Analysis of the Prime Mover

MOTOR POWER SURVEYS ANSWER THE FOLLOWING QUESTIONS:

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

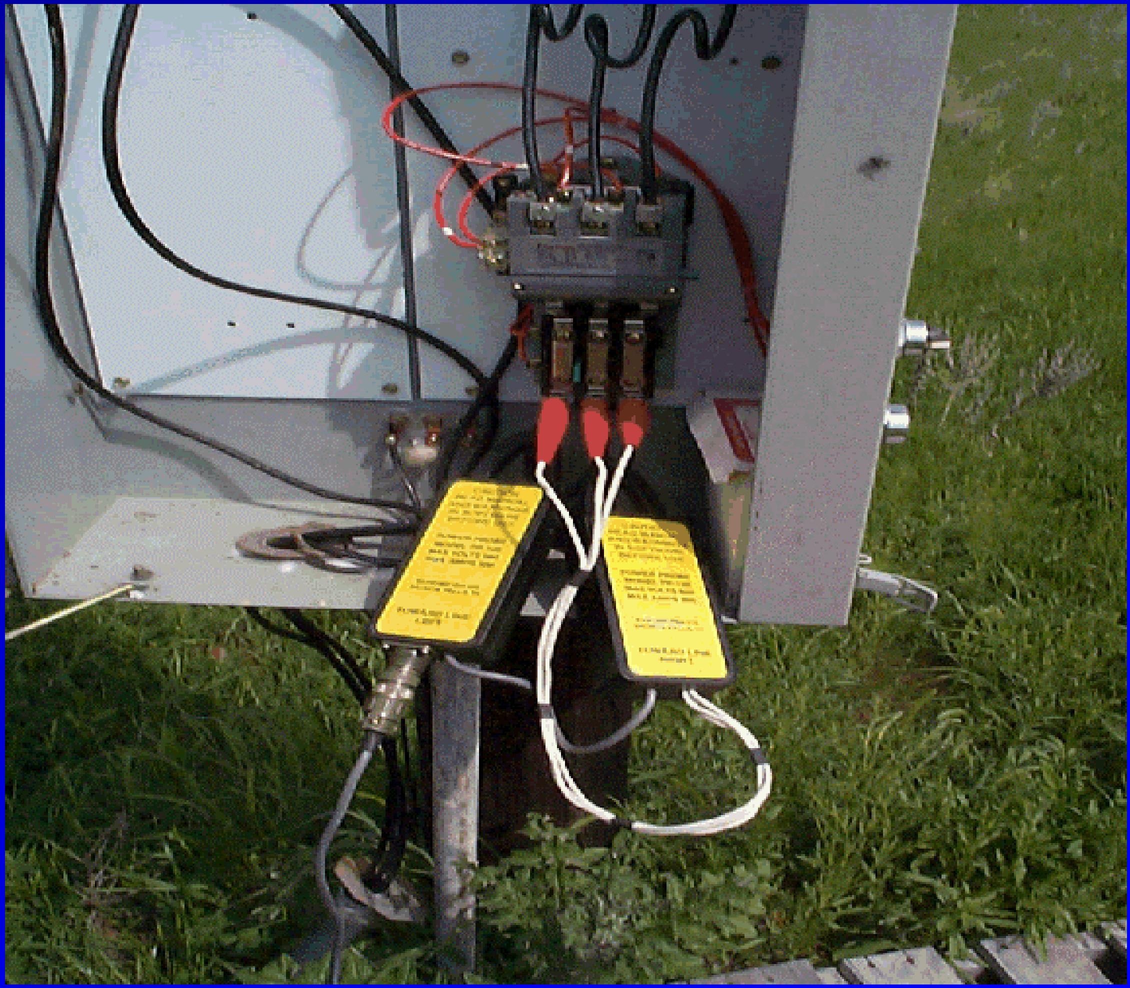
Limit Use of Power Probe Installation Where Maximums NOT EXCEEDED

MAXIMUM VOLTAGE
does NOT EXCEED

600 Volts AC

MAXIMUM CURRENT
does NOT EXCEED

300 Amps



If used in installations where these MAXIMUM ratings are exceeded it is possible to overload the transducer and to cause permanent damage to the transducer and possibly create a health hazard.

