The One-Half Inch Sucker Rod—Newest Development for the Cost Conscious Oil Producer

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DEVELOPMENT OF THE 1/2 INCH SUCKER ROD AND A BRIEF RESUME OF ITS RECENT HISTORY

The development of the 1/2 inch sucker rod was necessary to satisfy a growing problem within the oil industry. This problem has been pointed up in ever increasing importance by the upward trend in lifting costs in comparison to a more or less constant or even, at times, downward trend in production profits. There are two principal divisions of cost in any analysis of lifting costs: one of these is labor; the other, of course, is material.

Since the labor cost is a more or less uncontrollable cost, the obvious place to attack the lifting cost problem was from the material angle. Although the development of, and introduction into, the oil industry of a 1/2 inch sucker rod did establish a precedent in the rod industry, it was just one of the many logical steps that the producers were already undertaking to reduce their lifting costs through cheaper equipment. The first of these steps, of course, was to educate the industry to the fact that it could go to smaller casing sizes to produce most of the wells that are now being drilled and developed throughout the entire Mid-Continent Area.

There was a time, as you all well recall, when 7 inch casing was thought to be the smallest casing with enough room inside to successfully complete or work over a well. Economics demanded that this high priced casing be first replaced with 5-1/2 inch which most producers have found to be generally satisfactory from every point of view. More recently many producers, I would say a great percentage of majors and independents alike, have come down to 4-1/2 inch casing. Again, the economic factor of comparative material cost dictated this step. Now, in light of the 1/2 inch sucker rod, some producers, and I'm pleased to say a gratifying number of them, have come down to using 2-7/8 inch OD tubing for casing. Because of the introduction of the 1/2 inch sucker rod into the market, they are using for the first time in a pumping application tubing sizes smaller than 2 inch with 1-1/4 inch, since it is the cheapest, being the most popular size.

From these facts you can therefore see that the development of the 1/2 inch rod was a logical step that was taken by a manufacturer to complement the down-scaling of production equipment by producers to control their equipment costs and, consequently, offer at least a partial solution to overly high lifting costs. It must be pointed out, however, that the application of the 1/2 inch rod is limited to marginal wells. By marginal, we mean wells that can be economically pumped by a small bore pump, operating inside of smaller than 2 inch tubing, and wells with a fluid volume that will not exceed the maximum polish rod load capacities of the relatively small 1/2 inch sucker rod.

As much as we would like to take 100 per cent credit for the development of the 1/2 inch rod, we cannot honestly do so. Our initial interest was kindled by an inquiry from a major oil producing company as to the feasibility of making a rod that would pump inside of 1-1/4 inch tubing from a depth of approximately 5,000 feet. An investigation into the potential of such a rod prompted us to undertake the problem of design and manufacture. The major producer involved worked in collaboration with us in the development of the rod as it now exists.

This rod was made available to the oil producing industry about mid-July of 1958. The 1/2 inch sucker rod, as it is being manufactured today, is being produced in two grades, a basic carbon manganese and a nickel moly steel. We call your attention to Chart 1 for specifications and dimensions. Our first evaluation of the 1/2 inch rod, when we undertook to design and manufacture it, was that it would be used primarily in dually completed wells. We believed at that particular time that your dually completed applications, in which smaller than 2 inch tubing might be used, would probably constitute from 75 to 95 per cent of the total application of the rod. Quite contrary to this, our actual sales have indicated that perhaps dually completed wells constitute somewhere from 10 to 25 per cent of the total potential in the rod. The big application has proved to be and, I believe, will prove to be in the future, the use in wells that are considered marginal in light of conventional completion costs.

