral Jnt | 3/4", Slim Hole Cplgs | 1-1/4" | | 1-1/2" | 2" |
| 4" 9.5-14.0# | 2-3/8" | 7/8" Slim Hole Cplgs | 1-1/2" | 1-1/4" | 1-3/4" | 2-1/4" |
| 4-1/2" 9.5-12.6# | 2-7/8" Spec Clear Cplg | 1", Slim Hole Cplgs | 2" | 1-3/4" | 2-1/4" | 2-3/4" |
| 5" 11.5-20.3# | 2-7/8" | 1" Slim Hole Cplgs | 2" | 1-3/4" | 2-1/4" | 2-3/4" |
| 5-1/2" 14-20# | 3-1/2" | 1-1/8" | 2-1/2" | 2-1/4" | 2-3/4" | 3-3/4" |
| 6-5/8" 20-28# | 3-1/2" | 1-1/8" | 2-1/2" | 2-1/4" | 2-3/4" | 3-3/4" |
| 7" 17-29# | 4-1/2" | 1-1/8" | 3-1/4" | 2-3/4" | 3-3/4" | 4-3/4" |
| 7-5/8" and Larger | 4-1/2" | 1-1/8" | 3-1/4" | 2-3/4" | 3-3/4" | 5-3/4" |

Note: These are maximum sizes. Smaller tubing, sucker rods or pumps can be used than those shown for any particular row of maximum size choices.

Table II
Depth versus SRL production rate limits

| Depth (ft) | Weatherford (bfpd) | Clegg (bfpd) | New Design (bfpd) |
|---|---|---|---|
| 1,000 | 3,000 | 4,200 | 9,027 |
| 5,000 | 1,500 | 800 | 1,341 |
| 10,000 | 300 | 480 | 574 |
| 15,000 | 200 | na | 313 |
| 20,000 | na | na | 50 |

Table III

New design equipment and design considerations

| Depth (ft) | Unit Designation | Rod No. | Norris 97 Loading | Structure loading |
|---|---|---|---|---|
| 1,000 | C1280-305-216 | 87 | 68% | |
| 5,000 | C1824-305-240 | 86 | 81% | 110% |
| 10,000 | C1824-365-216 | 86 | 98% | 118% |
| 15,000 | C1824-365-216 | 86 | 104% | 129% |
| 20,000 | C1824-365-216 | 87 | 85% | 143% |

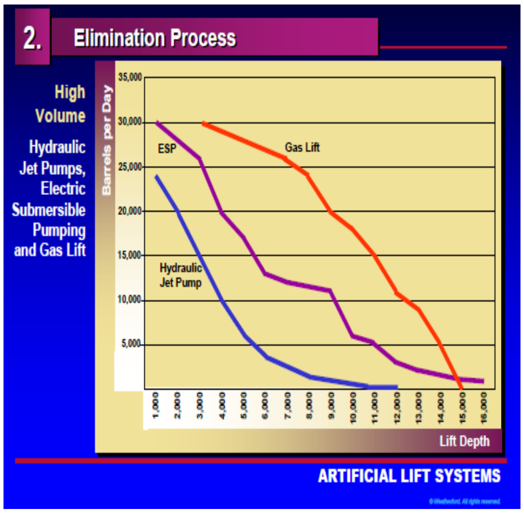


Figure 1 - High volume lift methods. (ref 1)

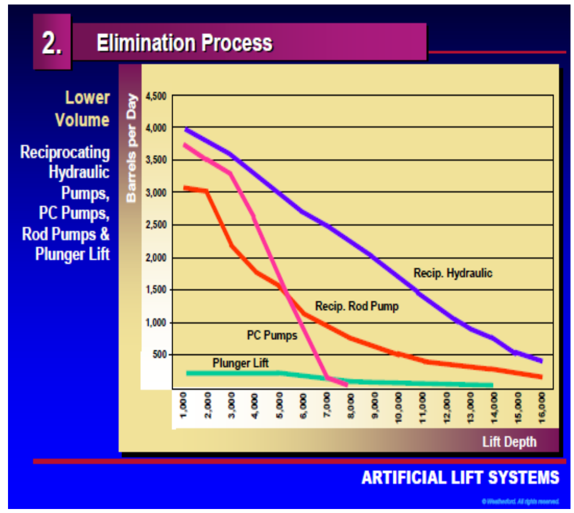


Figure 2 - Lower volume lift methods. (ref 1)

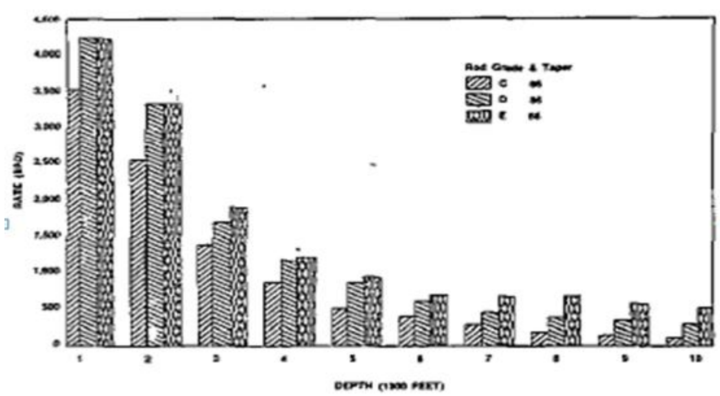


Figure 3 - Sucker rod lift rate capabilities (ref. 2)

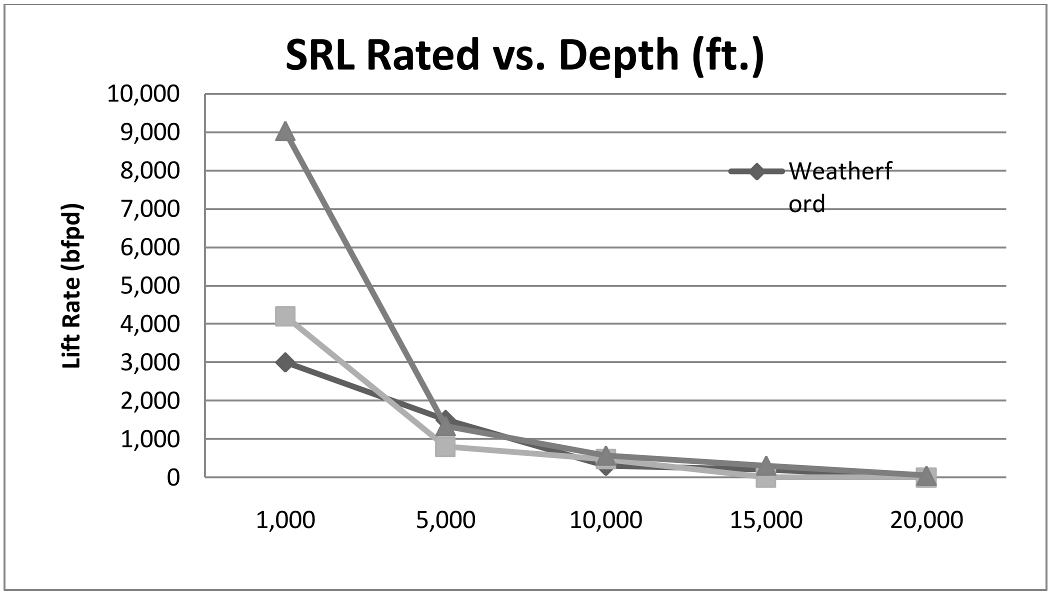


Figure 4 - Comparison of published versus new designs for SRL rate versus depth capabilities.