"BACK-PRESSURE" ON TUBING IN ROD PUMPED WELLS

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INTRODUCTION

There has been a lot of discussion about holding tubing backpressure in rod pumped wells. Although backpressure on tubing is not a panacea, there are definitely applications where it can aid in the operation of a rod pumped system. On the other hand, holding backpressure when it is not necessary can have adverse effects such as increased energy cost, equipment loading, etc.

The following discussion will cover tubing back-pressure in rod pumped wells and will give examples where tubing back-pressure is helpful and what effects it has on the pumping system. Actual dynamometer data will be included showing effects on rod loading as tubing pressure is increased.

BACKPRESSURE ON TUBING - DEFINITION

Backpressure on tubing, as the name indicates, is pressure held inside the tubing over and above flowline pressure. Backpressure can range from 50 PSI to several hundred PSI over existing flowline pressure. This pressure is usually set by an adjustable back- pressure valve on flow line side of the pumping tee.
Note: Since backpressure is contained inside of tubing and isolated from wellbore by the pump valves, no additional pressure is held against producing formation.

WHY TUBING BACKPRESSURE?

There are at least two cases where backpressure on tubing can be helpful:

The first case is where tubing is "flowing off" at surface. Indications of this are burnt stuffing box packing and the appearance well is not pumping. The cause of this "flowing off" effect is gas being pumped into tubing along with liquid. Gas can enter tubing in the form of "free gas" if pump inlet is set above casing perforations or gas may be "in solution" if pump intake pressure is high. As the oil and gas move upward in tubing, hydrostatic pressure is reduced. Pressure reduction causes gas bubbles to increase in size and lighten fluid column. The dynamic affect of enlarging gas bubbles can cause fluid to start flowing out of tubing and create a significant "dry" void in top portion of tubing. Since the polished rod now has no lubrication, it will get hot and burn stuffing box packing. The well appears, at surface, to not be pumping and since stuffing box packing is damaged, will make a mess when liquid is again pumped back to surface. A tubing backpressure valve can be used to hold hydrostatic pressure against the gaseous liquid to prevent this "flowing off" effect.

Another advantage gained by preventing this "flowing off" effect and maintaining a solid column of fluid in tubing, is constant pump valve spacing. If tubing is "flowing dry", rod buoyancy and pump load will change with lightened fluid column. This causes the critical pump valve spacing to also change and may reduce pump efficiency.

The second case, where backpressure can be used to improve pumping conditions, is to increase pressure differential across pump valves. A rod pump must have differential pressure across valves for proper seating. Pump discharge pressure must be higher than inlet pressure and the greater pressure difference across valves means greater seating force. If a well is pumping with a high fluid level in annulus, pressure differential may not be sufficient to effectively seat traveling valve on upstroke. This may be especially true if solids are suspended in fluid or a light gravity oil is being pumped. Backpressure in tubing will increase this seating force and may keep a well pumping when otherwise valves might be sticking open. Note: It is important to remember that as annular fluid level is lowered, pressure differential in pump naturally increases. After the well is "pumped down" or "pumped off", backpressure may no longer be needed.

HOW MUCH BACKPRESURE IS NEEDED?

Optimum backpressure on tubing is usually found by trial and error. Once optimum pressure is set for a given set of conditions, it may need adjusting as these conditions change through the producing life of a rod pumped well.

Optimum back-pressure on tubing will normally range from 150 PSI to 400 PSI depending on well conditions such as: amount of gas in tubing, oil API gravity, producing fluid level, pump setting depth, etc. A good starting point for setting backpressure is normally around 150 to 250 PSI.

EFFECTS OF BACKPRESSURE ON TUBING

Backpressure on tubing may have some unexpected effects on a rod pumping system. The following discussion will list two possible effects that should be considered.

1 – "SLIP STREAM" CHEMICAL FLUSH VOLUME

Continuous chemical treatment is sometimes used on high volume wells. In this situation chemical is continuously flushed down tubing-casing annulus via a small bypass line which connects the tubing to casing. As the well pumps, tubing pressure causes a small amount of fluid to bypass into casing and flush injected chemical down annulus. This method of flush is called "slip streaming". The volume of slip streamed fluid is usually controlled by a needle valve or a 1/4" pinched ball valve.

If the "slip stream" method is used to flush chemical, the "slip stream" volume will increase as tubing pressure increases. This volume can cause a significant amount of production loss if throttling valve or port opening is not reduced with increase in backpressure.