There are two different principals of application of

CHART 1

SPECIFICATIONS ON THE LIBERTY 1/2 INCH SUCKER ROD

TYPICAL PHYSICAL PROPERTIES	TYPE "A"	TYPE "NM"
Tensile Strength	95,000 PSI	93,000 PSI
Yield Strength	70,000 PSI	73,000 PSI
Elongation in 8"	19 %	21 %
Reduction of Area	60 %	65 %
Brinell Hardness	192	187

TYPICAL CHEMICAL PROPERTIES		
Type Steel	AISI C1036 MOD	AISI A-4621
Carbon	.35 %	.20 %
Manganese	1.35 %	.80 %
Phosphorus	.025 %	.025 %
Sulphur	.025 %	.025 %
Silicon	.23 %	.30 %
Nickel		1.80 %
Molybdenum		.25 %

MISCELLANEOUS ROD INFORMATION	
Rod Size	1/2" x 25' (Fully Normalized)
Wrench Flat Dimensions	5/8" Across and 3/4" Long
Pin Shoulder Diameter	1"
Pin Size and Thread	3/4" x 1" Long 10 UNC 2A (Unified thd. system)
Elevator Button Diameter	7/8"

COUPLING SPECIFICATIONS -- (AISI 8620 Alloy Steel)

Coupling Size		Average Tensile	Average Yield	Overall Length	Net Area
1 O.D.	R H/T	90,000 PSI 166,000 PSI	68,000 PSI 122,000 PSI	2.5 Inches	.4439 Inches^2
1-1/8 inch OD	C/H H/T	147,000 PSI 166,000 PSI	115,000 PSI 122,000 PSI	2.5 Inches	.5523 Inches^2
1-1/8 inch OD (WF)	C/H H/T	147,000 PSI 166,000 PSI	115,000 PSI 122,000 PSI	2.5 Inches	.4743 Inches^2

W/F - Wrench Flat (15/16 inxh x 1-1/8 inches)
R - Regular Coupling (Unhardened w/229 Avg. Bhn.)
C/H - Case Hardened (Rockwell "C" 58 Avg. for Case)
H/T - Thru-Hardened (Quenched and Tempered Rockwell "C" 34 Avg.)

the 1/2 inch rod among producers - some producers will equip the well with slim hole equipment, that is, small tubing, rods, pumping unit, on a basis of a small available fluid volume - others will go a step further in their thinking and equip a well to produce approximately the allowable imposed upon that well by the various regulating commissions. Their reasoning is that even though the well has a potential of 100 barrels they are only goint to be allowed to produce 25 to 30 barrels so why waste money on extra equipment. They are willing to gamble, and past history will bear out their gamble as being a good one, that the allowables are not apt to be substantially increased in the foreseeable future.

How far a man or a company wishes to go with this logic depends entirely upon the individual. At any rate, if the equipment is tailored to produce as nearly as possible the exact amount of oil that can be produced from that well, then the man has achieved his ultimate goal toward a sound economic investment in the producing well.

THE 1/2 INCH ROD AND ITS APPLICATION TO LOW AND MEDIUM VOLUME WELLS IN DEPTHS TO 6,000 FEET

A too casual consideration of the 1/2 inch sucker rod in light of its application to well depths and theoretical production figures might possibly lead one to believe its application is considerably more limited than it really is. To broaden our perspective on this application, let us first break down the potential applications into two fundamental catagories - first, marginal production wells wherein the total fluid can be handled by small bore pumps operating inside of smaller than 2 inch tubing. The smaller tubing is preferred by merit of the saving involved to the producer. This especially important where cost of the equipment is the determining factor in whether or not the producer can afford to complete and develop his propeties or abandom them. Second, dually completed wells where either economics or limited space within the casing demands pumping through smaller than 2 inch tubing. Here again, the production volume must be limited to the capacity of a small bore pump that can be used inside the small tubing.

The exception to the first catagory would be, as I have previously stated, where allowables limit the amount of production to the extent that a slim hole application is economically attractive. Where daily allowables are the governing factor in consideration of slim hole techniques, a man would not wish to scale his casing size down below 4-1/2 inches for in the event of an increase in allowables, he could then run 2 inch or 2-1/2 inch tubing and consequently pump with a larger pump and attain increased allowable. One concept is prerequisite to acceptance of the principal of slim hole completion; we must reeducate ourselves to equip a well for the amount of fluid it will actually produce.

In the past, it has become more or less the pattern of material procurement to buy a certain size or within a certain range of sizes a unit, prime mover, string of rods and pump for a specific depth well. A 2,500 foot well generally took a 25,000 inch-pound peak torque gear box, a 3,000 foot well a 40,000 inch-pound peak torque box or larger.