USE !!! CAUTION !!! DURING POWER MEASUREMENT

These measurements should *NOT BE PERFORMED*:

1. IF the operator is not in proper condition to operate safely.
2. IF wet or moist conditions prevail around the well and/or electrical power enclosure.
3. IF the operator has not been properly trained or educated.
4. IF the operator has not read and understood the Electrical Measurements section of the operating manual.

Electrical Safety

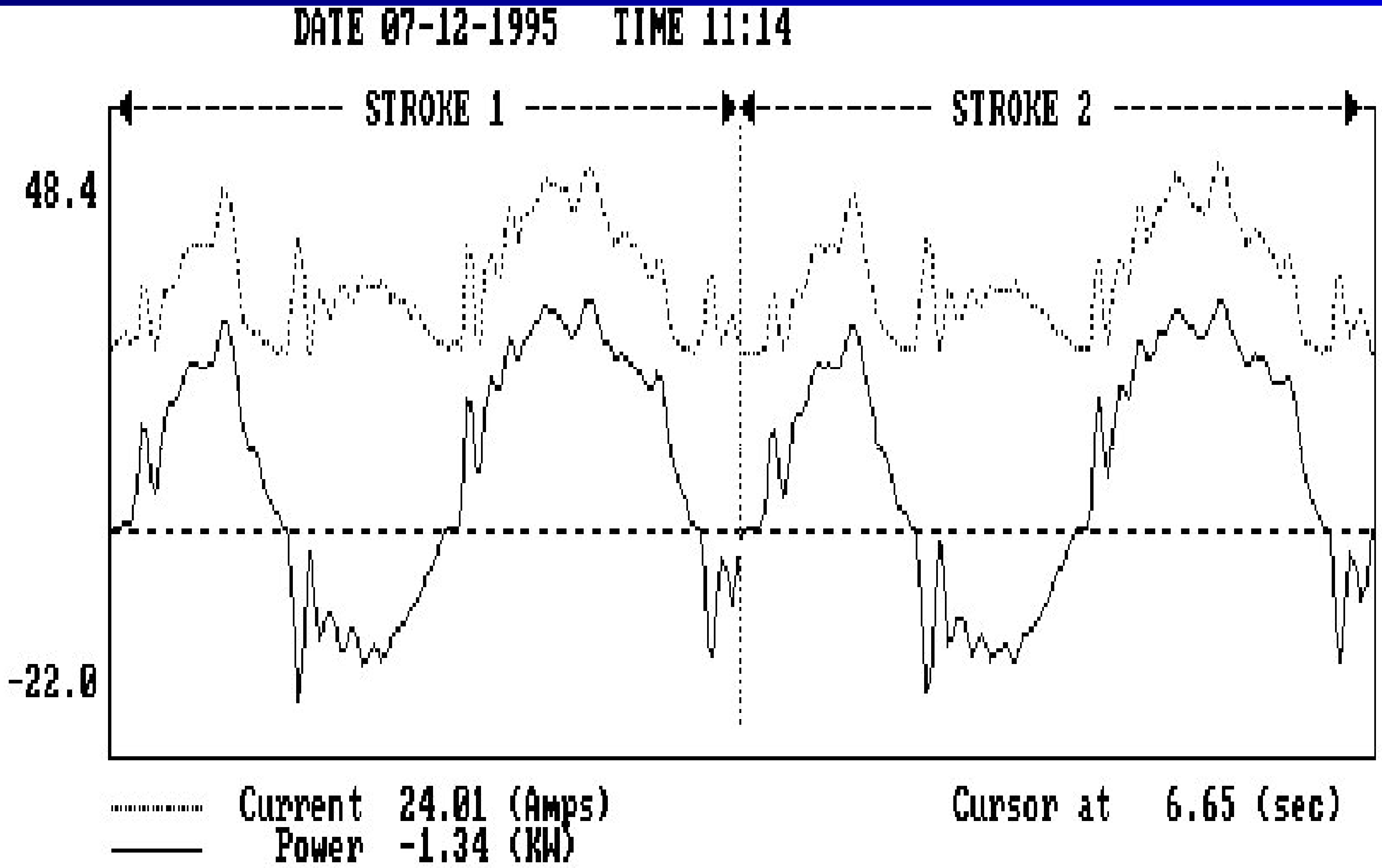
1. Power measurements generally require the operator to open the electrical switch box.
2. The operator is thus exposed to DANGEROUS HIGH VOLTAGE electricity.
3. The power transducer installation procedure is dangerous unless the operator exercises precaution and follows the recommended procedures in the attachment of the voltage and current sensors and uses the safety equipment which is provided with each set of sensors.
4. Additional safety equipment should includes lineman's rubber gloves with leather protectors.