In an attempt to calculate how much fluid can be bypassed through a predetermined orifice size, the following formula for a beveled orifice plate was used:

Q=C*A*SQRT(2gh)

Where: Q= Flowrate
C= Coefficient of discharge (Approximated at 0.6)
A= Area of orifice opening (square inches)
G= Acceleration due to gravity
H= Net fluid head

As can be seen by the graph in ***FIGURE #1***, an increase in upstream pressure or orifice size, will significantly change volume of fluid passing through orifice. Although slipstream valves do not usually have a beveled orifice plate, the effects of pressure and opening size are still the same. Higher upstream pressure and or larger valve opening means more volume bypassed into casing.

2 –TUBING BACKPRESSURE EFFECT ON POLISHED ROD LOADS (CASE STUDY)

Another unexpected result of tubing backpressure is the effects on polished rod loading. Most "predictive" pumping design programs treat tubing backpressure as if it only affects net lift on pump. In other words, as backpressure increases, so should net lift or fluid load on pump. Net lift definitely increases with the increase in backpressure but according to the following actual test results, there is another force effecting rod loads as backpressure increases. This force is pushing upwards on the rodstring with an apparent "piston effect" that increases as tubing pressure increases. This "piston effect" is acting upwards on polished rod with a force equal to the cross sectional area of polished rod liner multiplied by the back-pressure applied on tubing. As backpressure increases, this piston effect becomes more pronounced as it tends to lighten rod loads.

Figure #2 shows pumping parameters and static measurements of rod weight in fluid *(Standing Valve Load)* verses tubing pressure that were taken during the test. The measured "Weight of Rods in Fluid" (Wrf) illustrates a decrease in rod loading as tubing pressure is increased from 28 PSI to 375 PSI and then to 510 PSI. Note that when backpressure was released after the test, rod loading increased. It is interesting to note that beginning buoyant rod load at 28 PSI is 241 pounds heavier than ending buoyant rod load at 28 PSI. This discrepancy is probably caused by stuffing box and rod-tubing friction.

Specific gravity of tubing fluid is calculated using the measured weight of rodstring in fluid compared to weight of rodstring in air.

Sg = (W – Wrf) / (.128 * W)

Where:

Sg = Specific Gravity of fluid *(Fresh water = 1.0)*
W = Weight of rodstring in air (Lbs.)
Wrf = Measured weight of rodstring in fluid (Lbs.)

Since specific gravity of tubing fluid cannot be changing in this test, (tubing contains only water), a piston effect from the increased tubing pressure must be responsible for weight loss of rodstring. The far right column contains calculated rod weight loss from this assumed piston effect using the largest cross sectional area in rodstring (the polished rod liner 1.766 sq. in.), multiplied by the increase in tubing pressure. For example the piston effect for a backpressure value of 375 PSI is:

(375 PSI – 28 PSI)* 1.766 = 613 Lbs.
13981 Lbs. – 613 Lbs. = **13368 Lbs.**

Calculated rod weight value for the 375 PSI tubing pressure point is only 0.3% different than actual measured value of 13410 PSI. Calculated rod weight for the 510 PSI pressure point is only 0.1% different than actual measured value. The results of this test conclude that a piston effect on polished rod is causing a loss of rod weight as tubing pressure increases.

Another observation from this study was the dynamic effect on peak and minimum polished rod loads that occur as tubing pressure increases. The dynamometer cards in ***FIGURE #3*** show the effects of various backpressure settings. Since tubing pressure oscillated during upstroke and downstroke, average tubing pressure was used for each pressure point. As tubing pressure increased from 28 PSI to 330 PSI, peak polished rod load increased and minimum polished rod load decreased. Overall card area increased indicating an increase in power consumption by the system. This is expected since pump loading has increased. The unexpected effect is that when pressure increased from 330 PSI to 400 PSI, peak load began to decreas**e** while minimum load continued to decrease as expected. When pressure was increased to 610 PSI, again the entire surface card shifted downward with a continued decrease in peak and minimum loads. The surface dynamometer card overlay in ***FIGURE #4*** shows the first card with tubing pressure at 28 PSI and last card with a tubing pressure of 610 PSI. This surface dynamometer card overlay clearly shows a downward shift in polished rod loads when tubing pressure increased from 28 PSI to 610 PSI. This information can be helpful when monitoring polished rod load trends. If a shift in polished rod load occurs, instead of assuming rod-tubing friction is changing or the loadcell accuracy is drifting, it would be advisable to also check for a change in tubing pressure.

The graph in ***FIGURE #5*** shows peak and minimum polished rod load versus tubing pressure, to better illustrate how the loads changed as pressure was increased during test. The interesting thing about this graph is that peak polished rod load increased as tubing pressure came up to approximately 250 PSI and then began to decrease as pressure was increased beyond 250 PSI. On the other hand, minimum polished rod load continually decreased with each increase in tubing pressure throughout the test.