All of these things were not necessarily related to the amount of fluid to be moved but to the use of the maximum stroke length of the unit and generally a 1-1/2 inch pump was used, assuming, of course, that water or total fluid volume was not a problem; in that event, a larger size pump was bought. In most cases, the total volume of fluid available would not permit continuous operation of the unit; therefore, a time clock or some other device designed for intermittent operation was installed. This was added expense, not only from the standpoint of the additional equipment purchase, but, with electric motors as the prime movers, the increased electricity requirements for larger electric motors and the added electrical drain of intermittent high torque starting loads caused an additional daily expense.

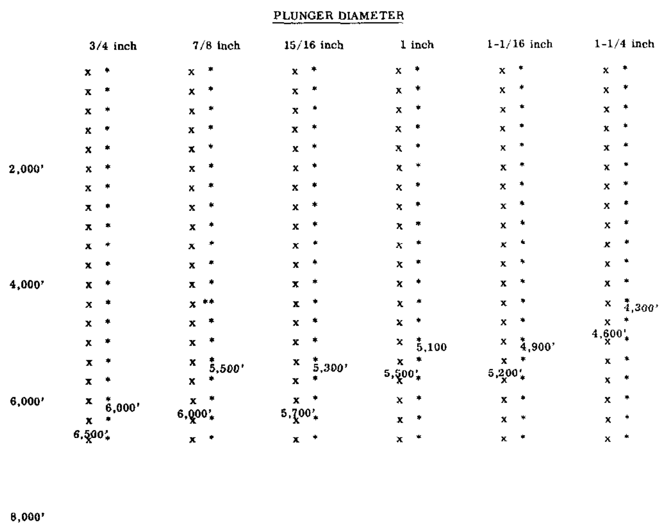
Another problem inherent to intermittent operation is that of sand or other abrasives settling out of the oil on top of the pump plunger during the down period. This, too, is eliminated by continuous operation which is only possible when the pumping equipment is designed to handle the available amount of fluid in a 24 hour operation. To present a broader perspective to the potential application of the 1/2 inch sucker rod, I would like to give some maximum theoretical depths for the 1/2 inch rod to show about what we can expect in its ultimate application. These are theoretical or calculated production figures, maximum depth figures, polish rod loads, and peak torque requirements. We wish to call your attention to Chart 2 showing representative calculations.

CHART 2

MAXIMUM DEPTH RECOMMENDATIONS FOR LIBERTY 1/2 INCH SUCKER RODS

x Type "NM" - Calculated at 30,000 Lb./Sq. In. Rod Stress
* Type "A" - Calculated at 28,000 Lb./Sq. In. Rod Stress

Loads based on specific gravity of one
Subject to fluid viscosities capable of flow through plungers listed



Strokes/Min 10	11	12	13	14	15
Lgth. Stroke 54"	48"	44"	42"	36"	34"
Appx. Prod. 25 B/D	30 B/D	32 B/D	35 B/D	37 B/D	43 B/D

Peak torque requirements on above applications vary only slightly from 25,000 inch-pound.

Polished rod load requirements on above applications are in the range of 6,000 pound.

Note: Considerable volume increases are possible at lesser depths than maximums shown above.

In the event of greater fluid requirements a 5/8 inch and 1/2 inch tapered string could be employed in a 4,000 foot well. Here, however, we would suggest 1-1/2 inch tubing which would necessitate a 5/8 inch rod with slim hole couplings using a 1-1/4 inch plunger maximum. As long as **only** a 1-1/4 inch plunger is used, then the 1/2 inch rod **has** sufficient wroking stress in noncorrosive fluid to support the peak polish rod load. Though we do not consider it generally a desirable installation, we have several strings of 1/2 inch rods running in 2 inch tubing with various size plunger pumps.

In this installation it is our recommendation that an oversize coupling be used, at least 1-1/2 inch OD. The existing installations, however, do not have these couplings and to date have given us no trouble. There is no reason why the 1/2 inch rod could not perform satisfactorily in 2 inch tubing at slow speed as far as tensile loads are concerned; however, as flexible as the 1/2 inch rod is, there is a greater possibility of wadding on the down stroke with any restriction of the pump plunger. This increased area in 2 inch tubing could permit more rapid fatigue due to an increase in concentrated bending stresses.