To increase safety of working conditions YOU should report ALL SHOCKS and defective equipment. A SHOCK means that SOMETHING IS WRONG. The slightest shock when operating an electrical device might, in another situation, result in instant death if part of the body made only slightly better contact with the ground or a grounded metallic object.

WHAT DOES WELL ANALYZER ACQUIRES FROM THE POWER PROBE?

1. RMS (thermal) motor current
2. Average (real) motor current
3. kW during a pump stroke cycle

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



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.

MOTOR CHARACTERISTICS

NEMA	MOTOR CHARACTERISTICS
B	4% -5% Slip, 180% Starting Torque, Lower Cost and High AMPs
C	6% -7% Slip, 200% Starting Torque, High Starting AMPs
D	8% - 13% Slip, 275% Starting Torque, More Efficient under Cyclic loads.

Output HP = Torque x RPM / Constant

kW Input = (HP Output) x 0. 746 / Efficiency

Motor Slip (%) = (Synch. RPM - Running RPM) / Synch. RPM

Where:

Torque	= Motor Torque (Ft-Lbs or In-Lbs)
rpm	= Motor Speed (revolutions per minute)
Constant	= 5,250 (torque units of Ft-Lbs) or 63,000 (torque units of In-Lbs)
HP	= Output motor horsepower
kW	= HP * 0.746
Synch speed	= RPM of motor under no load

Motor Performance Data NEMA D - 40 HP

Speed (rpm)	Torque (in-lbs)	Current (Amps)	Efficiency (%)	Output (HP)
0	3500	(2) 290	0.0	
100	3649	275	8.2	
200	3756	264	16.0	
300	3836	254	24.4	
400	3889	241	32.3	
500	3940	228	40.7	
600	(3) 3947	212	48.1	
700	3883	196	55.7	
800	3734	177	63.3	47.4
900	3373	153	71.7	48.2
1000	2606	117	79.8	41.4
1100	1357	64	87.0	23.7
1150	633	30	89.3	11.6
(1) 1200	0	25	0.0	0.0
(4) 1250	-680	29	88.8	-13.5
(4) 1300	-1062	56	85.2	-21.9

Note:

1. **No-load/synchronous speed is the RPM at which the motor rotates under no load, at faster speeds the motor produces power, and slower speeds the motor is doing work using power. No-load speed @ 1200 RPM / 25 AMPs / 0.0% Efficiency.**