The polished rod load range, or peak polished rod load minus minimum polished rod load, was also affected by tubing backpressure. The Tubing Pressure vs. Load Range graph (***FIGURE #6***) illustrates this effect. In this test, load range increased along with an increase in tubing pressure up to 340 PSI, then load range began to decrease. This would indicate power requirements for this pumping system might increase up to the 340 PSI pressure point and then began to decrease thereafter.

A graph of electrical consumption in KWH vs. Tubing Pressure (***FIGURE #7***) reinforces the idea of additional power consumption caused by tubing backpressure up to a point, then like the Load Range graph, power consumption starts decreasing. Two graphs are included in this plot. One graph shows actual KWH usage with existing counterbalance. (Note: Pumping unit was initially over counterbalanced due to a high fluid level resulting from casing leak.) The second plot shows what power consumption would be if pumping unit were balanced for each tubing pressure setting. In “real world” conditions, it is highly unlikely pumping unit counterbalance will be perfectly adjusted for each backpressure setting, so Existing Counterbalance graph would be more applicable.

In this KWH vs Tubing Pressure graph, actual power consumption increased with tubing pressure up to the 340 PSI pressure point. When tubing pressure increased above 340 PSI, KWH usage began to decrease... In the perfectly balanced graph, power consumption increased up to the 250 PSI pressure point and then began decreasing.
It is interesting to note that normal backpressure used on rod pumped wells range between 150 PSI to 300 PSI. According to this test, most pumping wells with normal tubing backpressure will have increased power consumption due to the backpressure.

Downhole pump stroke was calculated by dynamometer analysis for each tubing pressure point. (See ***FIGURE #8***) According to these figures, gross pump displacement was only reduced by a total of 5 BFPD from beginning to end of test.

NOTE: In order to keep things in perspective, it must be pointed out that the tubing pressure versus rod load test results, used in this paper, were obtained from only one well. More testing would be necessary to find what affect different rod materials, pump size, or pumping parameters have on changes in rod loads as tubing pressure is increased.

A somewhat shorter but similar test, showing effects of tubing backpressure, was made by Ken Nolan and Sam Gibbs with Lufkin Automation. This test is an example of a more common use for tubing backpressure and has been presented in the Lufkin Dynagraph Interpretation class. (See ***FIGURE #9***) This dynamometer survey was taken on a well that obviously has gas interference in the pump. Since gas is being ingested into tubing, backpressure was used to prevent well from "flowing off". In this test, two tubing pressure points were used (100 PSI and 410 PSI). Results show polished rod loads and load range increased with higher tubing pressure. Another interesting fact is that tubing gradient value increased with higher pressure. This would indicate buoyant rod weight is less in the 410 PSI tubing pressure survey. Reduced buoyant rod load, in this case, could be attributed to either "piston effect" on the polished rod or increased fluid density in tubing caused by backpressure. Irregardless, It is clear to see in this test that higher tubing backpressure is causing increased power usage by pumping system.

CONCLUSION

Backpressure on tubing follows Newton's law of physics which states "for any action there is an equal and opposite reaction". By holding backpressure on tubing, pumping conditions can be improved in certain given situations but we also must be mindful of the reactions or effects this additional pressure has on the system.

Here are six points obtained from this study to summarize tubing backpressure – its uses and effects:

1) Backpressure can help prevent "Flowing Off" when gas is present in tubing

2) Backpressure can be used to increase differential pressure across pump valves, if valves are not seating properly.

3) The amount of tubing backpressure required, to improve pumping conditions, is usually found by trial and error. *(A good starting range is 150 to 250 PSI)*

4) Backpressure increases the amount of "Slip Stream" flush volume. *(NOTE: Reduce size of port opening as backpressure is increased to prevent over flush and significant loss of efficiency)*

5) Increasing tubing pressure will affect polished rod loads. *(This is a point to keep in mind when monitoring polished rod load history and or pumping unit counterbalance.)*

6) Backpressure will usually cause increased power consumption by the pumping system; therefore, it should only be used when well conditions require.

REFERENCES

1 -Russell W. Henke: *"Introduction to Fluid Mechanics"*
2 –F.W. Gipson and H.W. Swaim: *"Beam Pumping Fundamentals"* Presented at Southwestern Petroleum Short Course 1969, Courtesy of Continental Oil Co.

ACKNOWLEDGEMENTS
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Thanks to Ed Delgado with Cambrian Management for providing supportive dynamometer data to reinforce ideas presented in this paper. (Note: Actual data was not included in paper for the sake of brevity.)