The one major disadvantage to running 1/2 inch rods in tapered strings in 2 inch tubing is the fact that the 1/2 inch rods might corkscrew and possibly bend and kink if excessive weight of the top section were to drop in the tubing. This could happen of course, if a rod failure occurred at the polish rod permitting the weight of the entire string to drop upon the 1/2 inch section. We believe it may be difficult to maintain sufficient stability of the 1/2 inch rod in 2 inch tubing for the best possible sucker rod service; but, in spite of this problem, we have good reason to believe that there is definitely some considerable application of 1/2 inch rods to tapered strings.

In addition to the obvious economic advantages of the use of slim hole tubing and 1/2 inch rod in dually completed wells there is another radical departure from the conventional in dual completion methods that offers additional food for thought. The practice is different from the conventional in that 2 strings of 2-1/2 inch casing are strapped together, run and cemented in the same hole. Each string is perforated in individual producing zones and completed separately. In perforating the upper zone, a method of positioning the gun to avoid damaging parallel deeper strings has been developed. The only relation to the wells is their closeness, each being entirely separated from the other. This method eliminates the problem of packing off the two zones in one casing string.

We speak of dual completions, but three or more 2-1/2 inch strings can be run in the same manner. In fact, one company is runnign the third casing string for water injection. The 1/2 inch rod is going to make possible a second look at some existing wells in the light of a belated dual completion. These would be wells that were overlooked as potential dual completions when they were drilled, but in the light of subsequent developments now seem to indicate that they could have been dually completed. Generally speaking, these wells were completed initially with 5-1/2 inch casing. This made dual completion, where both zones had to be pumped, an almost insurmountable problem until the 1/2 inch rod was developed to pump inside of your small tubing, thus giving you room within the annulus of 5-1/2 inch and smaller casing to pump two different strings of tubing. Your small tubing also makes for a more desirable well head set-up. There is room within your tubing head dimensionally to suspend two or more strings of small tubing on separate slips thus enabling the operator to pull either string independently of the other.

There is one other item worthy of mention when considering the application of 1/2 inch rods and small tubing to either single or multiple completions; when used in connection with hydraulic units, the 1/2 inch sucker rod and small bore pump has a tendency to greatly increase the depth capacity of these units. This is due to the fact that there is a saving in rod weight alone of 1/2 pound to the foot over 5/8 inch rods. Since the capacity of your hydraulic unit is determined by the polish rod load, this saving of 500 pounds per 1,000 feet means a great increase in the depth limitations of the hydraulic unit. This is especially true in view of the fact that there is no counterbalance method possible with the existing hydraulic units. This saving in weight,

CHART 3

COST COMPARISON BETWEEN SLIM HOLE AND CONVENTIONAL COMPLETION

(This is a 2,750 foot Well producing 25 barrels per day)

		Conv.	S. H.
SURFACE PIPE			
4-1/2 inch 9.50# H-40 Lone Star Casing	$116.77 cft.		$116.77
8-5/8 inch 24# J-55 Lone Star Casing	285.13 cft.	285.13	
CASING			
2-1/2 inch 6.40# H-40 Lone Star Tubing	83.16 cft		2,286.90
5-1/2 inch 14# J-55 Lone Star Casing	170.53 cft	4,689.58	
TUBING			
1-1/4 inch EUE 10 rd. CW Line Pipe w/J-55 Tubing Cplgs.	36.50 cft.		1,003.75
2 inch EUE J-55 Electric Weld Tubing Lone Star 4.70#	62.08 cft	1,870.55	
SUCKER RODS			
1/2 inch x 25 foot Type A Liberty Dbl. Pin w/Cplgs.	30.80 cft.		847.00
5/8 inch x 25 foot Type A Liberty Dbl. Pin w/Cplgs.	36.30 cft.	995.50	
PUMPING UNIT			
U2-DR64A Hamer Unit w/Slide Rails, Belt Grd., Beam Wts., Fdn. Bolts			621.19
LU7-25DR Liberty Unit Ditto		1,507.90	
ELECTRIC MOTOR			
1-1/2 HP 1200 RPM, 1 Phase, Hi-Torque Pumping Unit Motor			116.96
5 HP 1200 RPM, 1 Phase, Hi-Torque Pumping Unit Motor		468.52	
CASING HEAD			
4-1/2 inch x 2-1/2 inch Hamer Type T-1 Braden Head w/2-2 inch Outlets			32.50
8-5/8 inch x 5-1/2 inch Norris-Hinderliter Casing Head w/2-2 inch Outlets		170.50	
TUBING HEAD			
2-1/2 inch x 1-1/4 inch and 2-2 inch Outlets Hamer Type T-1 Tubing Head w/slips			47.50
5-1/2 inch x 2 inch with 2-2 inch Outlets Norris-H Hinderliter tubing Head liter Tubing Head		141.50	
STUFFING BOX			
Skinner Slim Jack 1-1/4 inch x 1 inch Stuffing Box			16.00
Hercules Duplex 2 inch x 1-1/4 inch Stuffing Box		23.50	
		$10,152.68	$5,088.57

