Ask Echometer 22 Online Seminar – November 11, 2020

(((ECHOMETER)))

Motor Power-Current-Voltage Measurements and Analysis

TOTAL ASSET MONITOR (TAM)

http://www.echometer.com/Software/Total-Asset-Monitor

"Net Torque Acting on a Pumping Unit Gearbox ", Ask (((Echometer))) Online Seminar #12 – August 5, 2020 – www.echometer.com

"Artificial Lift Power Efficiency", Lea, Rowlan, McCoy, SWPSC 1999

"How to Maintain High Producing Efficiency in Sucker Rod Lift Operations", McCoy, Rowlan, Becker, Podio, SWPSC 2004

"Motor Power/Current Measurement for Improving Rod Pump Efficiencies", McCoy, Podio, Ott, Rowlan, Garrett, Woods, SPE 1997

"Wireless Motor Power-Current-Voltage Measurements and Analysis", McCoy, Rowlan, Taylor, Becker, Podio, West, SWPSC 2015

Presenters: O. Lynn Rowlan and Carrie-Anne Taylor

Q & A: Gustavo Fernandez and Echometer Engineering and Support

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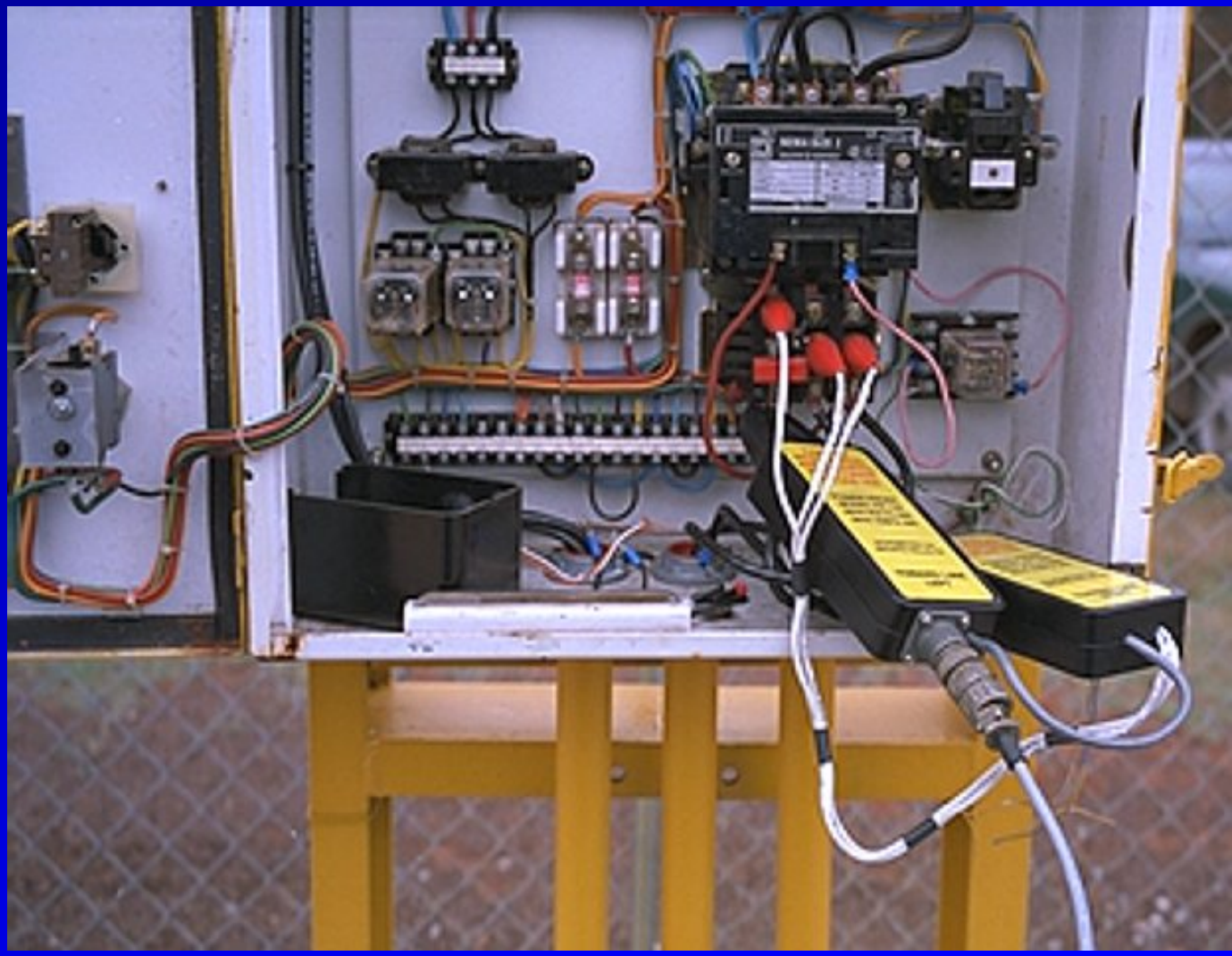
Download the Session 22 PDF Bundle and TAM Example Data from

https://echometer.com/Support/AskEchometer

Operator's Use of Power Probes Identifies Inefficiencies and Reduces Electrical Cost.

1. The power measurement system is designed to give instantaneous power values within 5% of actual values.
2. Electrical cost is one of the highest expenses in operating a well



MOTOR POWER SURVEYS ANSWER THE FOLLOWING QUESTIONS:

1. What is the overall electrical efficiency of the pumping system?
2. Is the surface electrical efficiency less than 80%?
3. Is the overall electrical efficiency above 50%?
4. What is the power consumption, $/month, $/BBL, and power demand, KW?
5. What is the motor current? Does the motor overheat?
6. Does the motor generate electricity at some time during the stroke? Is credit allowed for generation?
7. Is the gearbox overloaded?
8. Is the pumping unit properly balanced?
9. Required movement of counterweights to balance unit?
10. What are transmission line losses in relation to power consumption ?

Electrical Safety

1. Most power measurement devices require the operator to open the electrical switch box to install sensors.
2. The operator is exposed to DANGEROUS HIGH VOLTAGE electricity.
3. The cabled portable power transducers installation procedure is safe when the operator exercises precaution and follows the recommended procedures in the attachment of the voltage and current sensors and uses proper safety equipment.
4. Permanently installed WIRELESS connector for power/voltage/current sensors eliminates risk of contact with electrical components inside panel.

Power Measurement Equipment

1. Acquire:
   - RMS (thermal) motor current
   - Average (real) motor current
   - kW during a pump stroke cycle.

2. Three voltage sensing leads "**RIGHT**", "**CENTER**" or "**LEFT**".

3. Two current sensors.

Portable Wireless Power Probes with Cable Harness

Used for wells that are not outfitted with permanent external power sensing connector.

Permanent Internal Power Probe Sensors

Requires: mounting two current transformers around power wires and attaching three voltage sensing leads to electrical lines and installing safe external connector in switch box.

Sensor connection may be done while pumping unit is operating.

Sensor is powered up then data acquisition and transmission is initiated by depressing “Acquire” switch.

Generally power/current are acquired simultaneously with dynamometer data but stand alone power acquisition is also an option.

API Unit Description

C-320D-256-100

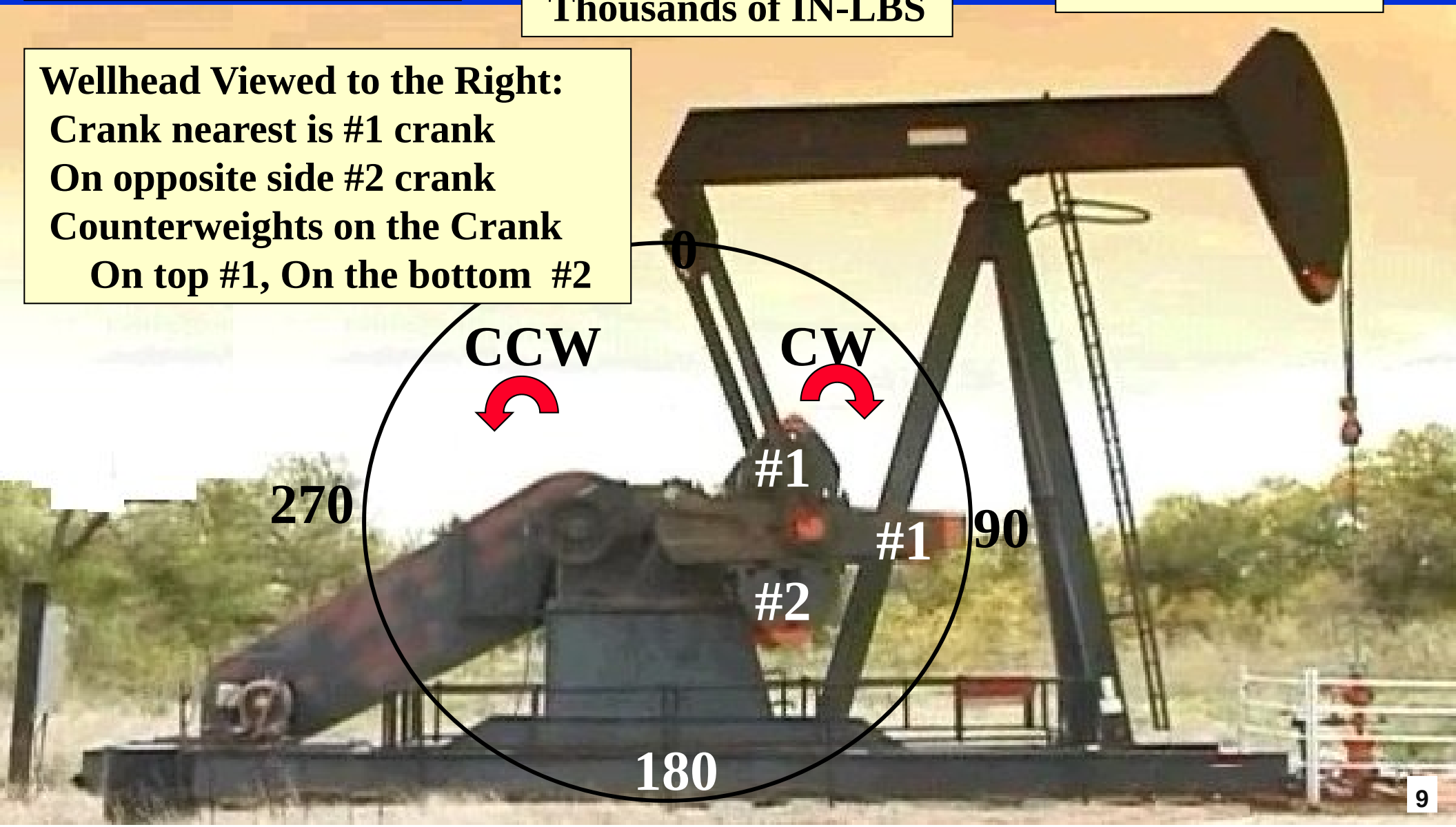
Type:
A - AIR BALANCE
B – BEAM BALANCE
C – CONVENTIONAL
M – MARK II

Peak Torque Rating
Thousands of IN-LBS

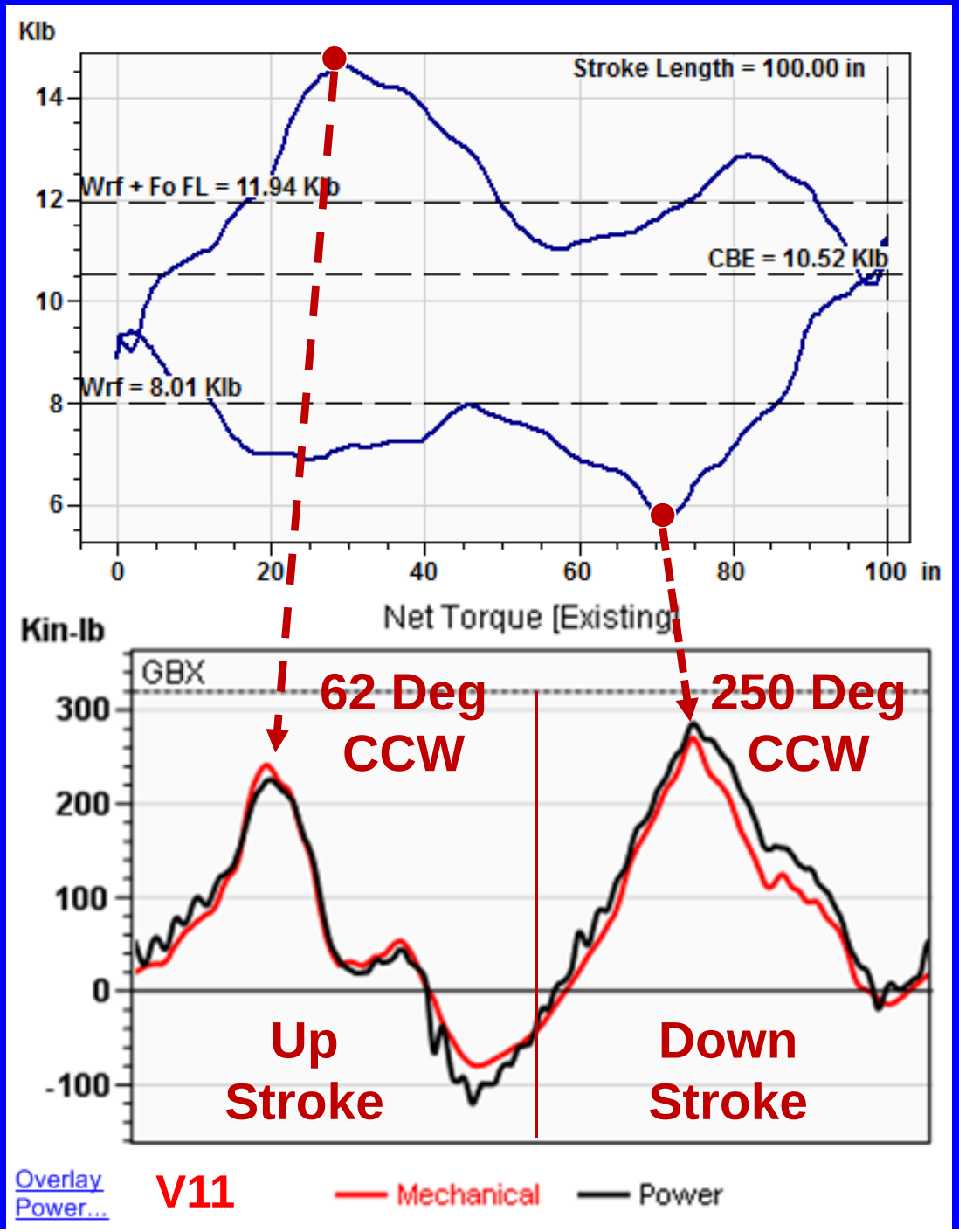
Maximum Stroke Length in Inches

Structure Rating in 100s of LBS

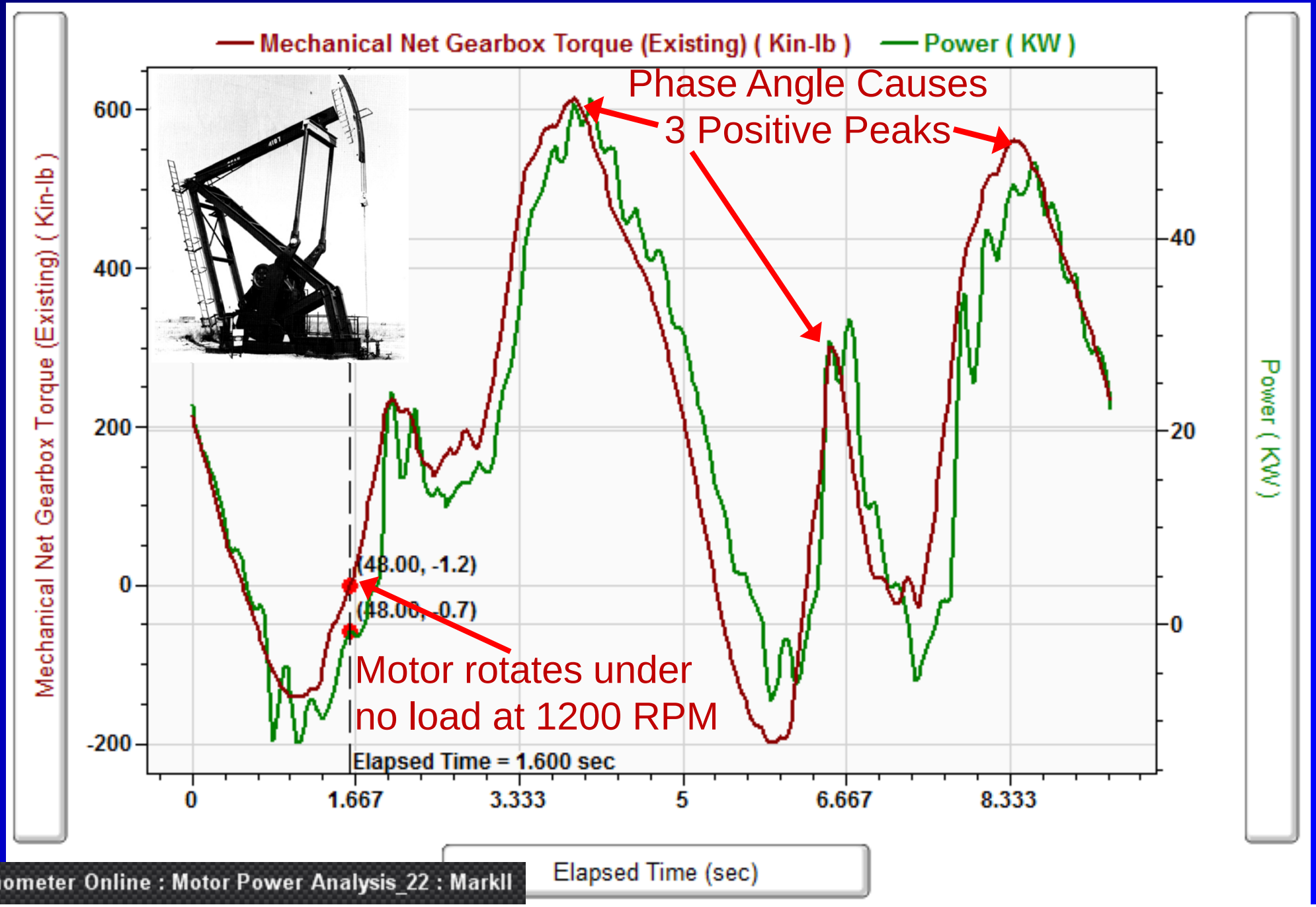
Wellhead Viewed to the Right:
Crank nearest is #1 crank
On opposite side #2 crank
Counterweights on the Crank
On top #1, On the bottom #2