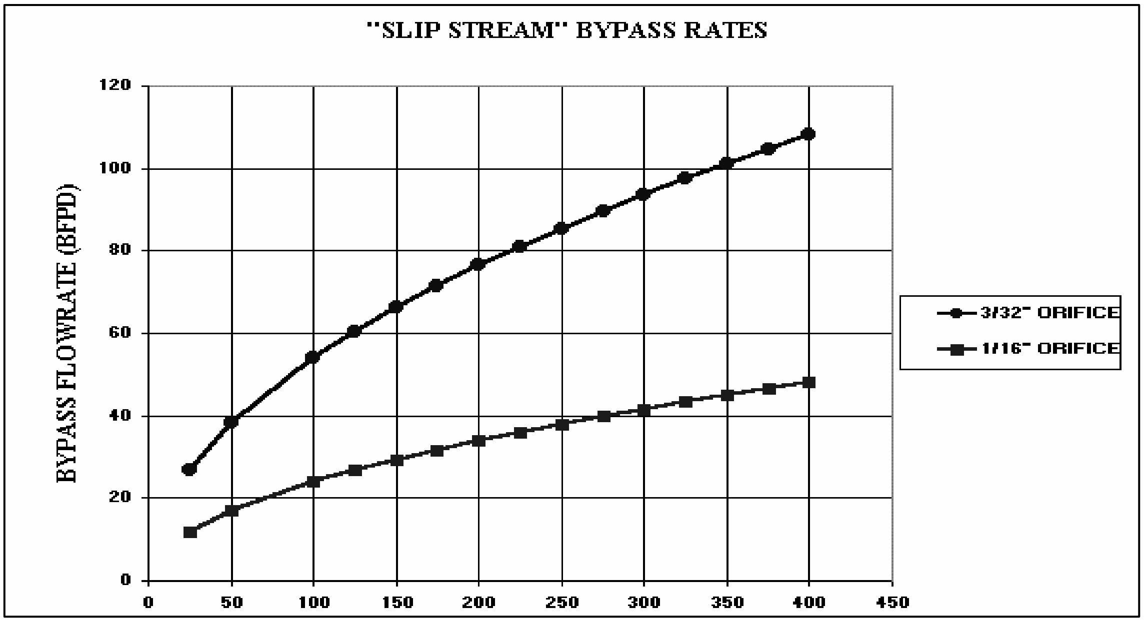


Figure 1

WELL INFORMATION

PUMPING PARAMETERS		RODSTRING & TBG.			PRODUCED LIQUID	
SPM:	10.3	**7/8" RODS:**	3,262'		**OIL (BPD):**	0
SL:	74"	**3/4" RODS:**	4,543'		**WATER (BPD):**	100
PUMP:	1.25"	**1.5" S.B.:**	150'		**GAS (MCFPD):**	0
SN @:	7,955'	**WR(air):**	15,577	lbs.	**SG. WATER:**	1.006
		POLISHED ROD:	1.25" W/ 1.5" LINER		**CALC. WR(fluid):**	13,571
		TUBING:	2.375"			

EFFECT OF TUBING PRESSURE ON S.V. LOADS

STATIC TBG. PRESS. (PSI)	Meas. Wrf. (LBS)	Calc. Sg	Calc. Wrf W/ Piston Effect (LBS)
28	13981	0.80	13981
375	13410	1.09	13368
510	13146	1.22	13129
28	13740	0.92	13998