coupled with the saving in weight resultant from the use of a small bore pump, frequently lets a producer down-scale his unit purchase two or three sizes with a consequent saving in price.

A REVIEW OF COMPLETE INSTALLATIONS. DETAILS ON HOW THE 1/2 INCH ROD HAS BEEN USED BY VARIOUS PRODUCERS

We have recently furnished rods and units to a producer in the Cushing, Oklahoma area for ten 3,300 foot to 3,400 foot wells. These wells are being pumped by a pumping unit with a 5,500# beam capacity and a 16,000# inch-pound peak torque gear box with a macimum 32 inch stroke. The customer has 1/2 inch type A rods with 1 inch OD couplings running inside of 1-1/4 inch upset 10 round thread continuous weld line pipe, coupled with J-55 tubing couplings. Mostly because he already had it on hand he used 4-1/2 inch 9.50# electric weld casing. This operator states he saved between $8,00 and $10,000 per well by slim hole completion of these wells.

The pattern of completing these particular Red Fork wells in that area in the past had been to use 5-1/2 inch casing, 2 inch tubing, 3/4 inch rods and 1-1/2 inch pump. In order to operate the 1-1/2 inch pump and lift the weight of the fluid column and the rods, the operators were installing pumping units with a 10,000# structure and a 57,000 inch-pound torque gear box. These 10 wells, are making an average daily production of 40 barrels per well. Two of the wells, however, drilled on the edge of the lease came up with some unexpected heavy water loads. In these wells the operator has presently operating 1-1/4 inch pumps and 2 inch tubing with the 1/2 inch rods, and with the small units. He is moving approximately 70 barrels per day from these two wells and is operating the unit at the rate of 19 strokes per minute with a maximum 32 inch stroke. All of the other wells are equipped with 1 inch pumps and all wells are operating continuously.

We have furnished material for another independent operator in the Henryetta, Oklahoma area. This operator achieved the ultimate in slim hole completion costs. He drilled a 4-3/4 inch hole to 2,600 feet where he completed his well and installed as casing 2-7/8 inch OD tubing which he cemented from top to bottom. Inside of this tubing he has a string of 1-1/4 inch upset electric weld 10 round thread tubing coupled with J-55 tubing couplings, a string of 1/2 inch type A rods with 1 inch OD couplings and a 1 inch pump. His well is producing approximately 20 barrels per day with a small pumping unit that has a 3,000# beam and a 6,400 inch-pound peak torque gear box and a maximum 24 inch stroke. This man estimates in total drilling and completion costs he saved 60 per cent over conventional completion methods.

On the basis of the low drilling and completing costs he has planned to undertake a more extensive program in that area with an eye to drilling and completing some 5 to 10 barrel wells from approximately the same depth. In these wells he will go down to evan a smaller unit, one having a 2,000# beam and a 6,400 inch-pound peak torque gear box with a maximum 12 inch stroke. He is using on his present installations 1 HP, 1750 RPM, 3-phase electric motors. He is operating continuously and is very pleased with the saving in electricity costs over some wells operating with larger motors on time clocks on a nearby lease.