KW Power Analysis Motor and Gearbox Torque are Directly Proportional

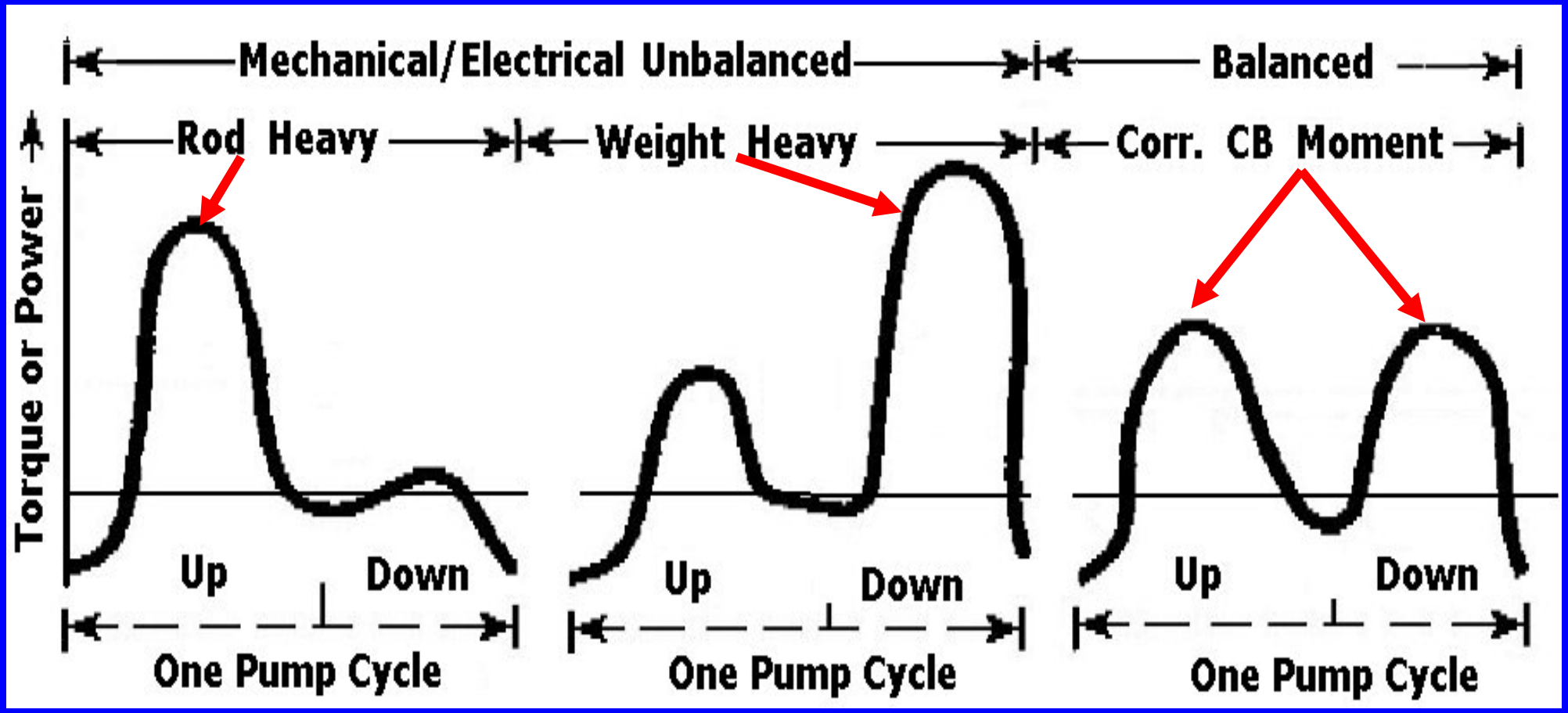


At speeds faster than 1200 RPM motor produces power
At slower speeds the motor is using power to do work.



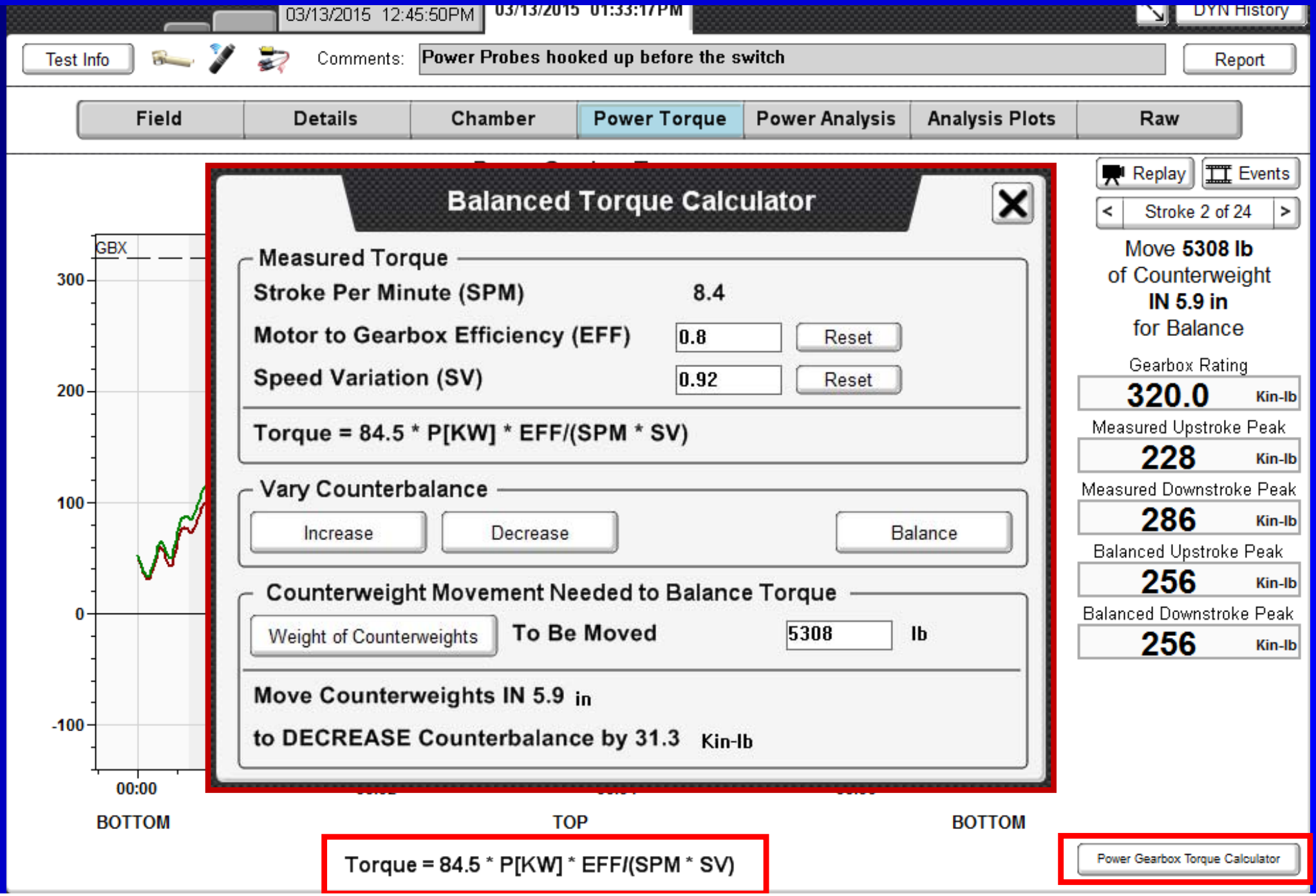
Balanced Torque Provides Uniform Loading Throughout Stroke

Mechanical/Torque (in-lbs) or Electrical/Power (kW) Signatures for a Unbalanced or Balanced Pumping Unit:

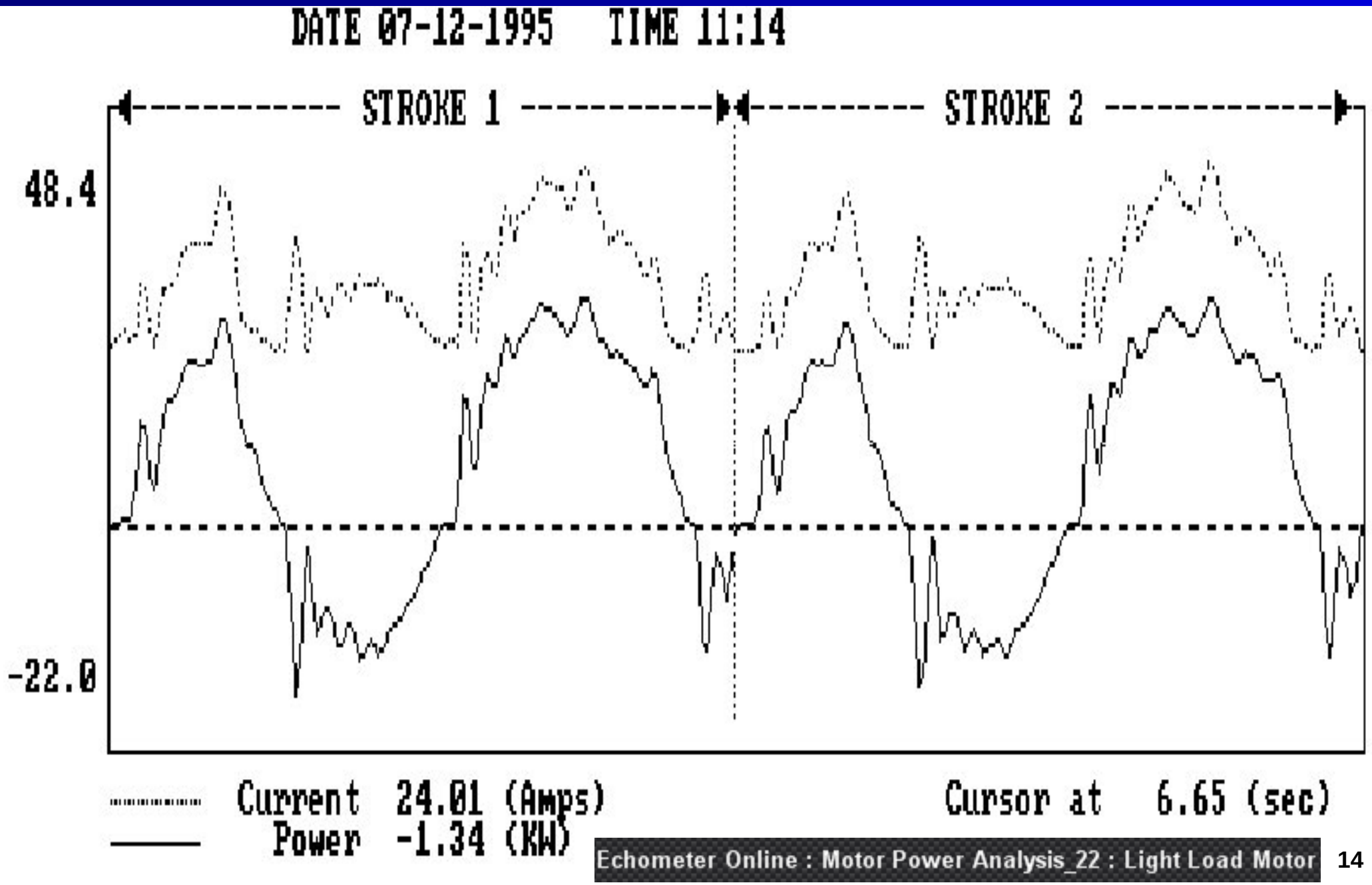


Gearbox Torque from Motor Power

"Net Torque Acting on a Pumping Unit Gearbox ", Ask (((Echometer))) Online Seminar #12 – August 5, 2020 – www.echometer.com

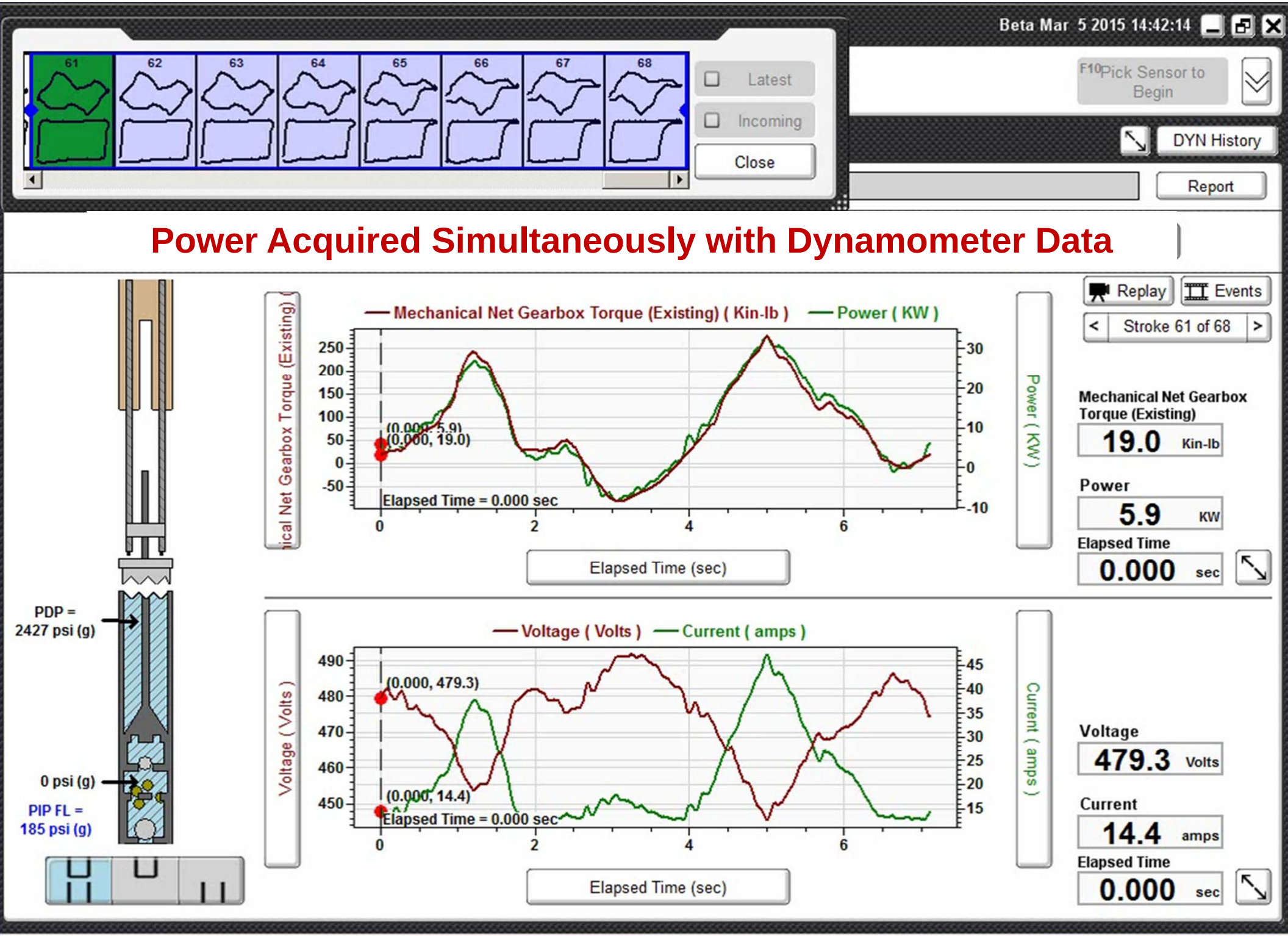


Electric Power (kW) and Current (Amps) Input to the Motor over the time of a Pump Stroke