Figure 2

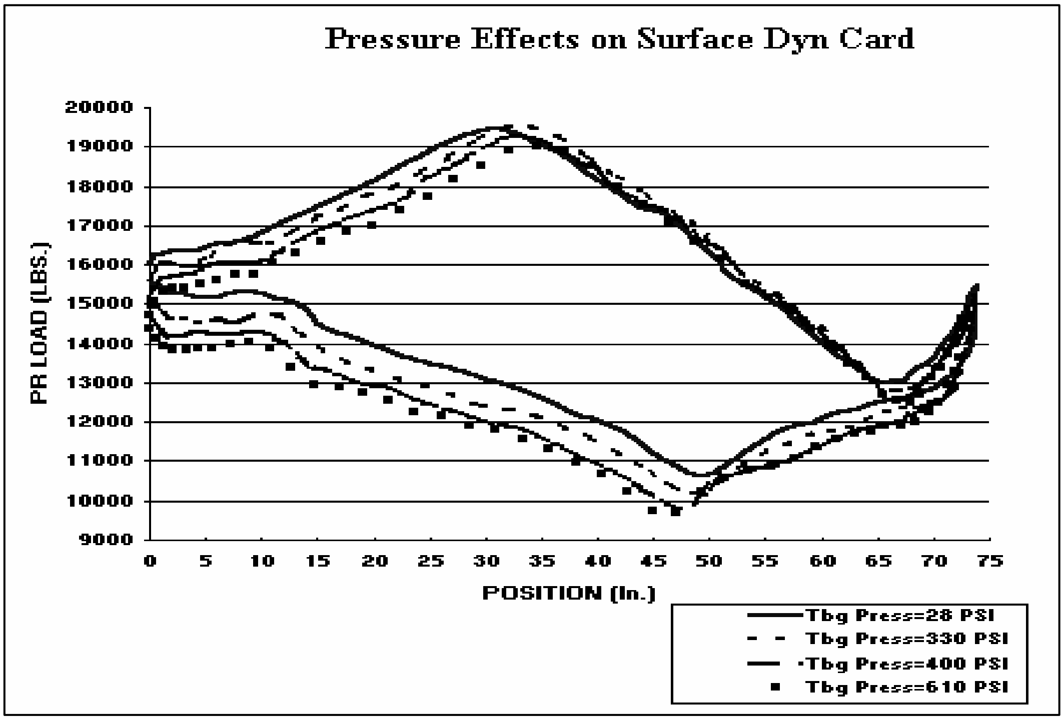
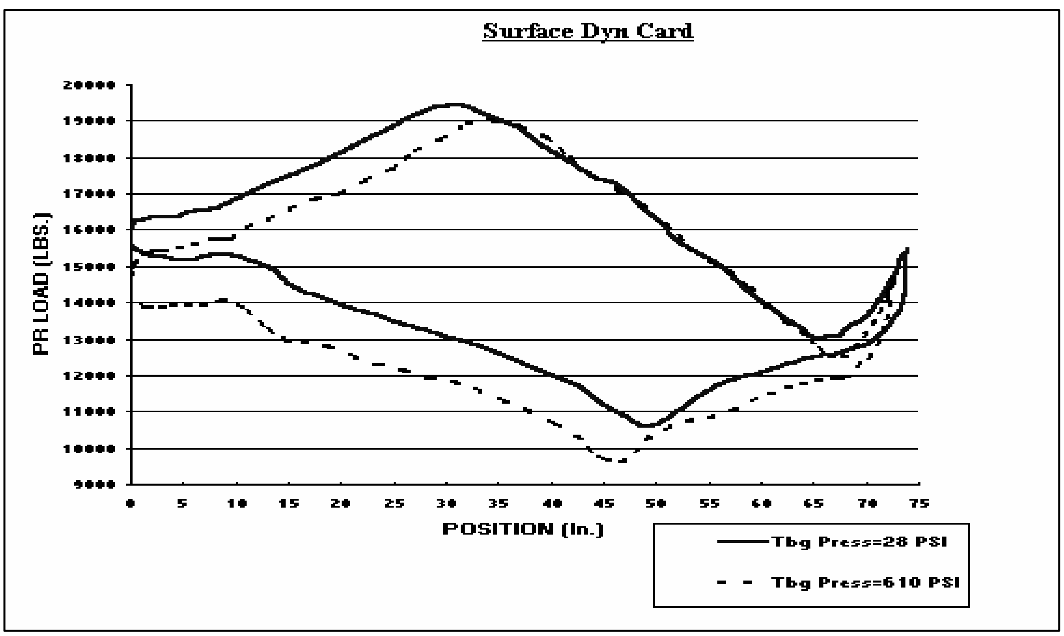


Figure 3



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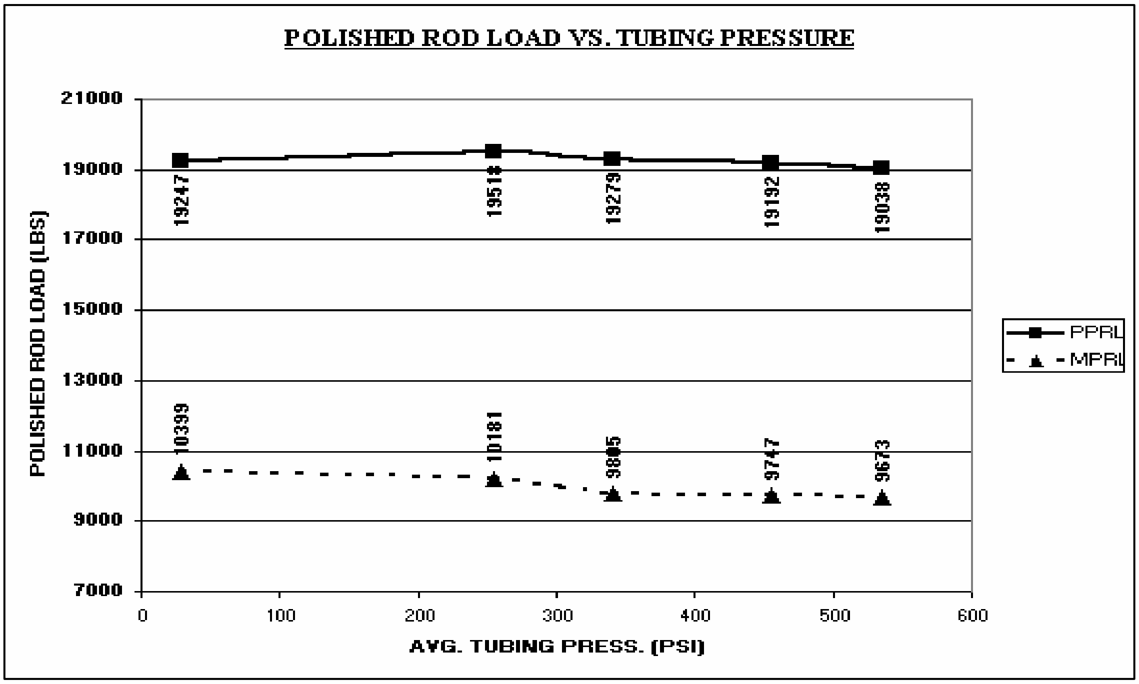