The very slimmest slim hole installation is in some wells for an operator near Antelope, Kansas. This operator has 17 wells that have been operating off two old antiquated central powers. These wells were originally completed with 2 inch tubing in the place of casing. They were being pumped with the tubing string used both as casing and tubing in some instances. The pump efficiency through the central power was very unsatisfactory. In some of the other wells this operator was employing 1 inch pipe as hollow rods. Here again, his pump efficiency was very low and the fatigue factor on the pipe was such that he was experiencing breaks almost daily.

In some of the wells he has elected to purchase 1-1/4 inch non-upset tubing and have the couplings machined down to make it possible to run it inside his 2 inch tubing. In these wells he has installed a string of 1/2 inch rods and a 1 inch insert type pump. In the wells where he has made this change the operator states that his production has come up from approximately 4 or 5 barrels per day to from 12 to 18 barrels per day. His next step is going to be to equip each of these wells with a small independent pumping unit and small electric motor and junk the old central powers.

Another large and active independent operator whose production is mainly in Central, Oklahoma has put on several 4,300 foot wells. These wells to which he has applied the 1-1/4 inch tubing, 1/2 inch sucker rods and 1 inch pump and small units are wells that were originally completed with substantially greater fluid volume than they now have. When these wells were completed 5-1/2 inch and some 7 inch casing was used along with 2 inch tubing, large units, 3/4 inch strings of rods and large pumps. The unit size, as I recall it, was about 228,000 inch-pound peak torque. Fluid through the years has been gradually decreasing and for the last several years has settled at about 10 barrels per day.

This customer elected to retire this large and expensive equipment for utilization on other heavy wells that he was drilling and to re-equip these now small volume wells with smaller equipment. By so doing, he is salvaging equipment that would cost him new approximately $10,000 and re-equipping with equipment specifically designed to pump the available amount of fluid at a cost of approximately $4,000, or a saving of $6,000 per well. This customer is using what is a common practice among compainies slim holing old wells inside of large casing. He is topping out his 1-1/4 inch tubing string with 1 joint of 2 inch upset tubing. This enables him to use the same casing head, tubing head, pumping and flowing tee, stuffing box, and polish rod that were originally on the well. These items he purchases new when he re-installs the old equipment.

In another installation with a major gas producing company in the Texas Panhandle, a company has installed a string of 1-1/4 inch tubing in combination with a small bore pump and 1/2 inch rods and a small hydraulic pumping unit to pump water off the gas wells. This water has been killing the wells and the company had been paying servicing companies to swab them down so they could start producing gas again. Now they are producing the gas in the annulus between the small tubing and their casing and employing the small hydraulic unit and slim hole rod and tubing string to keep this consideration and formation water pumped off for contin-

CHART 4

Calculations on rods and unit installation of 2,750 foot well w/1/2 inch rods, 1 inch pump, and 24 inch Maximum stroke U2-DR64A Hamer Pumping Unit.

	976	- Wt. of rods and fluid per 1,000 feet depth.
	x 2.75	- Depth of 1,000 foot units
	4950	-
	6832	-
	1952	-
	2684.70	- Static Load
	x 1.06	- Acceleration factor (14 SPMx24" stroke)
	1610820	
	2684700	
A.	2845.7820	- Peak Polish Rod Load
	848	- Effective counter balance per 1,000 feet of depth (wt. of rods plus 1/2 wt. fluid.)
	x 2.75	
	4240	
	5936	
	1696	
B.	2332.00	- Maximum effective counter balance
	2845.78	- Peak polish rod load (A)
	2332.00	- Max. effective C. B. (B)
	513.78	
	x 12	- 1/2 Stroke length
	102756	
	51378	
C.	6-65.36	- Peak Torque

D. 24" x 14 SPM = 336 336 x .117 (1 inch pump constant) = 39.3 barrels per cent x 80 per cent eff. = 31.4 barrels per day.

uous producing operations. This eliminates, of course, the service company expense and keeps their wells producing.