Echometer Online : Motor Power Analysis_22 : Light Load Motor

Power Acquired Simultaneously with Dynamometer Data

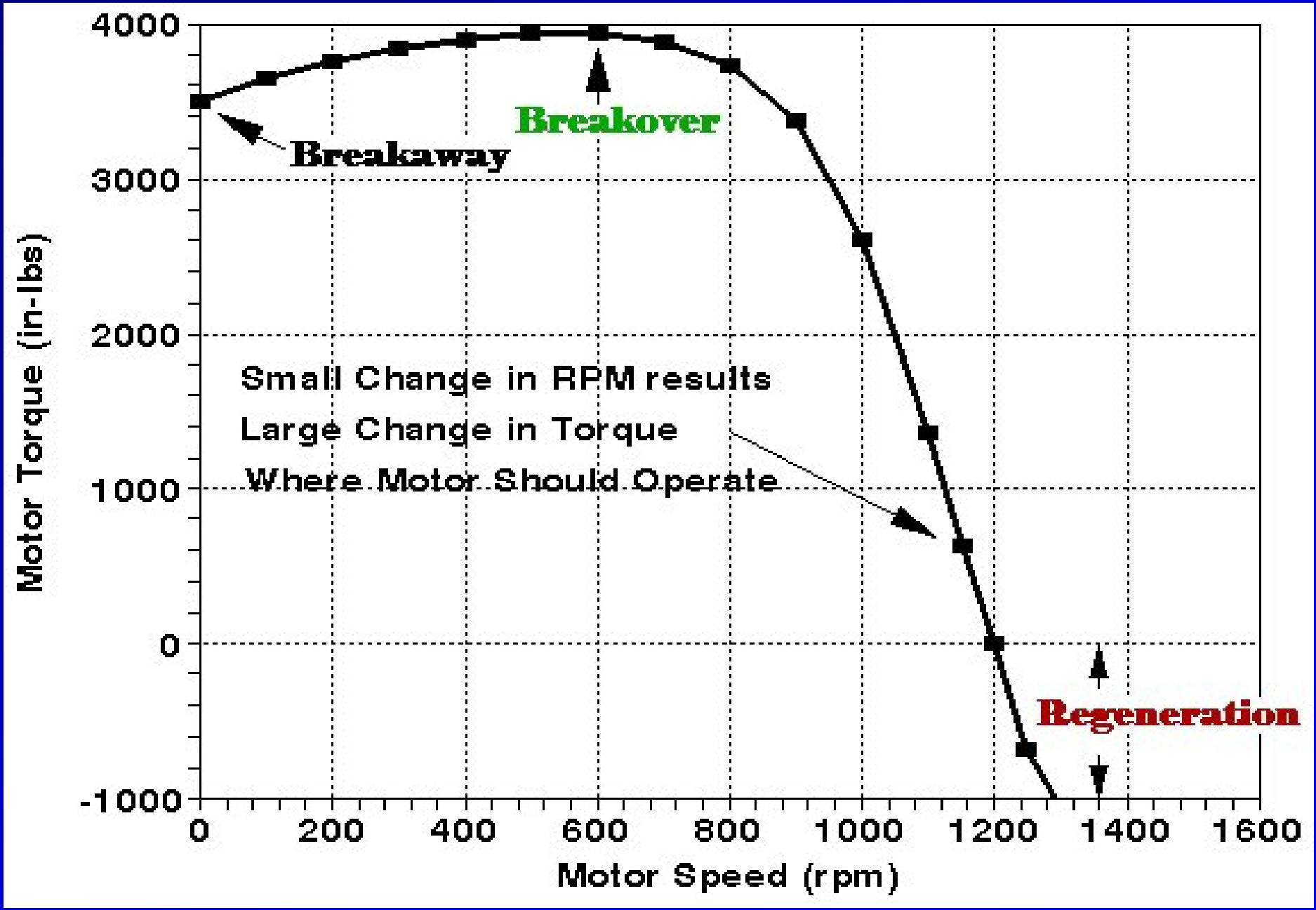


Nature of the Load

- Torque required to breakaway and accelerate a pumping unit is high
- Breakaway torque is a function of the pumping-unit size and well conditions.
- Conventional Pumping Unit net gearbox torque during a stroke has two max (peak) and two min (valley) power demands for each stroke.
- Peak torque or power are approximately equal for balanced operation.
- A balanced pumping unit reduces motor thermal load, because of:
  - a) Reduced peak torques imposed on the motor
  - b) Reduced peak power delivered by the motor,
  - c) Reduced peak current drawn by the motor.
- Polished-rod horsepower will vary depending on the well conditions. If Polished-rod horsepower changes then the balanced condition of the pumping unit change.

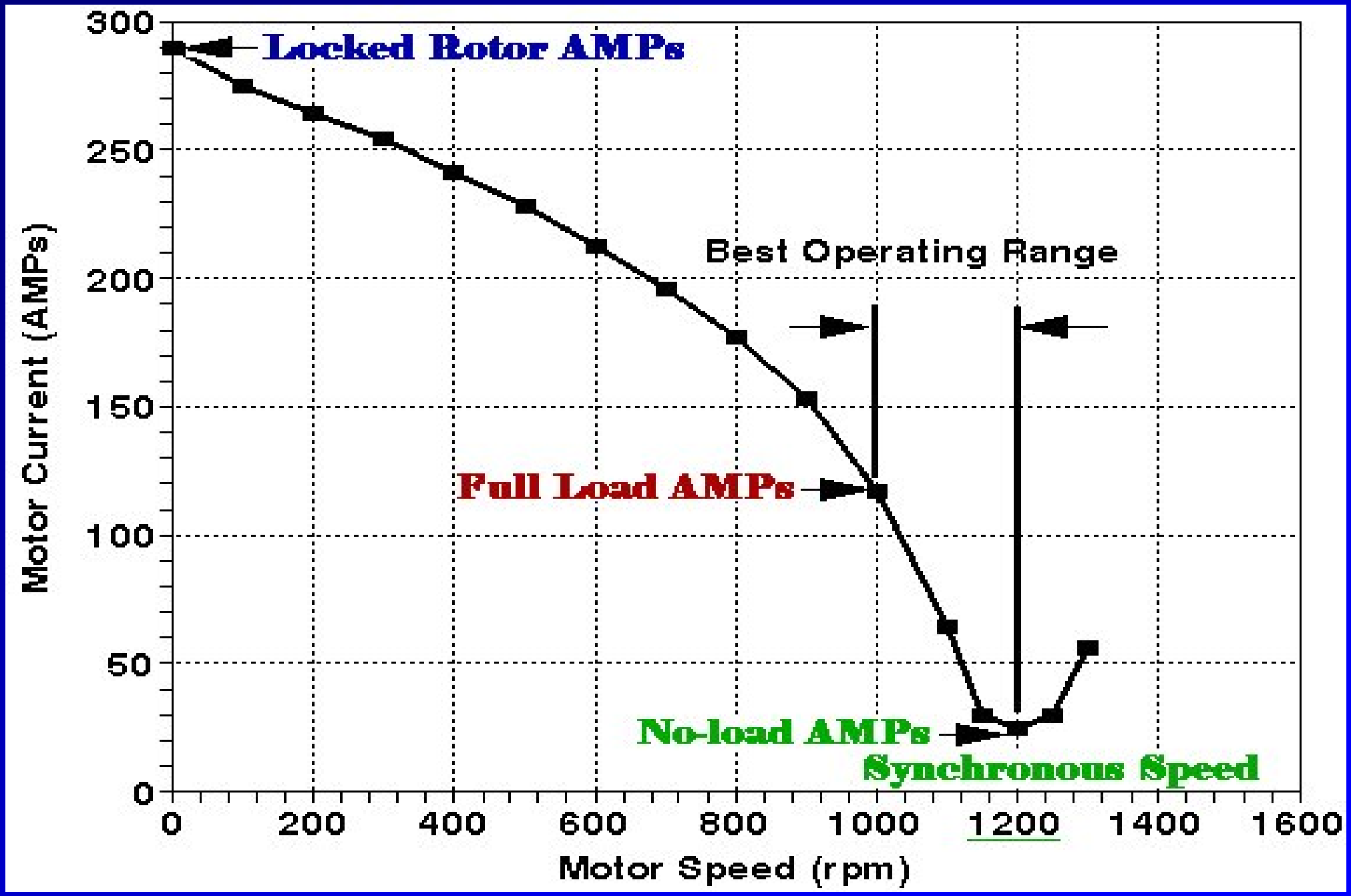
Motor Performance Data NEMA D - 40 HP

Output torque from the motor varies as motor speed varies



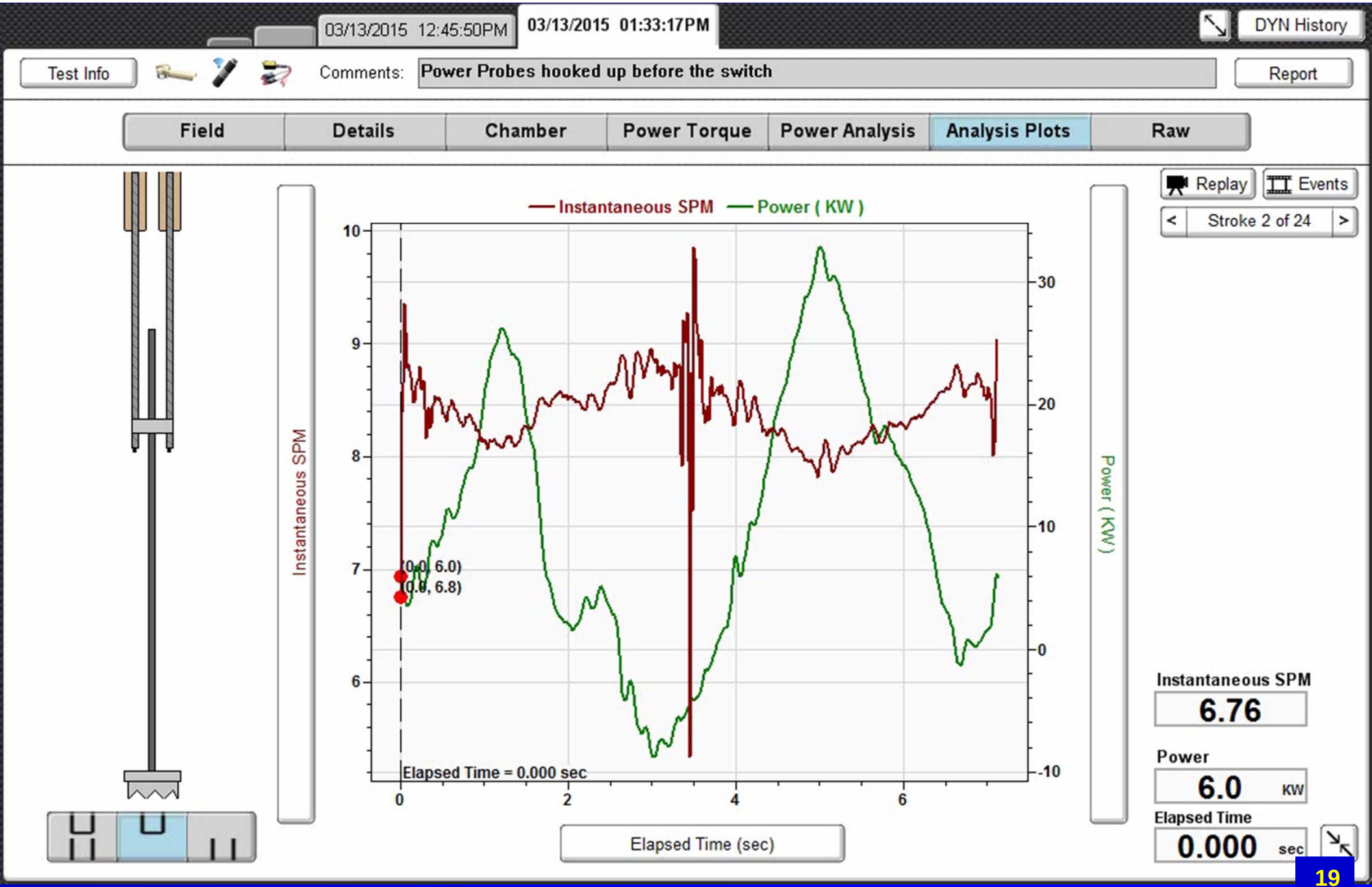
Motor Performance Data NEMA D - 40 HP

Relationship between current drawn and motor speed.



Motor Slip = (Sync RPM - Running RPM) / Sync RPM

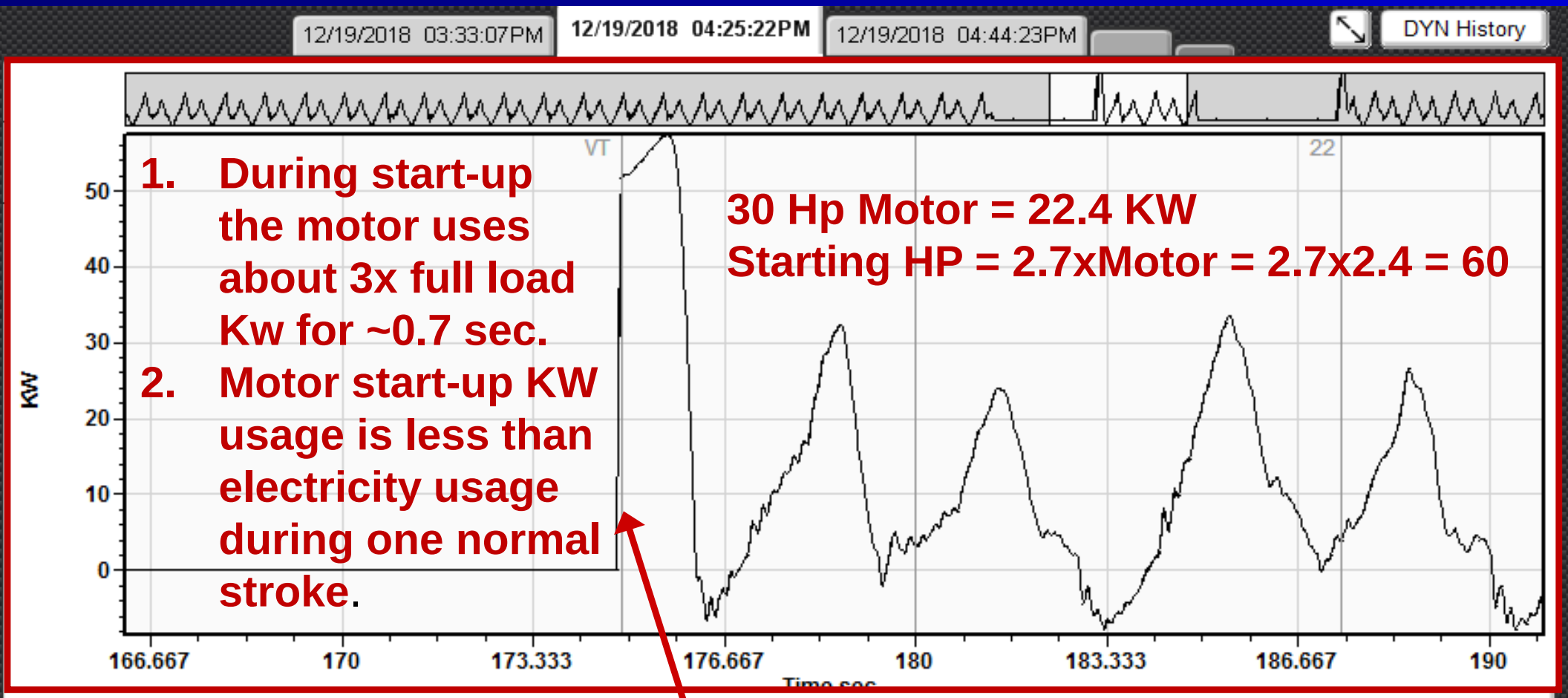
Instantaneous RPM computed from measured acceleration



INDUCTION MOTORS OBJECTIVES

- Understand the performance characteristics of a typical electric prime mover.
- Understand the nature of the load imposed on an electric motor, the torque required from the motor to break away and accelerate a pump jack.
- Pumping unit gearbox load presented to the prime mover, and the motor torque characteristics should have similar "signatures" to that of the gearbox torque.
- Cyclic loads translate to peaks and valleys in the power demand at the motor.
- <u>What the Gearbox demands the motor provides</u>.
- Identify and distinguish between an electrically unbalanced and balanced pumping unit.

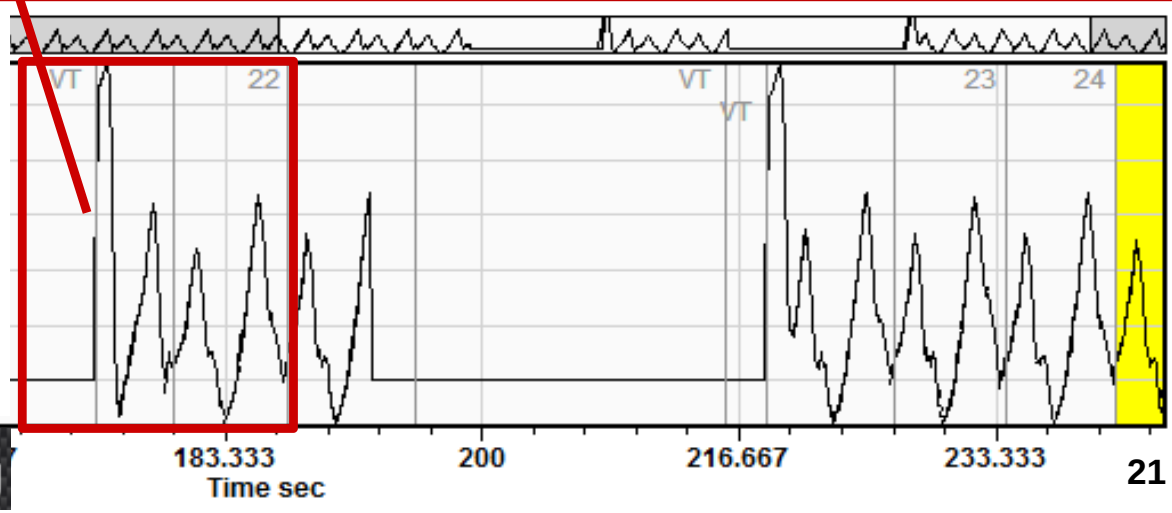
Startup Motor Power Consumption



1. During start-up the motor uses about 3x full load Kw for ~0.7 sec.
2. Motor start-up KW usage is less than electricity usage during one normal stroke.