2. **Locked rotor amps or breakaway amps.**

3. **Break-over torque, motor operates at rpms greater than break-over torque.**

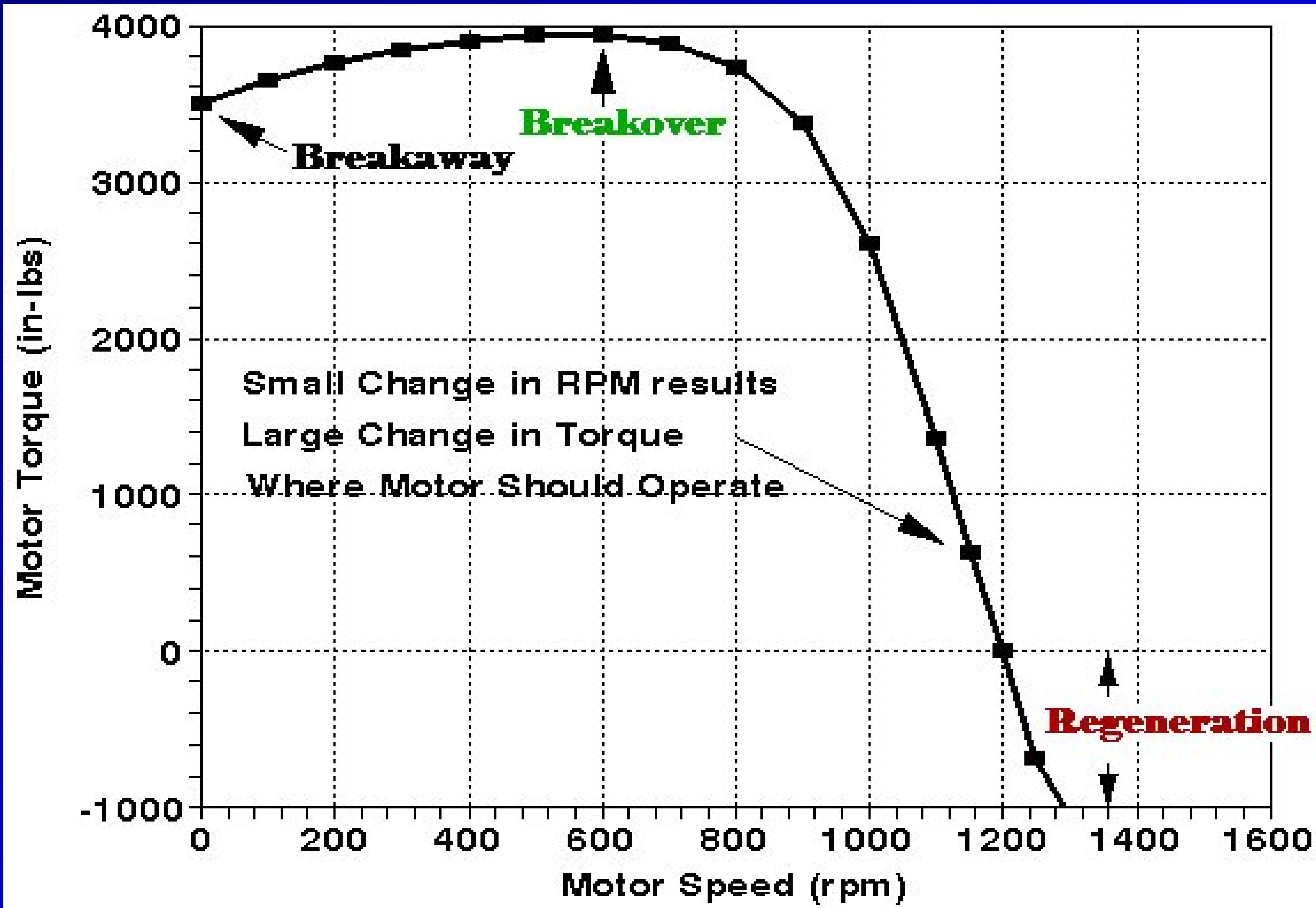
4. **Regenerative power is KW generated with motor RPM beyond the synch speed.**

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.
- The torque during a stroke has two maximum (peak) and two minimum (valley) power demands for each stroke.
- Peak torque or power are approximately equal for balanced operation.
- A balanced pumping unit reduces the AMPs, 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.
- Changing Polished-rod horsepower changes the balance of the pumping unit.