A major oil company is considering going back into some Arbuckle wells in Kansas in which they have 7 inch casing and 3-1/2 inch tubing to complete some upper zònes such as the Kansas City that do not bear water by this same slim hole technique. These wells were drilled as Arbuckle wells prior to the time that the dual completing techniques were popularly accepted in the industry. Now, because of the economics involved, this company believes that they can go back in and dual complete these wells and realize an additional 10 to 15 barrels per day of production for an expenditure of from $3,000 to $4,000.

Time will just not permit to go into all of the applications of the 1/2 inch rod but these installations will certainly give you some perspective as to the versatility of the rod and the tremendous potential application of it to various types of wells.

HOW THE 1/2 INCH SUCKER ROD CAN MATERIALLY REDUCE PUMPING INSTALLATION COSTS IN AREAS WHERE IT IS APPLICABLE

The application of the 1/2 inch rod to marginal wells when complemented by complete slim hole methods can offer savings to the producer ranging from 30 to 60 per cent. The savings realized depend upon the depth, fluid requirements, area being developed and the extent the producer wishes to go toward complete slim hole methods. The ultimate in this method would require the operator to scale downward in his completions to drilling a 4-3/4 inch or 6-1/8 inch hole. At present, or I might say until recently, the 6-1/8 inch bit has been considered best because some operators feel it to be the smallest size available with heavy enough bearings for top to bottom drilling. However, the various bit manufacturers state that they will or by now do have 4-3/4 inch heavy duty bits on the market which will satisfy the top to bottom drilling requirements.

This drilling of a smaller holr results in less cost per foot contracts through the use of smaller rigs which can be moved from location to location at a fraction of the cost of the big rigs now being used to drill the 7-7/8 inch, 8-3/4 inch and 9-5/8 inch holes for conventional completions. In talking about smaller rigs I have reference to small truck mounted rigs that can usually be moved in one load using, for instance, 2-7/8 inch upset N-80 tubing for drill pipe. Rigs of this size with this light drill pipe and light equipment can still achieve the maximum depth limitations of the 1/2 inch sucker rod. The use of smaller crews, less initial investment, less replacement costs on equipment, less insurance costs and less maintenance cost will enable the contractor to make more profit than he is now enjoying and still reduce the cost per foot bids that are now being made on these marginal wells being drilled with oversized drilling equipment.

Mud costs and cementing costs in slim hole completion result in a savings to the producer also worthy of consideration in the overall savings involved. However, the savings in drilling and servicing costs is not nearly as impressive as the savings in equipment cost to put the well on the pump. We would like to call your attention to an attached cost comparison on a 2,750 foot well producing 25 barrels per day. One set of figures is based on conventional equipment costs using 8-5/8 inch surface pipe, 5-1/2 inch casing, 2 inch upset tubing, 5/8 inch rods and 1-1/2 inch pump and the size unit and prime mover usually bought for this depth well.

The other set of figures is for the same well with the same allowable but with all material designed to most economically produce this amount of oil from the same depth. More concisely stated, one conventional hookup and one slim hole hookup. The slim hole equipment costs are based on no surface pipe - 2-7/8 inch OD regular tubing for casing - 1-1/4 inch upset continuous weld tubing, 1/2 inch rods, and 1 inch pump and the smallest pumping unit, prime mover, and other equipment that will satisfactorily handle the fluid load.

You will notice also on charts 3, 4 and 5 the two sizes of pumping units listed in the cost comparison to justify the selection of these units. This particular example is an actual request we received from a large independent producer who wanted this cost comparison for a marginal production lease which he could not afford to develop by the old conventional completion methods. The reflected saving in equipment costs of approximately 50 per cent will enable him to profitably produce his lease and favor sume supply company with the business they could not have enjoyed otherwise. This example is typical of a condition existant with majors and independents alike through the Mid-Continent area. In fact, several of the majors have estimated that the vast majority of wells in the entire U. S. could be produced easily because of allowables through slim hole completions.