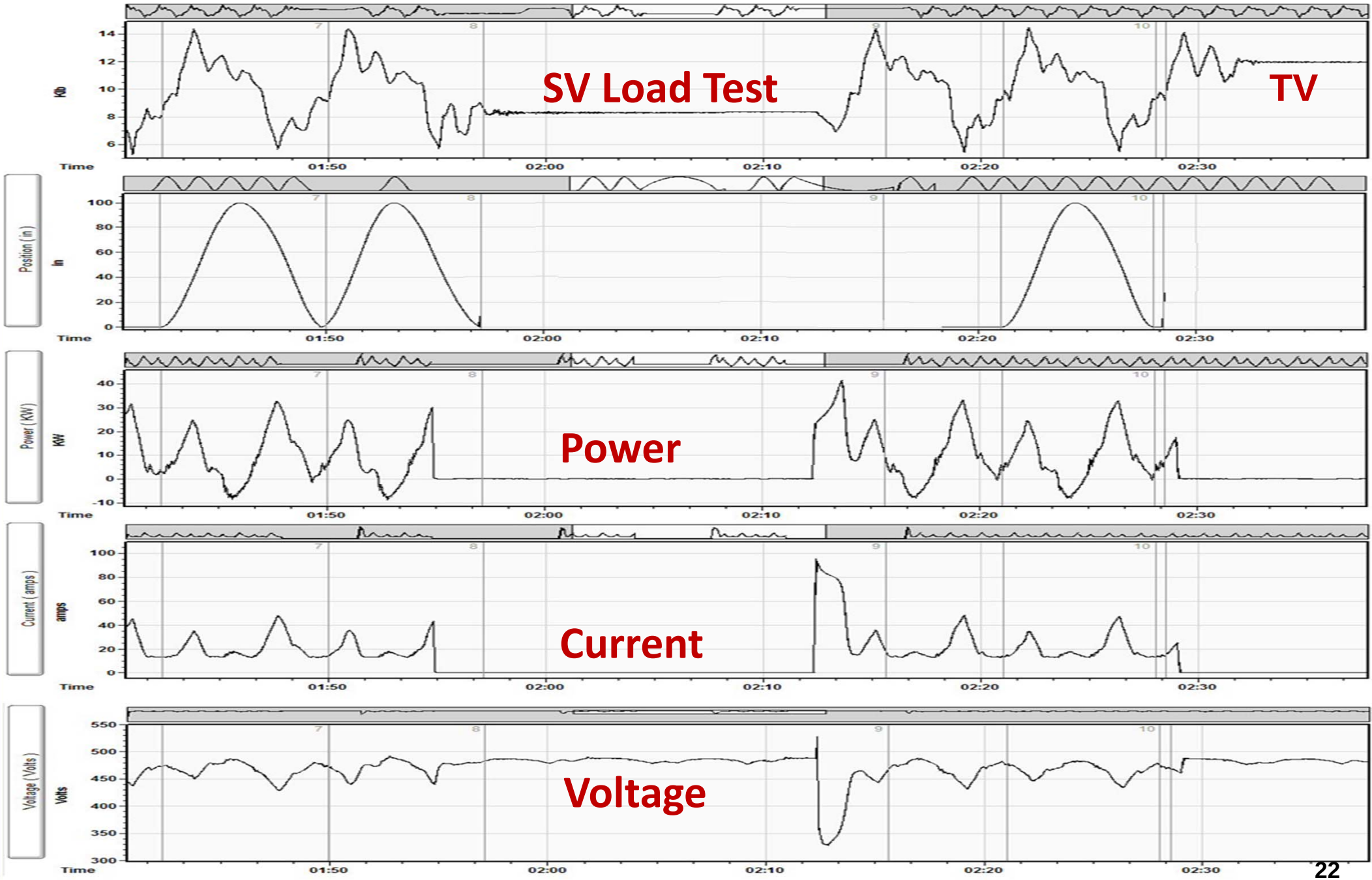
30 Hp Motor = 22.4 KW
Starting HP = 2.7xMotor = 2.7x2.4 = 60

Starting a beam pump motor to control run-time once each 15 minutes impacts demand charge less than 0.2 % compared to continuous operation.

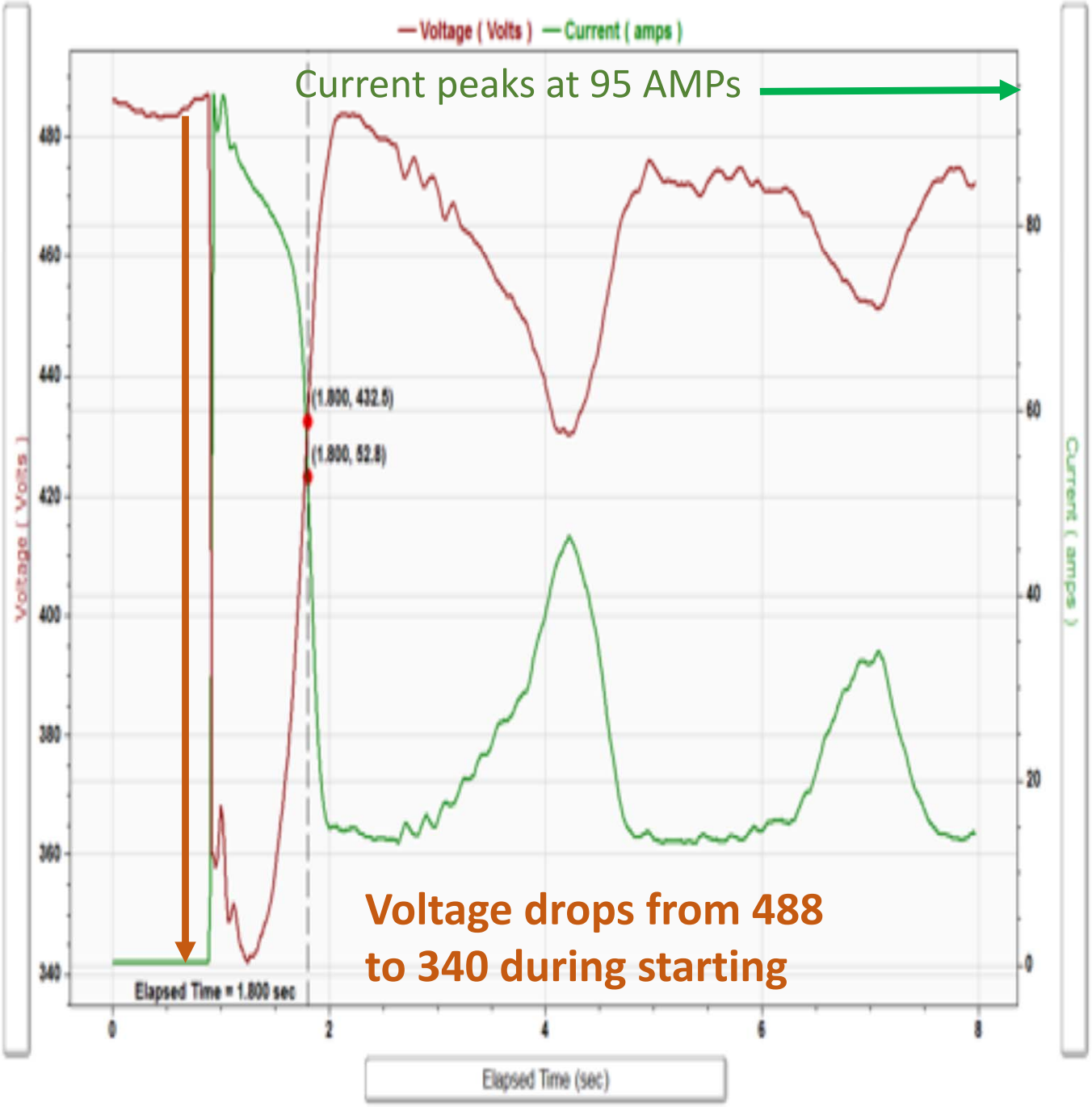


Echometer Online : Motor Power Analysis_22 : Power Probe Testing

Simultaneous Acquisition of Polished Rod Load, Polished Rod Position, Motor Power, Motor AMPs and Motor Voltage while Performing Valve Test.



Voltage and Current during Motor Startup



The voltage and current are analyzed in software to determine the line loss. The voltage drop and the current usage during startup are used to determine the resistance of the distribution electrical line. Then, the current and calculated resistance are used to calculate the line loss power. This data is acquired when the operator is acquiring the traveling and standing valve tests.

Operating Cost and Power Line Loss Cost

From above, Line Loss = 0.8015 KW

The Gross Input Power to the Motor is shown below as 9.7 KW

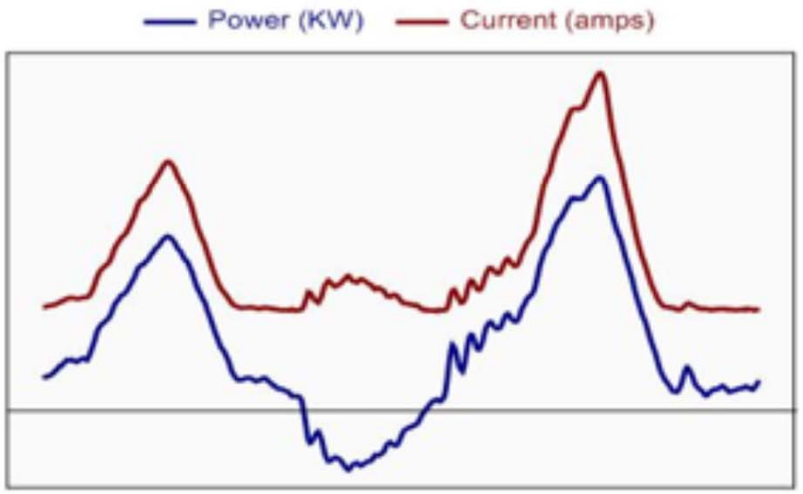
Avg. KW for stroke 16 is = 9.7 + .8015 = 10.502 KW @ $0.1/KWH 30 Days = $756.11 / Mo

Line Loss = 0.8015 /10.502 = 7.6% of Power Bill thus Line Loss Cost = $57.72 / Mo

Power Analysis

Monthly Operation Costs (30 Days/Month)

Run Time	24.0	hr/day
Cost With Gen. Credit	319.41	$
Cost No Gen. Credit	348.97	$
Demand Cost	84.12	$
Oil Production Cost	206.2	¢/bbl
Liquid Production Cost	13.5	¢/bbl
Oil Production	7	BBL/D
Water Production	100	BBL/D



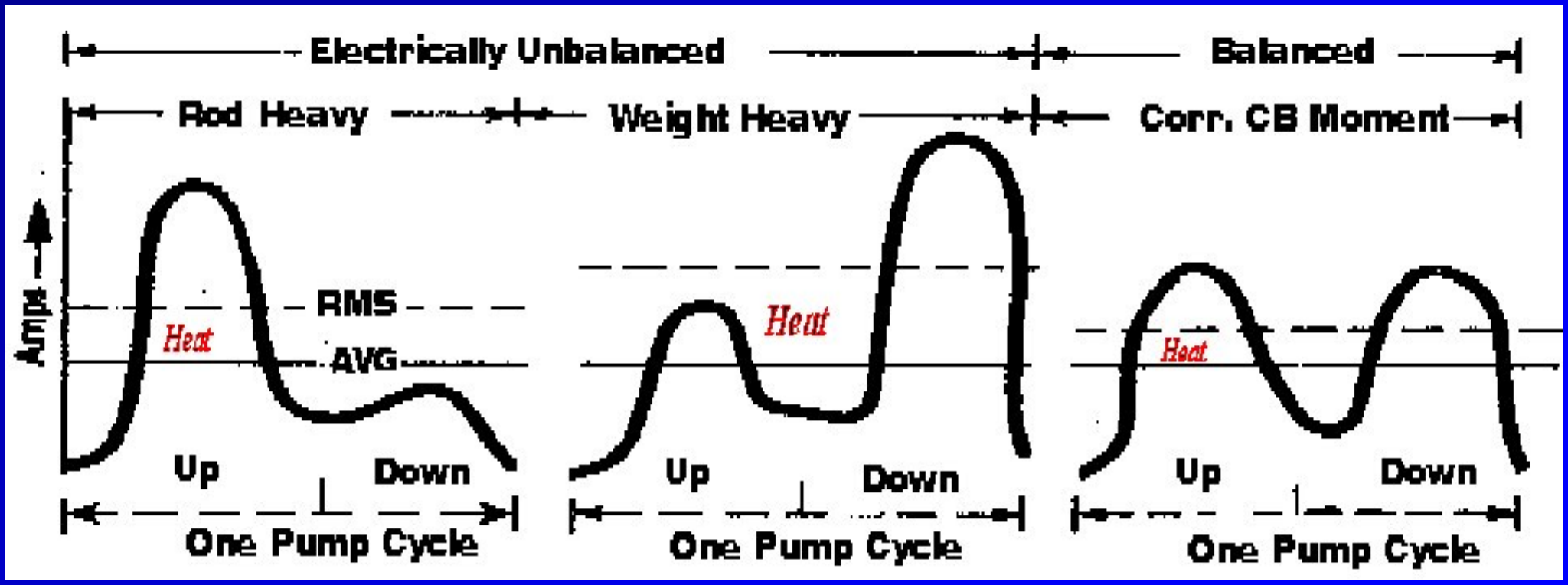
Recommended Min NEMA D Motor	13.3	KW
Rated HP	22.4	KW
Rated Full Load AMPS	39	
Thermal AMPS	22.0	
Gross Input	9.7	KW
Net Input	8.9	KW
Demand	10.5	KW
Average	9.7	KVA
Average Power		
With Generation Credit	8.9	KW
No Generation Credit	9.7	KW
Average Power Factor	73.5	%
System Efficiency	53.3	%

Cyclic Loading on Motor

Amp (current) signatures of an electrically or mechanically unbalanced or balanced pumping unit:

- **RMS Amps shows thermal loading on Motor**
- **Compare Acquired Thermal Amps to Motor Name Plate Amp Rating**

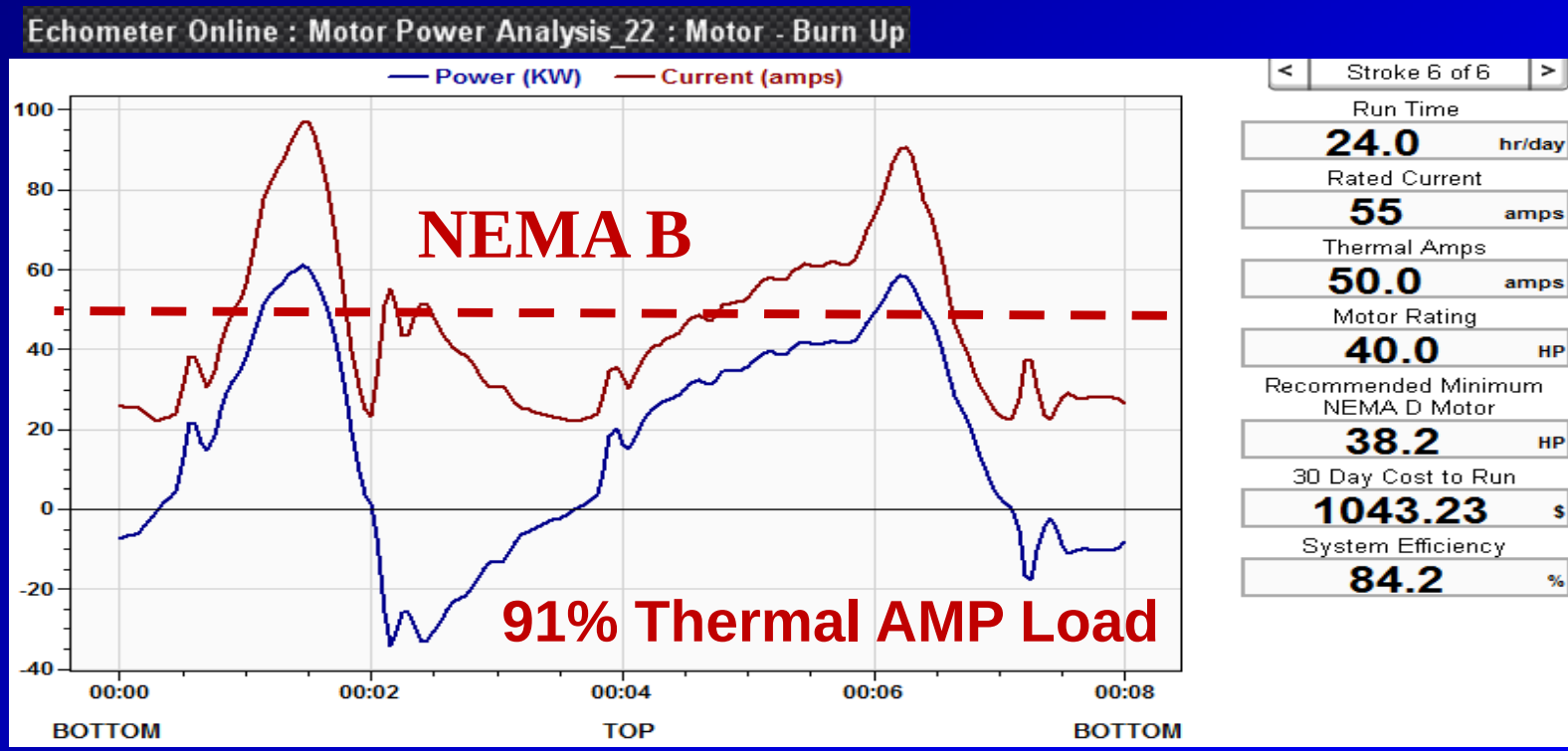
- **Overloading a Motor with Current is the Typical cause of Failure.**