Figure 5

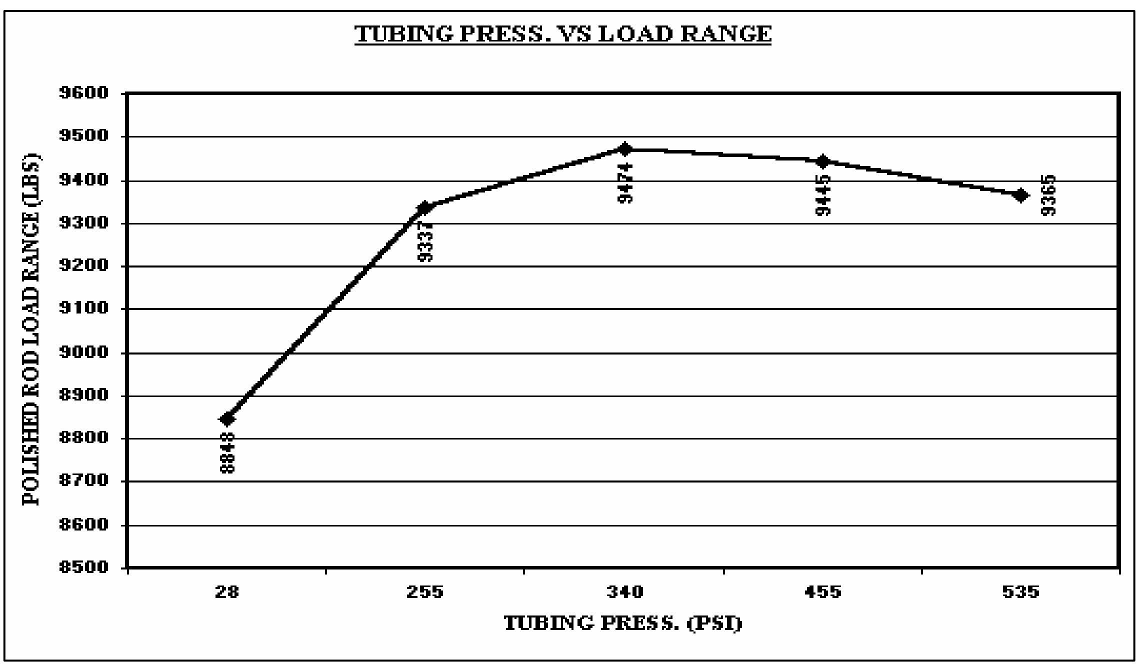


Figure 6

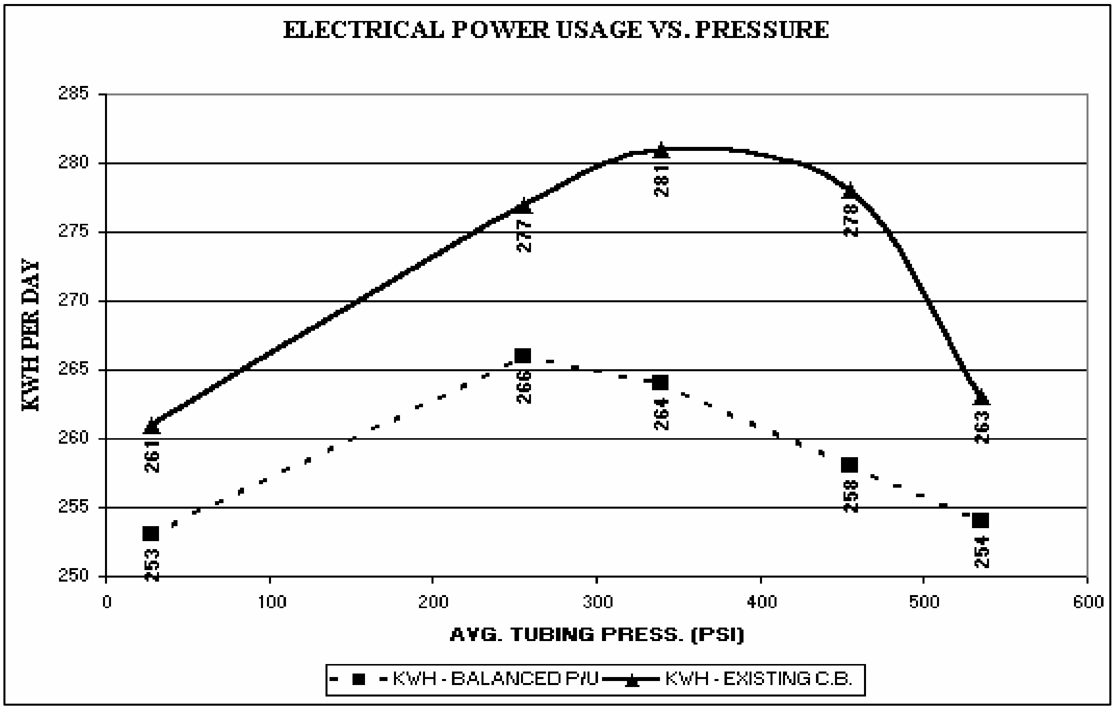


Figure 7

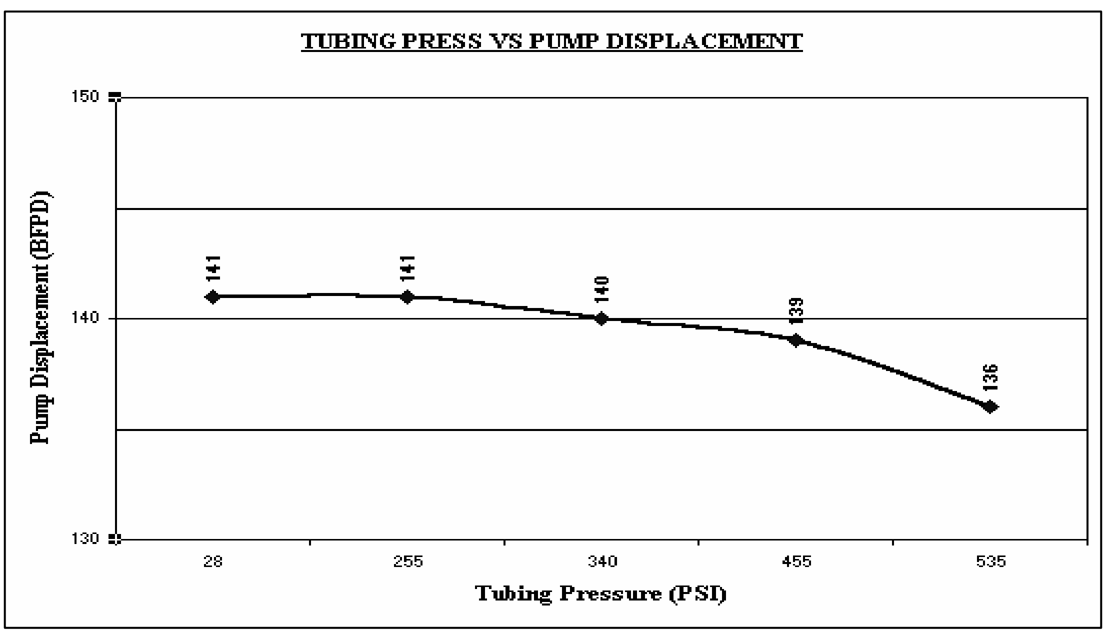


Figure 8

TUBING PRESSURE VS. ROD LOADS - DATA SHEET

Date of test: 4/28/05

COMMENTS: Sonic fluid level measurement shows annulus fluid level at 4,058' from surface
Dynamometer analysis calculates fluid level at 4,272'

PUMPING PARAMETERS		RODSTRING & TBG.		PRODUCED LIQUID	
SPM:	10.3	**7/8" RODS:**	3,262'	**OIL (BPD):**	0
SL:	74"	**3/4" RODS:**	4,543'	**WATER (BPD):**	100
PUMP:	1.25"	**1.5" S.B.:**	150'	**GAS (MCFPD):**	0
SN @:	7,955'	**POLISHED ROD:**	1.25" W/ 1.5" LINER	**SG. WATER:**	1.006
		TUBING:	2.375"		