This is taking into consideration not only marginal wells but also wells that have a relatively high production volume with no water to handle. Full exploitation of this market should result in a substantial increase in the overall activity through the development of leases that otherwise would not have been undertaken. The comparison of tubing and casing costs for this particular well is fairly representative for all wells down to approximately 4,500 feet. Beyond that depth, if one

CHART 5

Calculations on rods and unit installation of 2,750 foot well q/5/8 inch rods, 1-1/2 inch pump and 28 inch maximum stroke LU7-25DH Liberty Pumping Unit.

```
        1783 - Wt. of rods and fluid per 1,000' of depth
       x2.75 - Depth in 1,000' units
        8915
      12481
      3576
     4913.25 - Static load
      x 1.10 - Acceleration factor (20 SPM x28" stroke)
     4913250
    491325
A.  5404.5750 - Peak polish rod load

        1467 - Effective counter balance per 1,000' (wt.
               of rods plus 1/2 wt. of fluid)
       x2.75 - Depth in 1,000' units
        7335
     10269
     2934
B.   4034.25 - Max. effective counter balance

     5404.58 - Peak polish rod load (A)
    -4034.25 - Maximum effective counter balance (B)
     1370.33 -
     x    14 - 1/2 Stroke length
      548132
     137033
C.  19184.62 - Peak torque
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D. 28" x 10 SPM = 280 280 x .262 (1-1/2 inch pump constant) = 73.36 barrels x 80 per cent = 58.7 per day.

elects to run electric resistance weld thin wall 1-1/4 inch tubing, the comparison would be almost the same except that the thin wall tubing price is some 10 cents a foot higher than the continuous weld tubing used in this particular example.

On the basis of this pipe comparison there is a saving of $87.37 per hundred feet in casing costs, $31.52 per hundred feet in tubing cost and a saving of $10.31 per hundred feet in surface pipe cost by spreading the hundred feet cost over the entire 2,700 feet of depth. This, coupled with approximately a $5.00 saving per hundred feet in sucker rods, brings you to a net saving of $134.19 per hundred feet o well depth on tubing, casing, surface pipe and rods alone.

To realize a final figure of saving in each 1,000 feet of depth resultant from cheaper prime mover, cheaper head and related equipment, savings in drilling costs and completion costs, I think we could make a very good estimate of $2,000 savings per 1.000 feet of well depth for slim hole over conventional completion and equipment techniques. This at least should be close enough to enable an operator to justify further investigation into the exact savings involved, and I am quite certain it will be fairly close to a 30 to 60 per cent overall saving. This, of course, depends upon the well depth and ultimate selection of equipment.

The one last problem to be considered in the application of your 1/2 inch rod and related items to your marginal wells would be availability of allied equipment such as floating equipment, subsurface pumps, well heads, stuffing boxes, flowing tees and your service facility for rod wrenches and elevators. All of these items, material items and sefvice items are available through regular sources and procurement of them will not mean a delay in filling your requirements. The most commonly questioned item is the 1-1/4 inch upset tubing - this has been a commodity not readily available in the rade until the introduction of the 1/2 inch sucker rod.

Since that time the most commonly used pipe has been 1-1/4 inch plain end continuous weld line pipe which has been upset and threaded with 10 round threads and coupled with J-55 tubing couplings. At least one steel company has calculated that this pipe should satisfactorily run to 6,958 feet using a safety factor of 1.0, or 4,639 feet using a safety factor of 1.5. These are setting depths in tension at yield load in feet. No steel mill will publish setting depths for continuous weld line pipe because it is not manufactured for that purpose. However, it has been widely used as tubing by Kobe, Incorporated for years. More recently it has been used for tubing in pumping wells with good results.

Each operator's own best judgment will have to govern his recommendations for every application. There is one manufacturer of electric resistance weld thin wall tubing that has informed us that they expect to put on the market a thin wall electric resistance weld tubing in grades H-40, J-55 and possibly N-80. This will have a substantially greater setting depth which, in the J-55 grade, should greatly exceed the setting depth limitations of the 1/2 inch rod and should deliver to the customer in carload quantities for from 45 cents to 48 cents per foot.

To date comparative prices of 1-1/4 inch upset electric weld tubing in H, J and N grades and seamless tubing of the same size and grade have been priced out of competition to 2 inch upset electric weld or seamless tubing. However, even when the price advantage in the small tubing versus the 2 inch tubing is lost, there still is considerable economic advantage in the balance of your slim hole application. Economic factors should decide how far an operator is willing to go in exploiting the advantages and benefits of applying the 1/2 inch rod and allied equipment to his own production problems.