Motor Thermal Loading Characteristics

NEMA B 40 HP

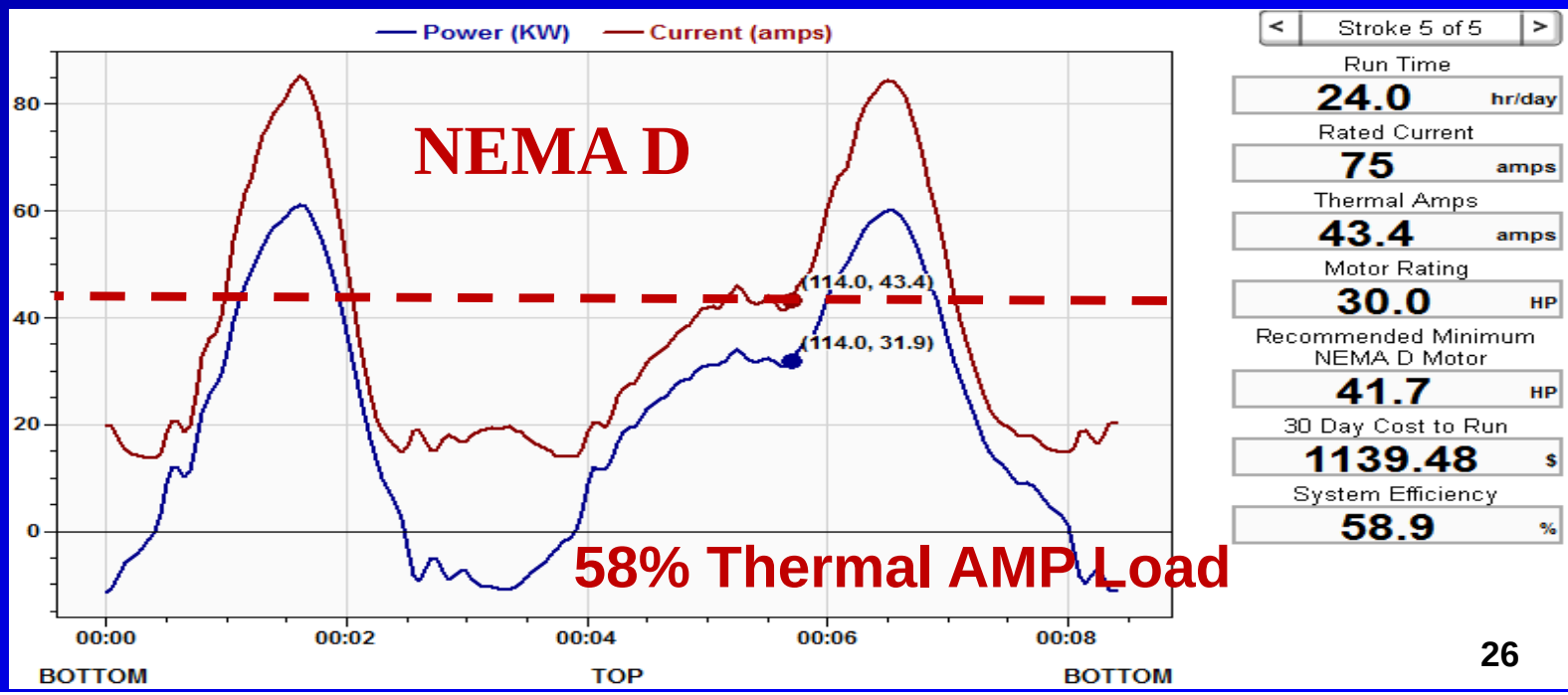
1) 4% - 5% Slip
2) 180% Starting Torque
3) Lower Cost
4) High AMPs
5) Constant Load



NEMA D 30 HP

1) 8% - 13% Slip
2) 275% Starting Torque
3) More Efficient w/ Cyclic loads.

Same Well with Different Motors



Prime Mover Selection

Two basic types:

1) electric motors and 2) internal combustion engines.

Advantages of electric motors over gas engines:

1) Lower initial cost
2) Lower maintenance costs.
3) Electric motors also provide dependable all-weather service
4) More easily fitted into an automatic system.

Advantages of over gas engines over electric motors:

1) More flexible speed control
2) Operate over a wider range of load conditions.
3) Fuel costs for gas engines may be lower than comparable energy costs for electric motors

Selection of one type of prime mover over another depends upon:

1) local availability 2) fuel supply 3) local conditions
4) availability of maintenance 5) personal experience or preference.

Design NEMA D Motor Size Using QRod

Min API Unit Rating 228-119-105

Design Inputs

Unit CWConv

Pump Depth 3,896 ft

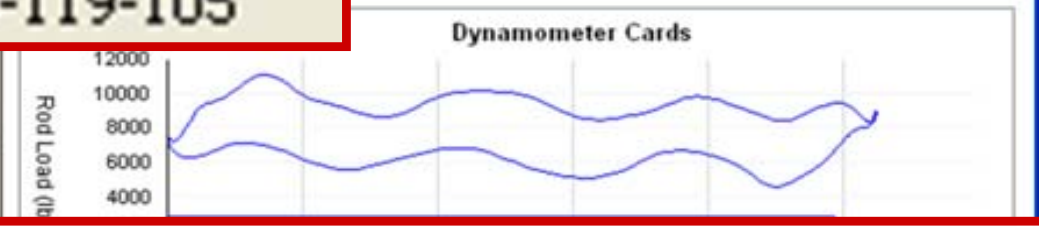
Results

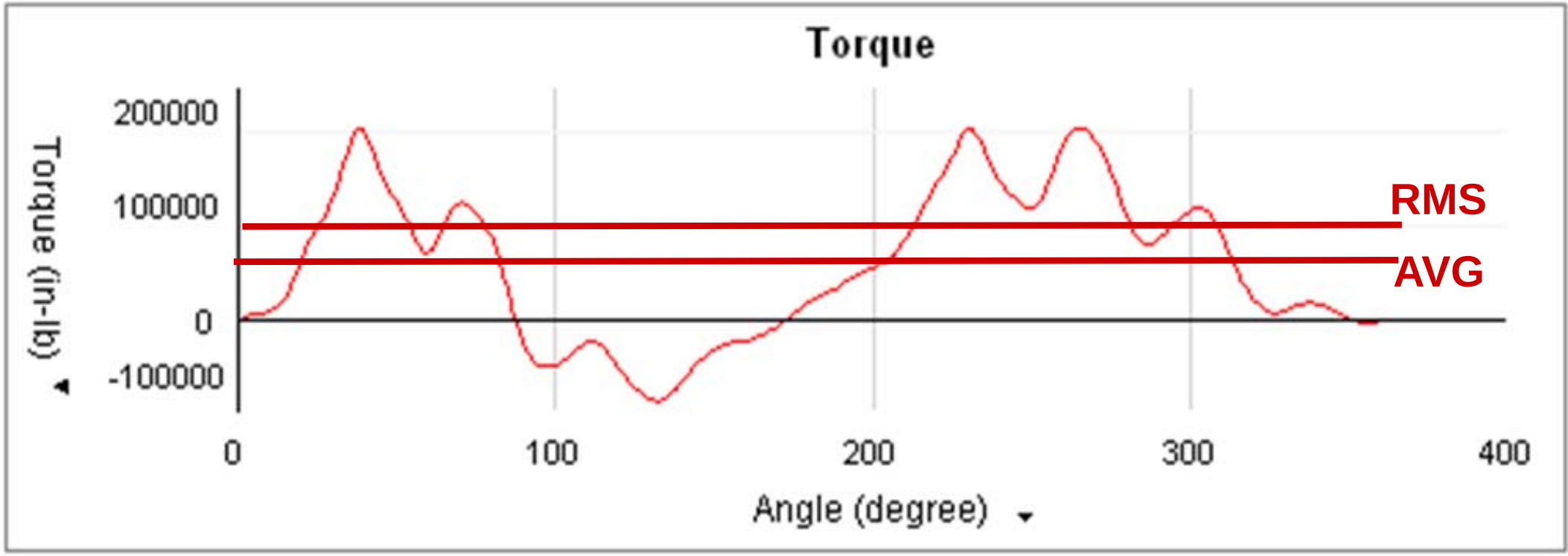
Rate (100% pump volumetric eff.) 182 BBL/D

Rate (90% pump volumetric eff.) 164 BBL/D

Rod Taper 34.0%, 66.0%

Min API Unit Rating 228-119-105





Peak GearBox Torque	204	Kin-lb
Counter Balance Moment	509	Kin-lb
Counter Balance Effect	10,222.6	lb

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Peak GearBox Torque 204 Kin-lb
Counter Balance Moment 509 Kin-lb
Counter Balance Effect 10,222.6 lb

Sizes Minimum Required NEMA D Motor Horsepower

Computer: HP = CLF * PRHP / Unit Efficiency

QRod uses:

CLF = *RMS Torque/ Average Torque*

RMS Power/ Average Power is OK.

(don't use CLF based on motor current)

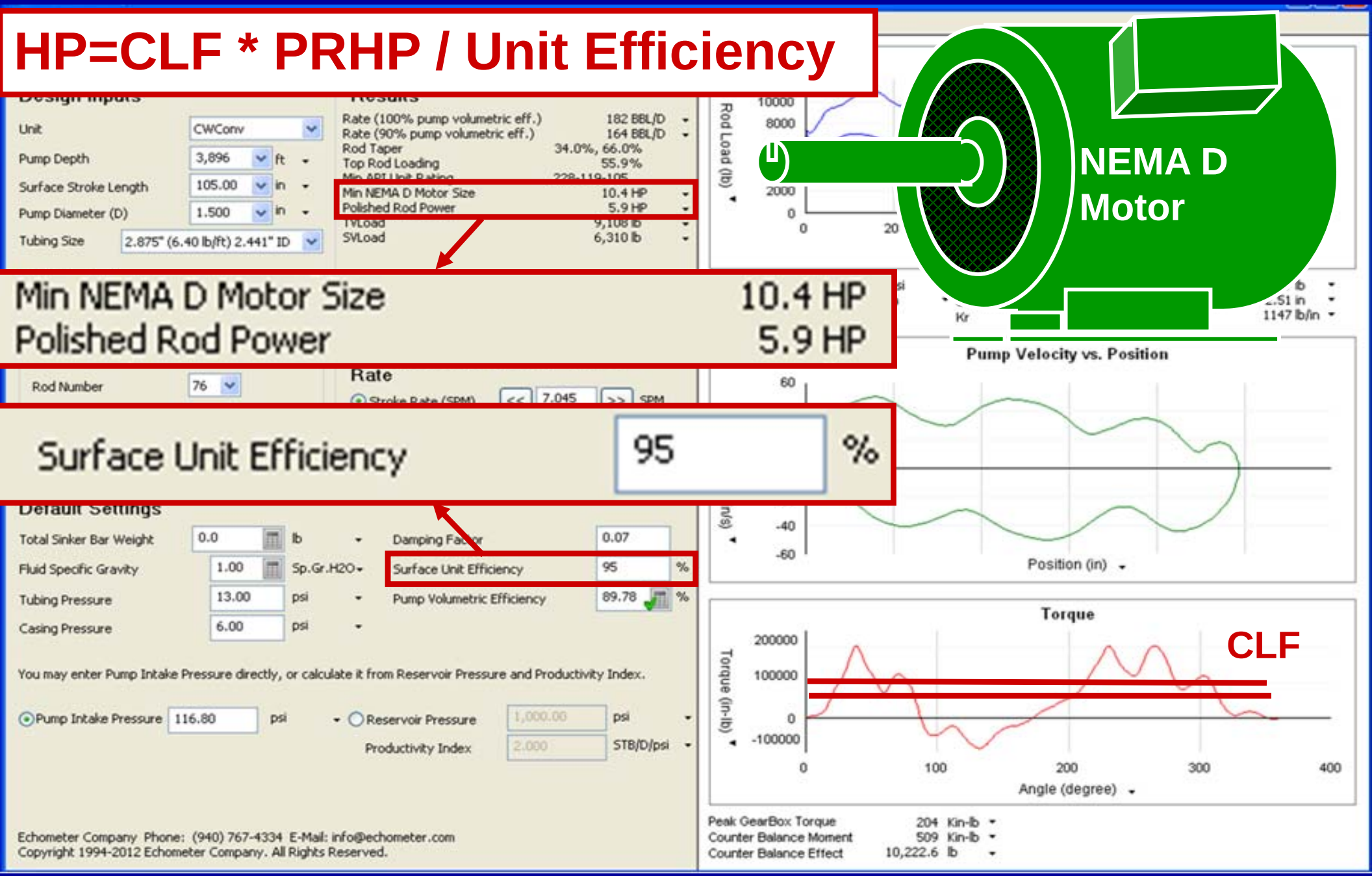
OR:

Gault: HP = 2. * PRHP

Unit Efficiency: 95 % for "Large" Units
80 % for "Small" Units

NEMA D Efficient Under Cyclic Loads
8-13% Slip ~ 275% Starting Torque

HP=CLF * PRHP / Unit Efficiency

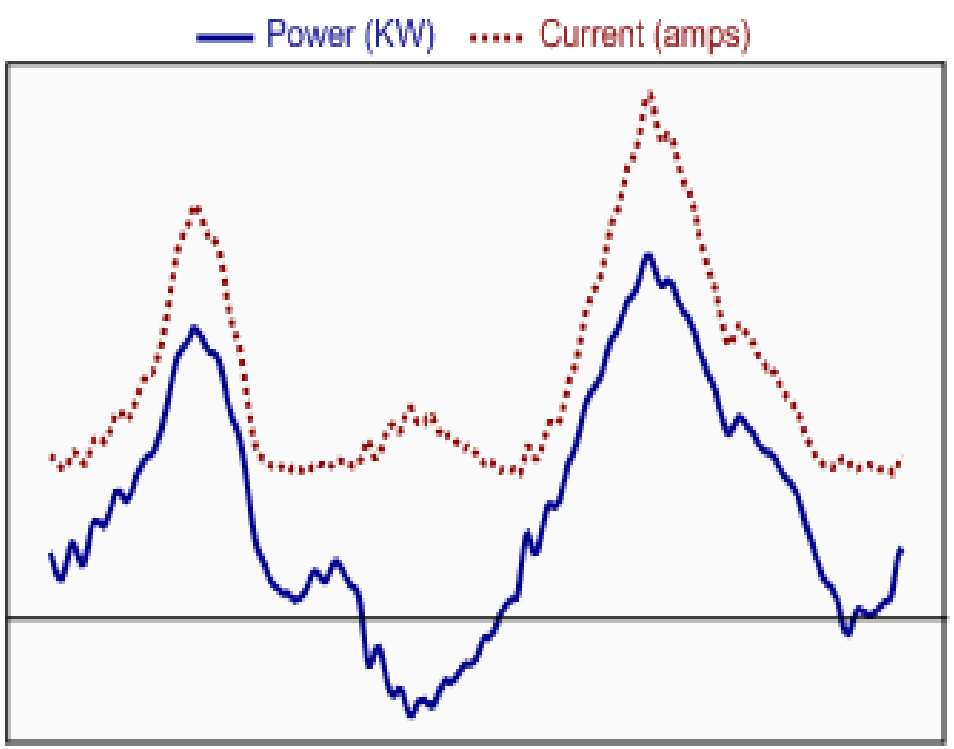


Motor Power and Electrical Analysis

Power Analysis

Monthly Operation Costs (30 Days/Month)		
Run Time	24.0	hr/day
Cost With Gen. Credit	358.04	$
Cost No Gen. Credit	387.52	$
Demand Cost	92.67	$
Oil Production Cost	228.7	¢/bbl
Liquid Production Cost	15.0	¢/bbl
Oil Production	7	BBL/D
Water Production	100	BBL/D

Cost $



Recommended Min NEMA D Motor	19.8	HP
Rated HP	30.0	HP
Rated Full Load AMPS	39	
Thermal AMPS	23.4	
Gross Input	14.4	HP
Net Input	13.3	HP
Demand	11.6	KW
Average	10.3	KVA
Average Power		
With Generation Credit	9.9	KW
No Generation Credit	10.8	KW
Average Power Factor	76.3	%
System Efficiency	56.9	%

Power

System Efficiency

What is High Efficiency?