DYNAMIC EFFECTS OF TUBING PRESSURE

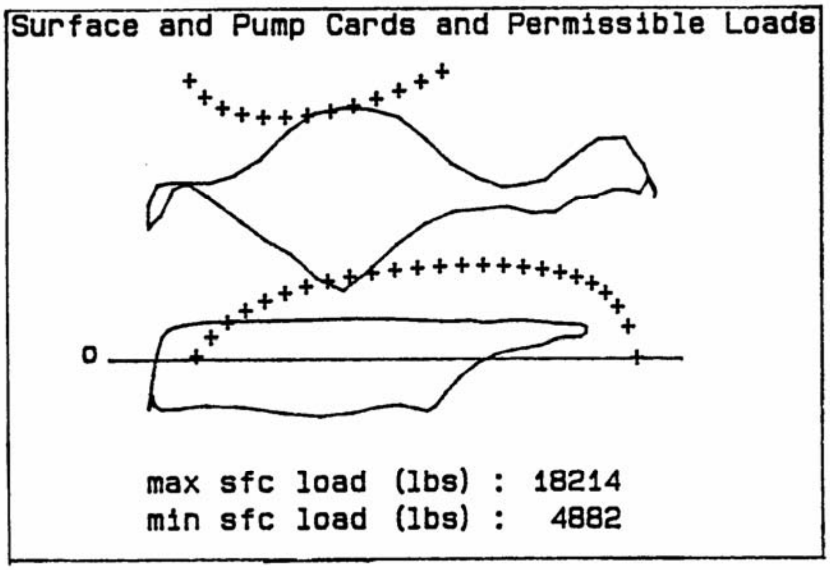
TUBING PRESSURE (PSI)			PPRL	MPRL	LOAD RANGE	PUMP LOAD (Fo)	GROSS PUMP STROKE	GROSS PUMP DISPL.	MOTOR AMPERAGE		PRIME MOVER
D/S	U/S	AVG.	(LBS.)	(LBS)	(LBS.)	(LBS)	(IN.)	(BPD)	U/S	D/S	H.P.
28	28	**28**	19,247	10,399	8,848	2,330	75	140	29	37	18
180	330	**255**	19,518	10,181	9,337	2,598	75	141	27	40	18
280	400	**340**	19,279	9,805	9,474	2,694	74	140	27	40	19
380	530	**455**	19,192	9,747	9,445	2,829	73	139	25	40	19
460	610	**535**	19,038	9,673	9,365	2,928	72	136	24	41	18

STATIC EFFECTS OF TUBING PRESSURE

STATIC TUBING PRESS. (PSI)	**28**	**375**	**510**	**28**
ROD WEIGHT IN FLUID (LBS)	13,981	13,410	13,146	13,740
	^			^
	Start Test			*End Test*

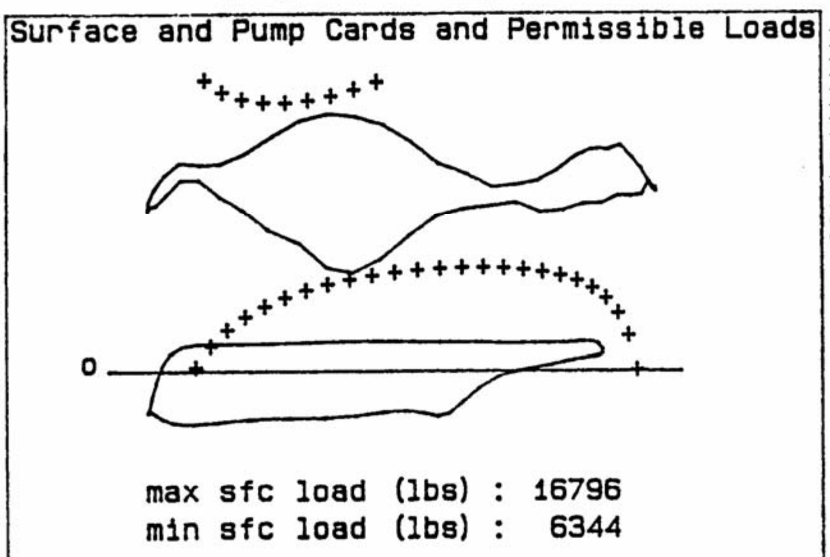
Case Study Data Sheet

Tubing Head Pressure - 410 psi



Peak Torque - 353300 in-lbs
Max P.R. Load - 18214 lbs
Min P.RL - 4882 lbs
P.R. Power - 13.2 HP
Gross Pump Stroke - 84.9 in.
Net Stroke = 50.9 in.
Fluid Load - 5450 lbs
Tubing Gradient = .357 psi/ft

Tubing Head Pressure - 100 psi



Peak Torque - 296799 in-lbs
Max P.R. Load - 16796
Min P.R. Load - 6344
P.R. Power - 11.0 HP
Gross Pump Stroke - 88.1 in
Net Stroke - 49 in.
Fluid Load - 3700 lbs
Tbg. Gradient - .311 psi/ft

Lufkin C320-256-100 Unit
86 Rod design
2 in pump at 5338 feet
Pump Intake Pressure - 580 psi

Figure 9 - *Courtesy of Lufkin Automation*