Electrical Efficiency

- Total System Efficiency Should be greater than 50%
- Surface Efficiency should be greater than 80%

Mechanical Efficiency

- Pump, Rods, Pumping Unit Size and Balance

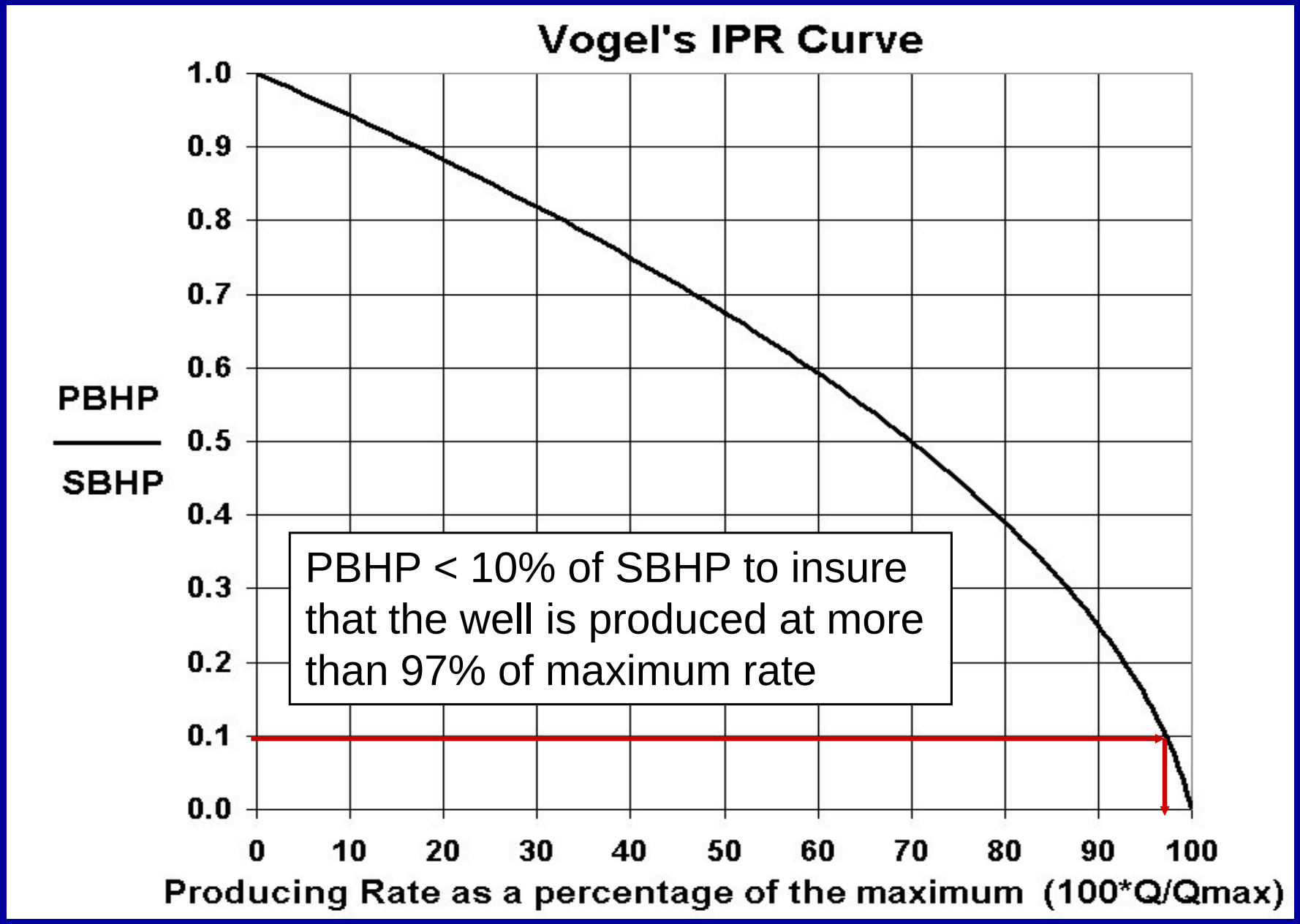
Reservoir Producing Rate Efficiency

- Should be greater than 97%, PBHP < 10% of SBHP

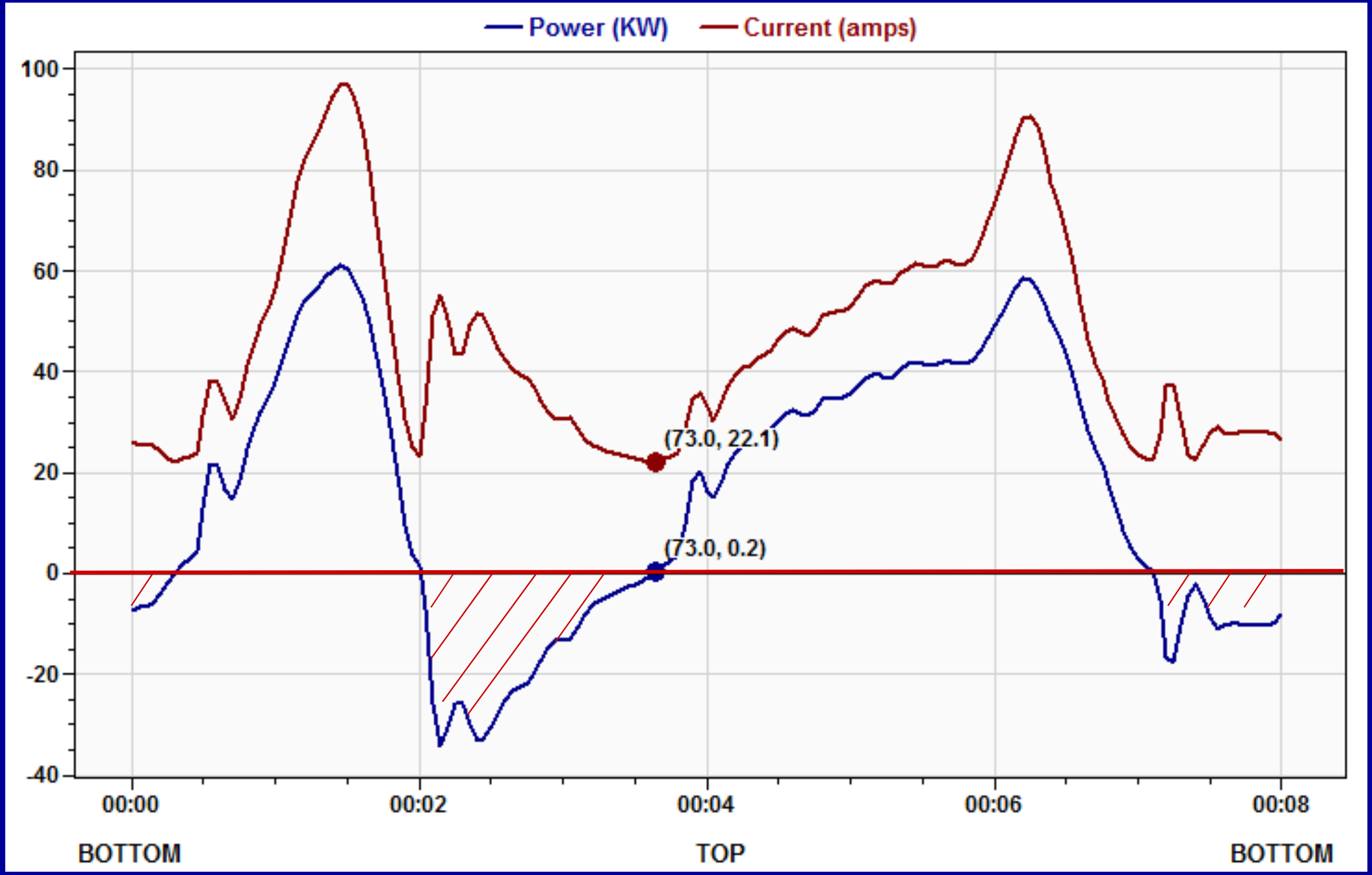
Analyze Well To Determine Efficiencies:

1. Analyzes the well's inflow performance to determine if additional production is available. (>95% Eff.)
2. Determines the overall electrical efficiency.
3. Analyzes the efficiency of the pump.
4. Analyzes the efficiency of the down-hole gas separator.
5. Analyzes the mechanical loading of rods and pumping unit.
6. Analyzes performance of prime mover.

Vogel IPR Relationship



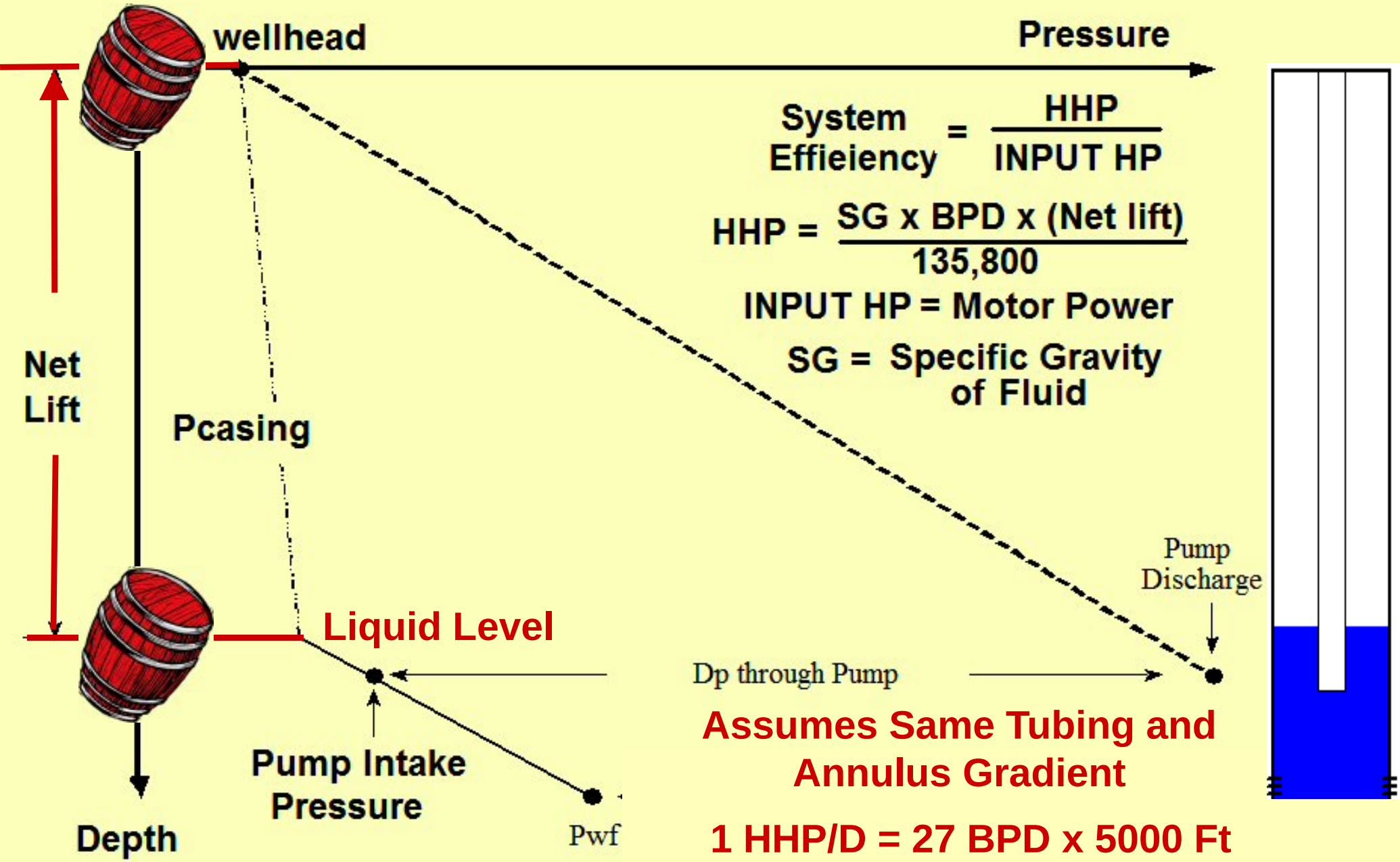
Electric Power (kW) and Current (Amps) Input to the Motor over the time of One Pump Stroke



Efficiency

1. Power Input into Sucker Rod Lift System
   a) System Does Work to Add Energy to Fluids
   b) Fluids then flow to the Surface
2. Surface & System efficiency
3. Use Fluid Level, Dynamometer, and Power Surveys to Determine Efficiency
4. Low Efficiency Used to Identify Problems
5. How to maintain a high producing efficiency in sucker rod lift operations

Net Lift ~ System Efficiency Equation



$$\text{System Effieiency} = \frac{\text{HHP}}{\text{INPUT HP}}$$

$$\text{HHP} = \frac{\text{SG x BPD x (Net lift)}}{135{,}800}$$

INPUT HP = Motor Power

SG = Specific Gravity of Fluid

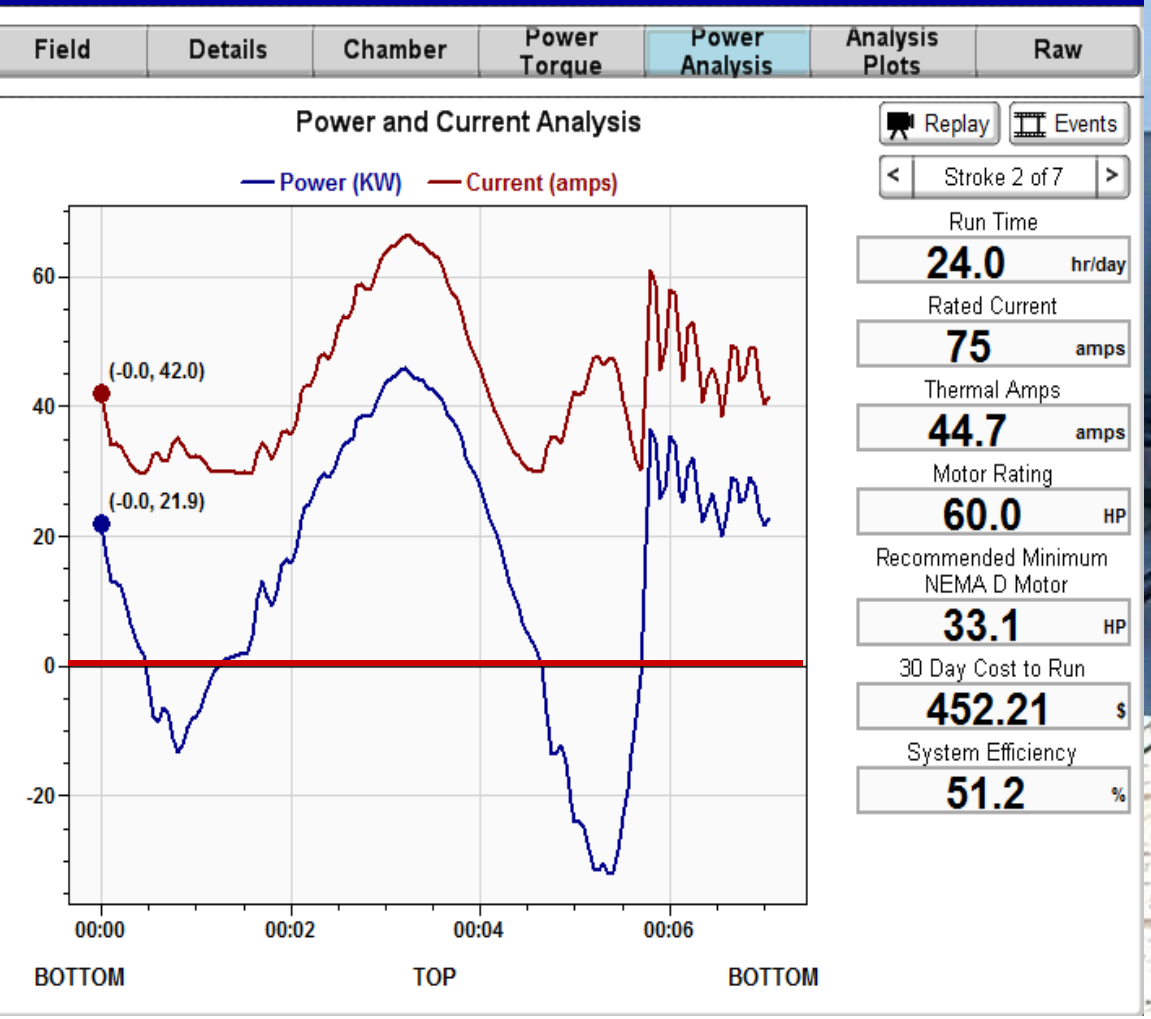
Assumes Same Tubing and Annulus Gradient

1 HHP/D = 27 BPD x 5000 Ft

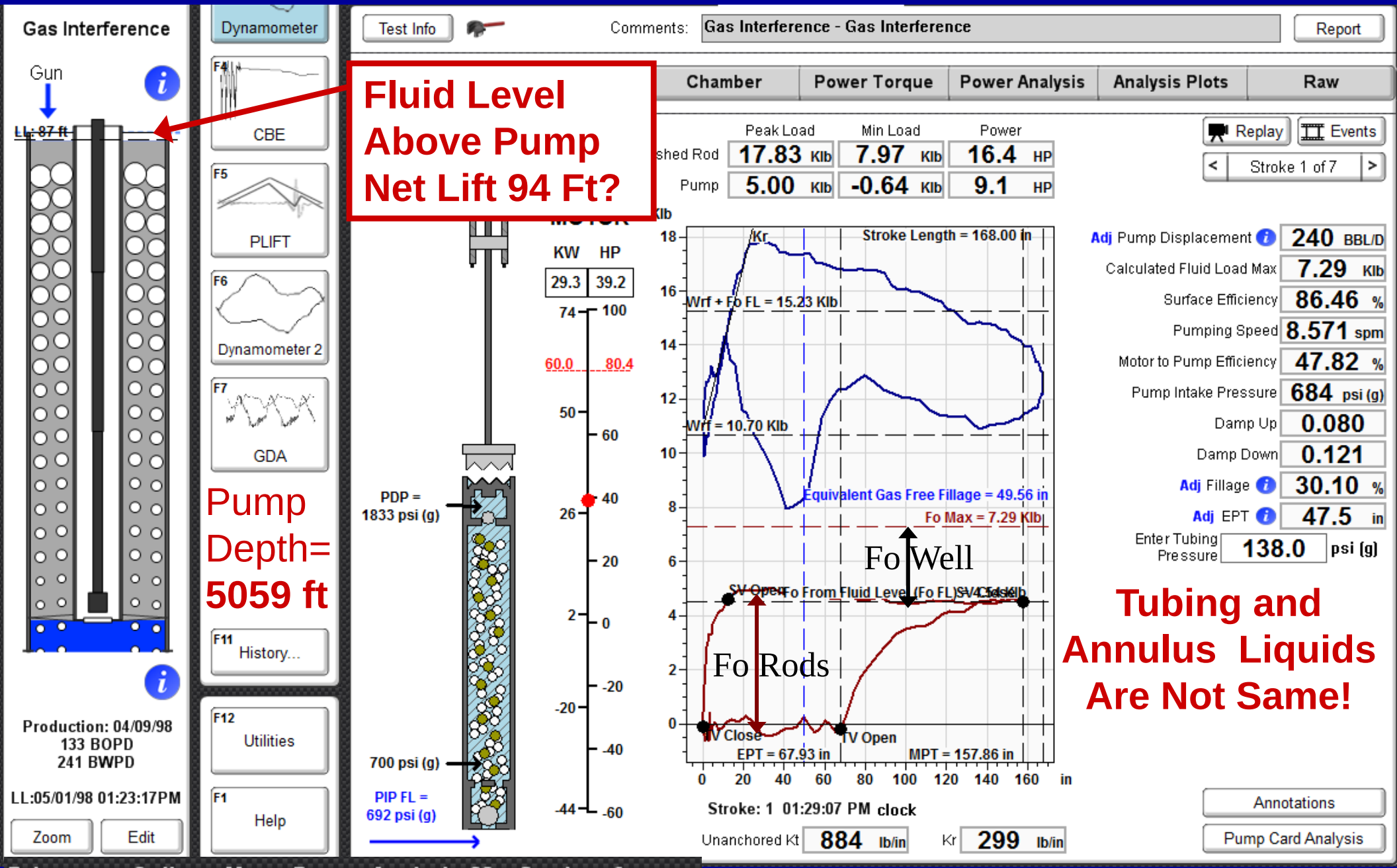
Measure Motor Input = 13.9 kW

Acquire:

- RMS (thermal) motor current
- Average (real) motor current
- kW during a pump stroke cycle.

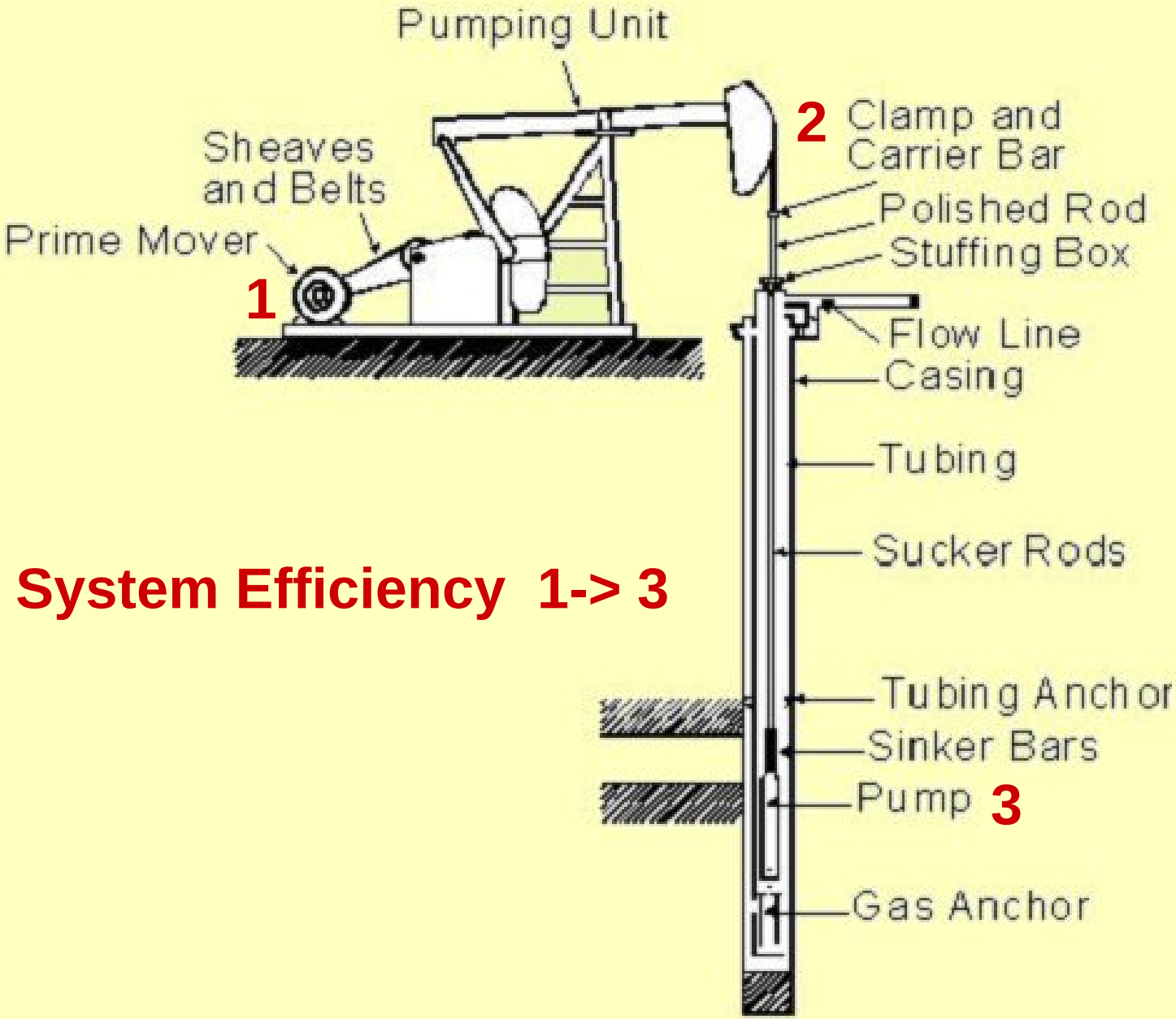


Pump Intake Pressure = 730.7 Psig 133 BOPD
Tubing Fluid Gradient = 0.335 psi/ft 241 BWPD



$$\eta \text{ system} = \frac{(Q,_{BPD})\ (Depth - PIP/.433XSG)\ (SG)\ (7.368\ E\text{-}06)}{(Kw\ /\ 0.746)}$$

Surface Efficiency 1-> 2



System Efficiency 1-> 3

Determine:

1. **Input Kw**
2. **PR Hp**
3. **Pump Hyd Hp**

System Efficiency Calculation

Theoretical amount of work required to lift the liquid from the intake pressure at the pump to the surface divided by the energy supplied to the motor.

Measure:

- Pump Intake Pressure from Acoustic Liquid Level

Net Lift = P Depth–PIP/ .433xSG

= 5059 – 730/0.335 = *2880 ft*

- Fluid Volumes and Properties
- Motor Input Power Measurement

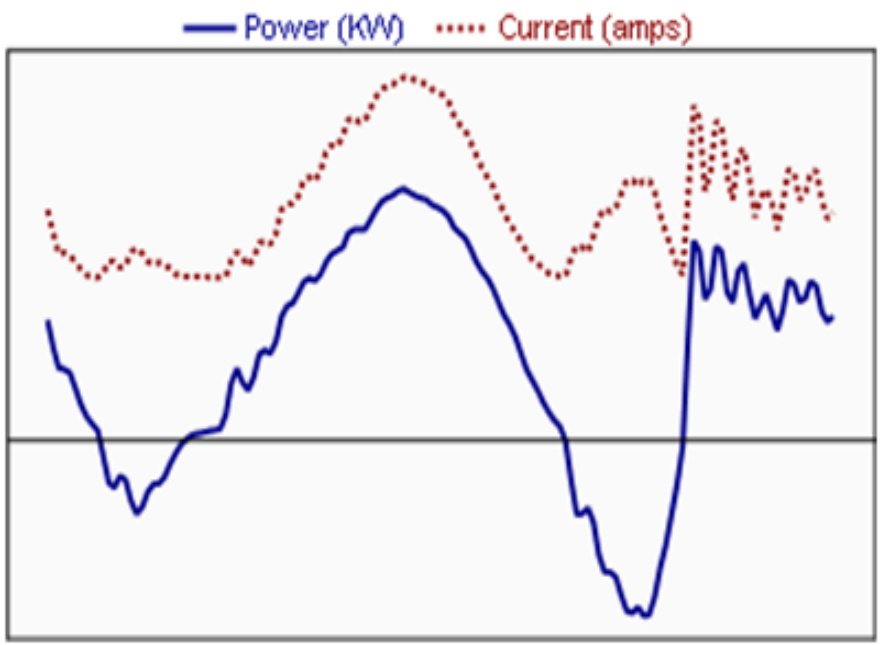
51% System Efficiency

PDF | Email | + | - | 120% | < Stroke 2 of 7 > | Word Doc | DYN | Torque | Power | Analysis Plot

Power Analysis

Monthly Operation Costs (30 Days/Month)

Run Time	24.0	hr/day
Cost With Gen. Credit	356.08	$
Cost No Gen. Credit	452.21	$
Demand Cost	174.08	$
Oil Production Cost	15.7	¢/bbl
Liquid Production Cost	5.6	¢/bbl
Oil Production	133	BBL/D
Water Production	241	BBL/D



Recommended Min NEMA D Motor	33.1	HP
Rated HP	60.0	HP
Rated Full Load AMPS	75	
Thermal AMPS	44.7	
Gross Input	24.1	HP
Net Input	18.9	HP
Demand	21.8	KW
Average	19.9	KVA
Average Power		
With Generation Credit	14.1	KW
No Generation Credit	17.9	KW
Average Power Factor	57.8	%
System Efficiency	51.2	%

Echometer Online : Motor Power Analysis_22 : Gas Interference

Why is Efficiency a Useful Benchmark?

- **Measure of work input (power requirements) relative to useful output (liquid production).**
- **Directly related to operating costs**
- **Relatively easy to measure**
- **Generally accepted guidelines**

Efficiency

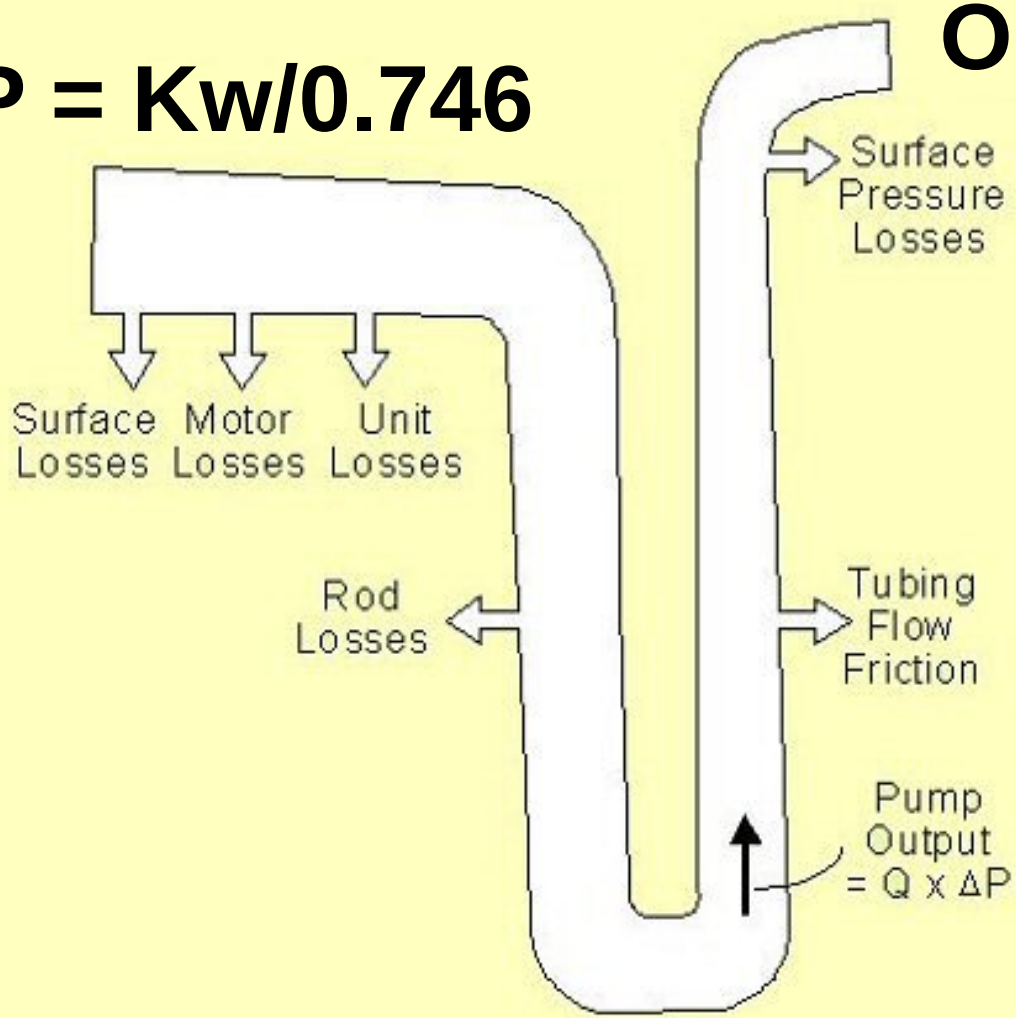
- System Efficiency should be > 50%
- Surface Efficiency should be > 80%

Losses ~ System Efficiency

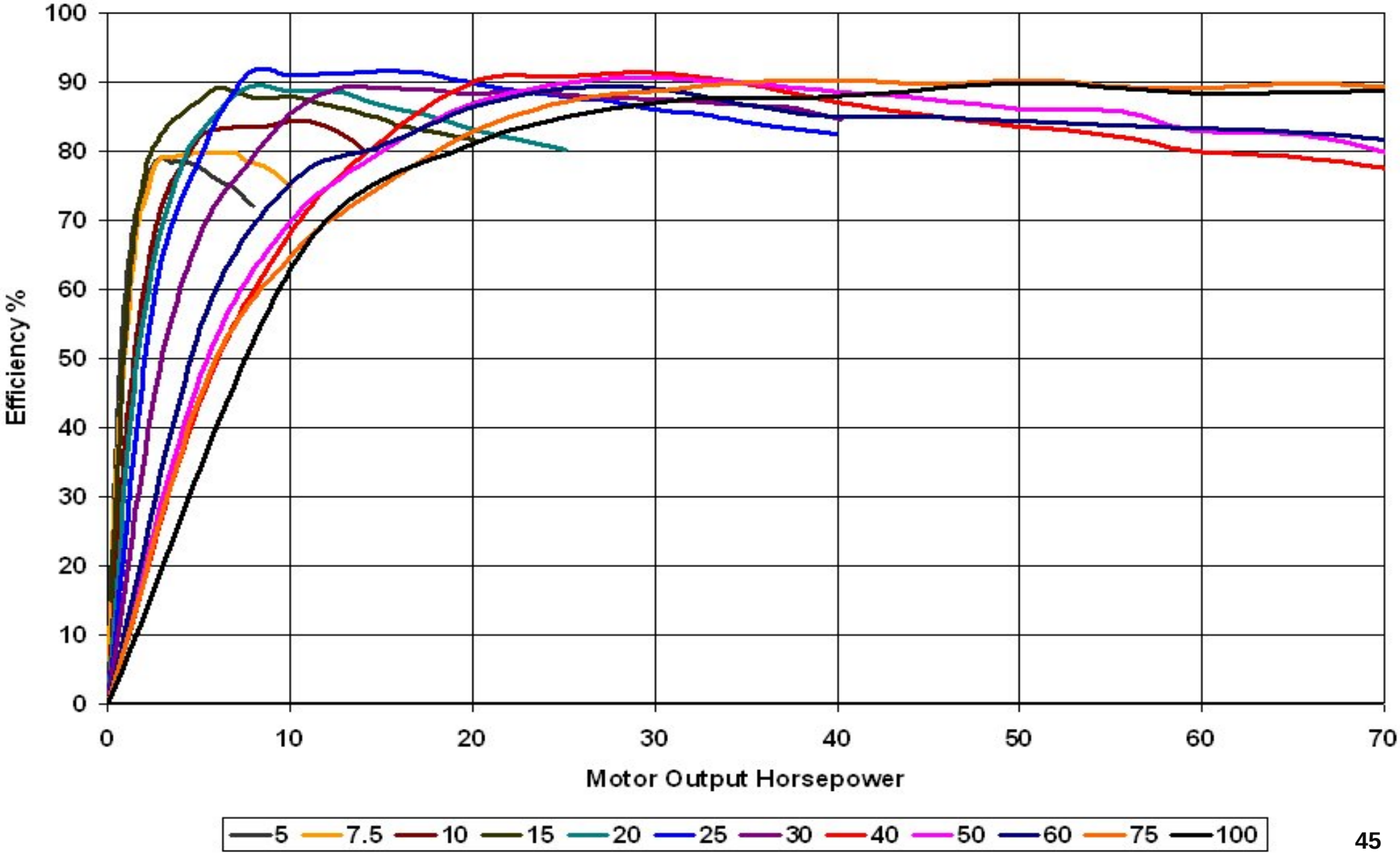
η BEAM, system= η surface η motor η unit η rods η tubing friction η surface pressure

Input HP = Kw/0.746

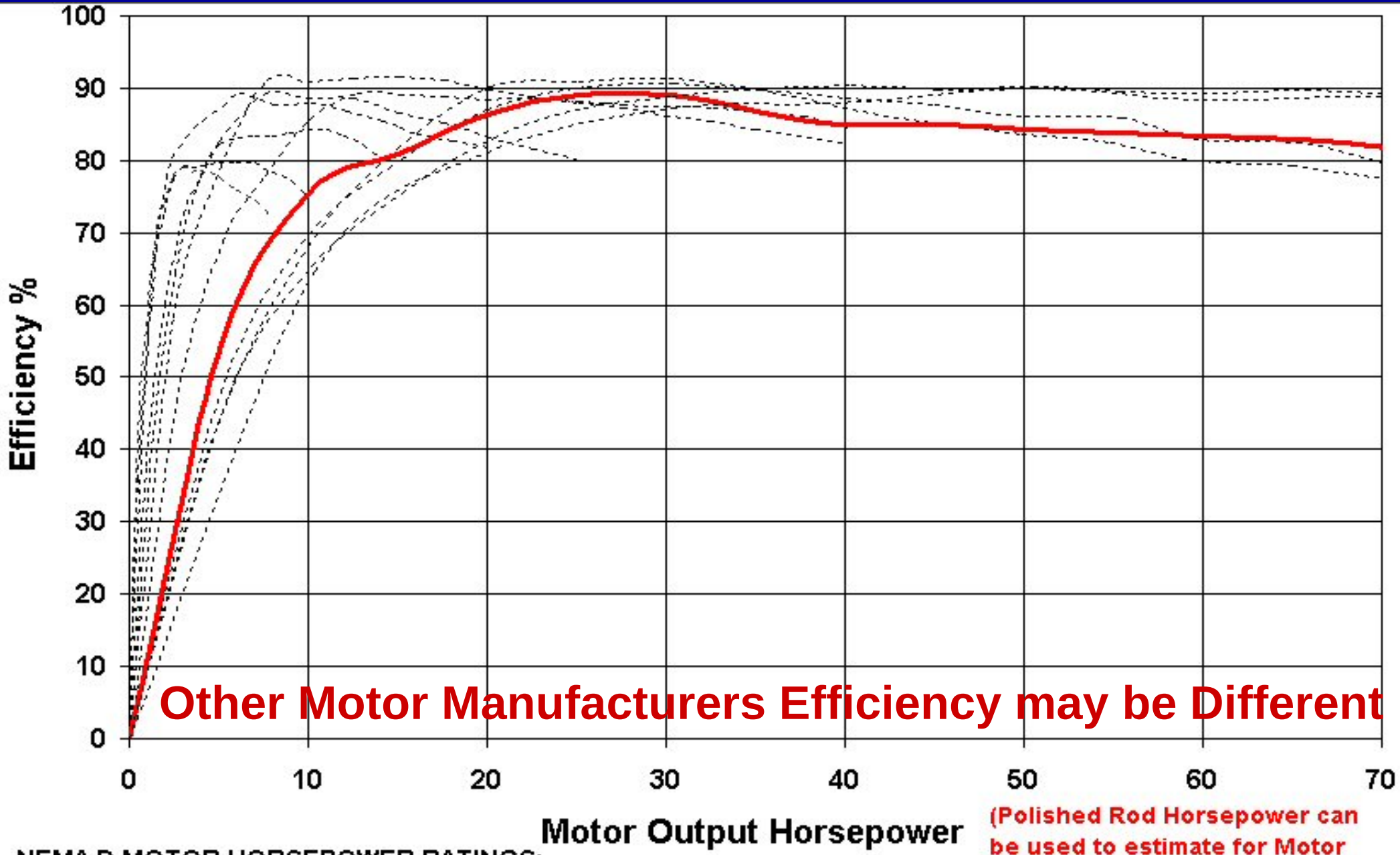
Output



Motor Performance Data – Efficiency vs. Output Hp Comparison of NEMA D Motors



60 Hp NEMA D Motor (Surface Efficiency)
Motor Performance Data – Efficiency vs. Output Hp

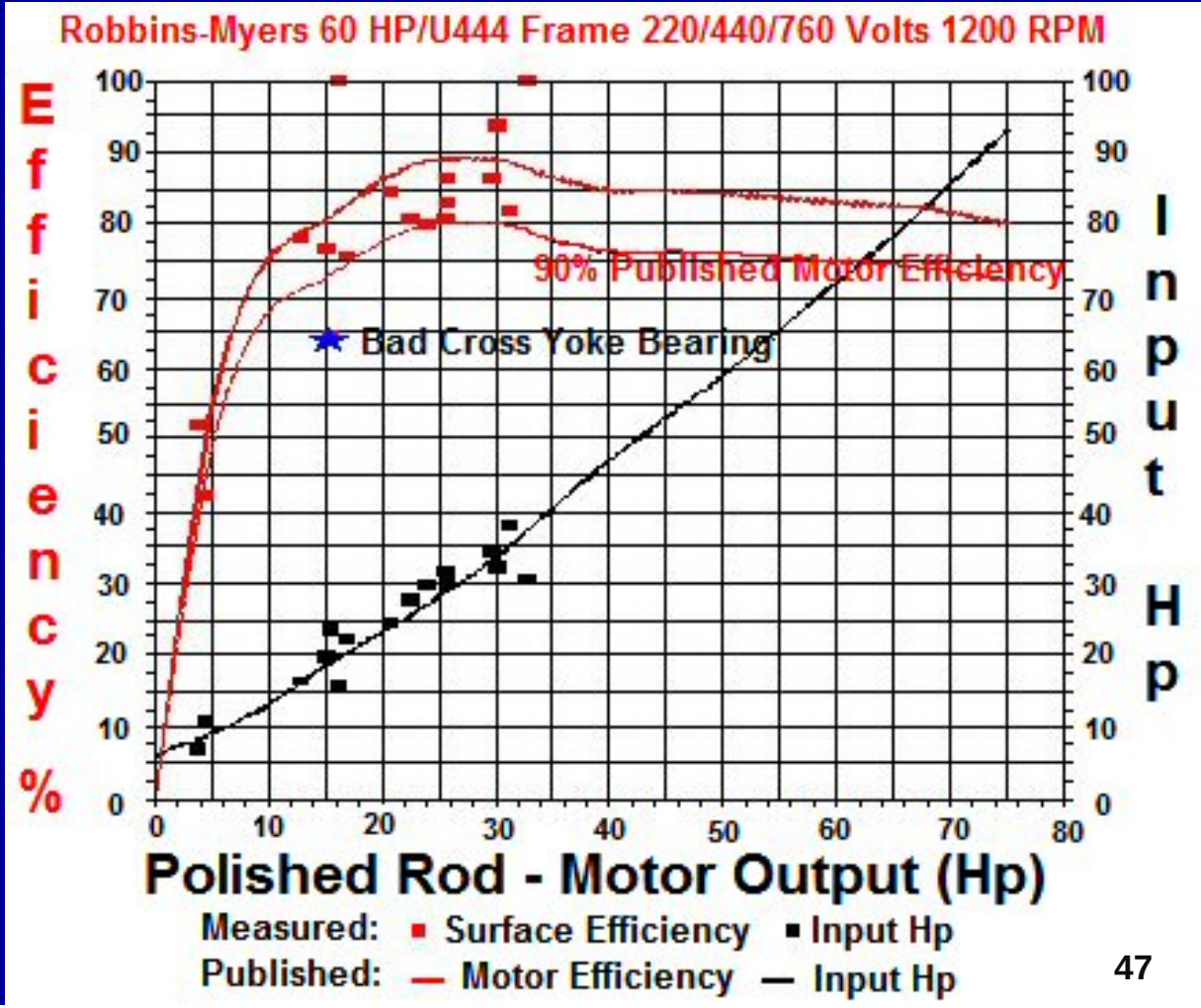


Motor Performance –NEMA D Motors Minimum Surface Efficiency

Motor HP - NEMA D	5	7.5	10	15	20	25	30	40	50	60
Motor Efficiency (30%-80%) Load	78	80	84	85	88	91	88	91	90	86
Minimum Surface Efficiency	70	72	76	77	79	82	79	82	81	77

Surface Efficiency **measured over one revolution of the crank is an excellent indicator of the operating performance of the surface equipment.**

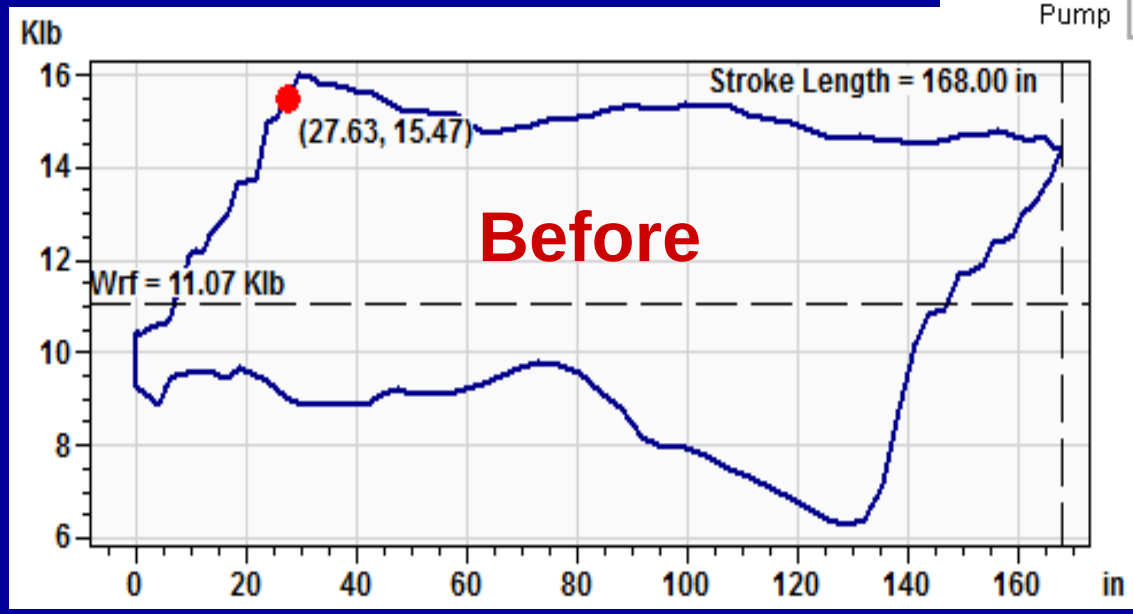
Surface Efficiency **includes losses per crank revolution in wirelines, structural bearings, transmissions, V-belts, and the electric motor.**



Example of Low Surface Efficiency

Echometer Online : Motor Power Analysis_22 : Bad Tail Bearing

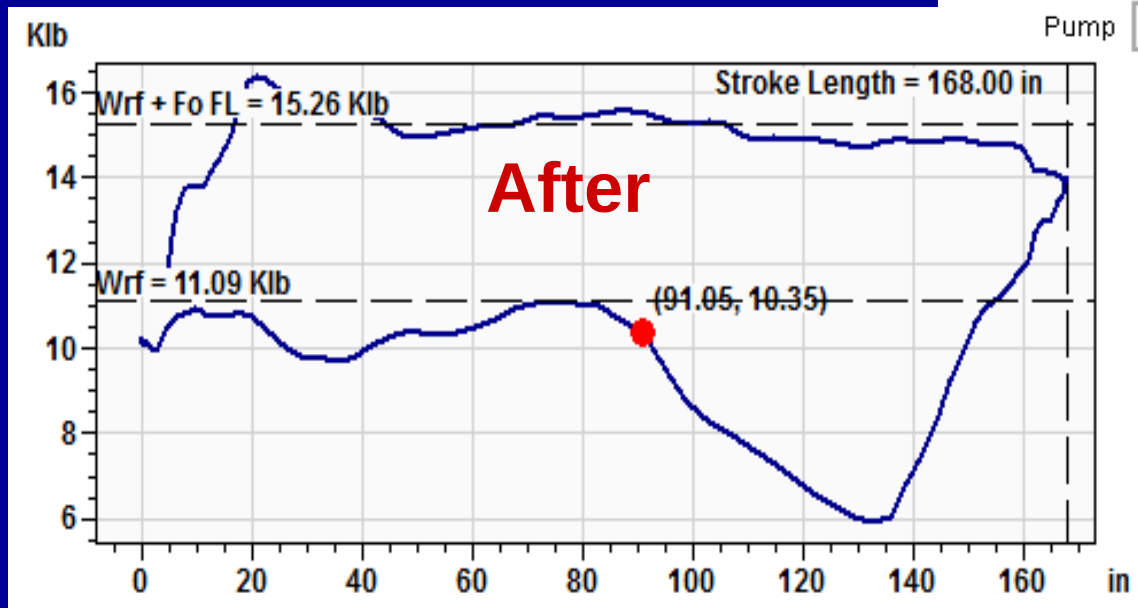
Bad Tail Bearing Resulted in Low Surface Efficiency of *66%*



	Peak Load	Min Load	Power
Polished Rod	16.01 Klb	6.28 Klb	15.8 HP
Pump	4.77 Klb	-2.35 Klb	9.1 HP

Adj Pump Displacement	288 BBL/D
Calculated Fluid Load Max	5.61 Klb
Surface Efficiency	66.65 %
Pumping Speed	6.780 spm
Motor to Pump Efficiency	38.37 %
Pump Intake Pressure	1112 psi (g)
Damp Up	0.147
Damp Down	0.147

Surface Efficiency of *83%* After Repair of Bad Tail Bearing



	Peak Load	Min Load	Power
Polished Rod	16.38 Klb	5.92 Klb	16.0 HP
Pump	4.59 Klb	-1.50 Klb	10.0 HP

Adj Pump Displacement	355 BBL/D
Calculated Fluid Load Max	5.57 Klb
Surface Efficiency	83.31 %
Pumping Speed	7.059 spm
Motor to Pump Efficiency	51.88 %
Pump Intake Pressure	979 psi (g)
Damp Up	0.119
Damp Down	0.119

Use Both Producing Fluid Level Survey and Dynamometer Analysis to Answers the Following Questions:

1. Is the well being produced at its maximum production rate?
2. Does a fluid column exist above the pump intake?
3. Is the pump completely filled with liquid?
4. Is *low efficiency* caused by incomplete pump fillage due to over-pumping the well or due to gas interference?

Acoustic and Power Surveys Show System Efficiency Less Than 35%

Drawdown →	Low Producing BHP or Low Fluid Level	Low Producing BHP or Low Fluid Level	High Producing BHP or High Fluid Level
Dynamometer →	Pump Full	Low Pump Fillage	Low Pump Fillage
Your Job →	Low Priority Study Surface Efficiency *Tubing Leak ?*	*Potential to Improve Study Control Run Time*	*High Priority Study Gas Interference*

Acoustic and Power Surveys Show System Efficiency Greater Than 35%

Drawdown →	Low Producing BHP or Low Fluid Level	High Producing BHP or High Fluid Level	High Producing BHP or High Fluid Level
Dynamometer →	Pump Full	Pump Full	Low Pump Fillage
Your Job →	Well OK	*Potential to Improve Study Pump Capacity*	*High Priority Study Gas Interference*

HOW TO MINIMIZE ELECTRICITY USAGE?

- Maintain a high pump volumetric efficiency:
  - Match pumping unit capacity with wellbore inflow.
  - Pump a Full Stroke of liquid by controlling run time with a POC or Timer
  - Eliminate Gas interference.
- When System Efficiency is low, find and fix problem.
- Mechanically/Electrically balance pumping unit.
- Properly size pumping unit, rods and pump to match well loads.
- On severely over-sized motors where surface efficiency falls below 50%, reduce motor size.

Periodically Monitor Well's Operations To Maintain Efficient Operations

1. Check pump for proper operation

2. Produce all available liquid from the Wellbore

3. Operate well with high volumetric pump efficiency

4. Use POC or TIMER or VSD to reduce run time if pump capacity exceeds production rate

Low Efficiencies of Sucker Rod Lifted Wells Are Often Caused by Partial Pump Fillage

- More efficient operations and lower electrical power usage will result if wells are operated with a pump filled with liquid.
- Full pump fillage also requires an efficient downhole gas separation that results in a full pump if sufficient liquid is present to fill the pump.
- Full pump fillage generally requires controlling the run time of the pumping unit to match the pump capacity to the maximum well inflow rate.

Maintaining High Efficiency in Sucker Rod Lift Operations Results in:

1. Reduced Electrical Costs
2. Reduced Mechanical Operating Expense.
3. Increased in Oil and Gas Production.
4. Longer Run Times Before Failure.