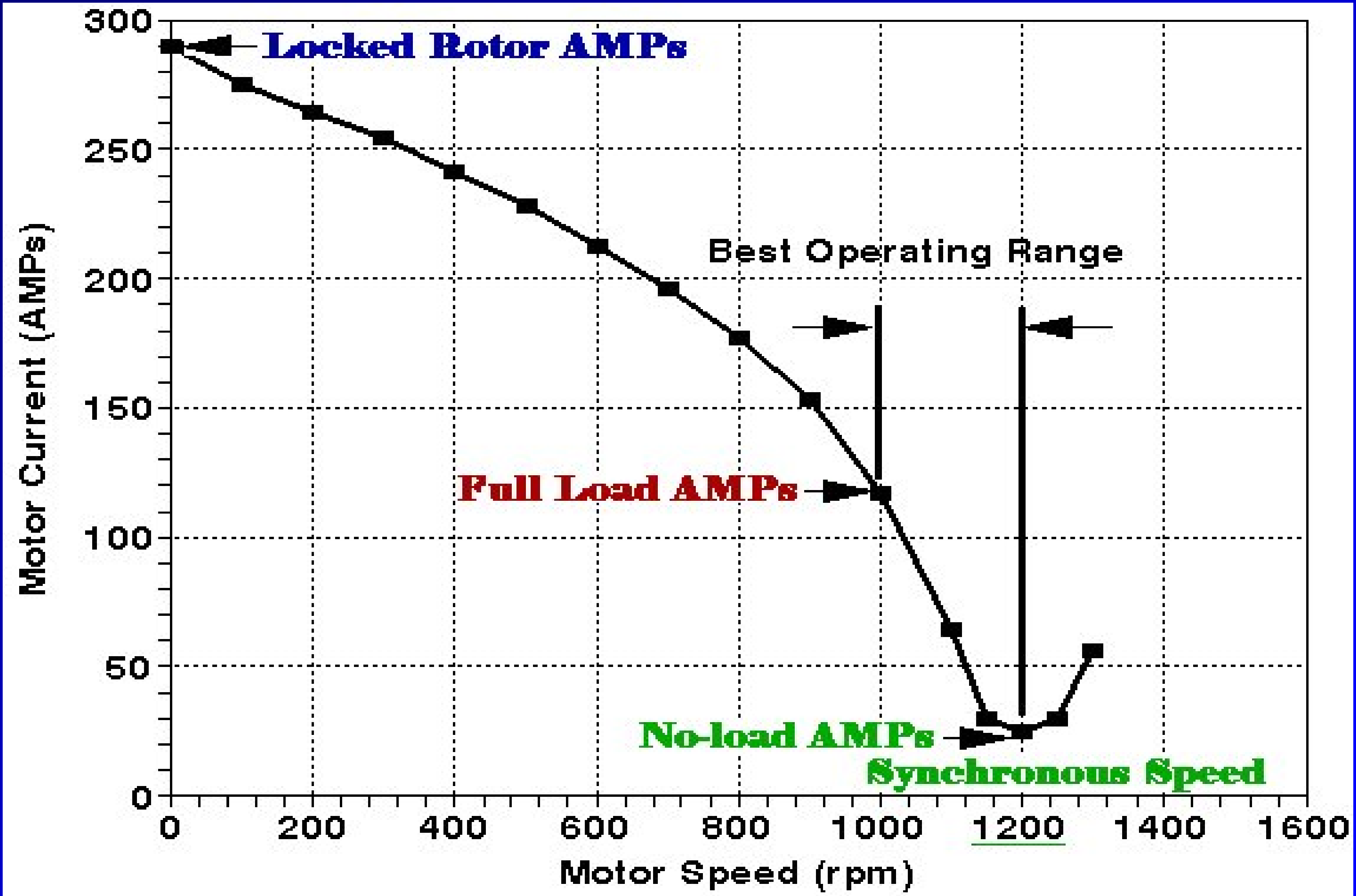
Motor Performance Data   NEMA D - 40 HP

Output torque from the motor varies as motor speed varies

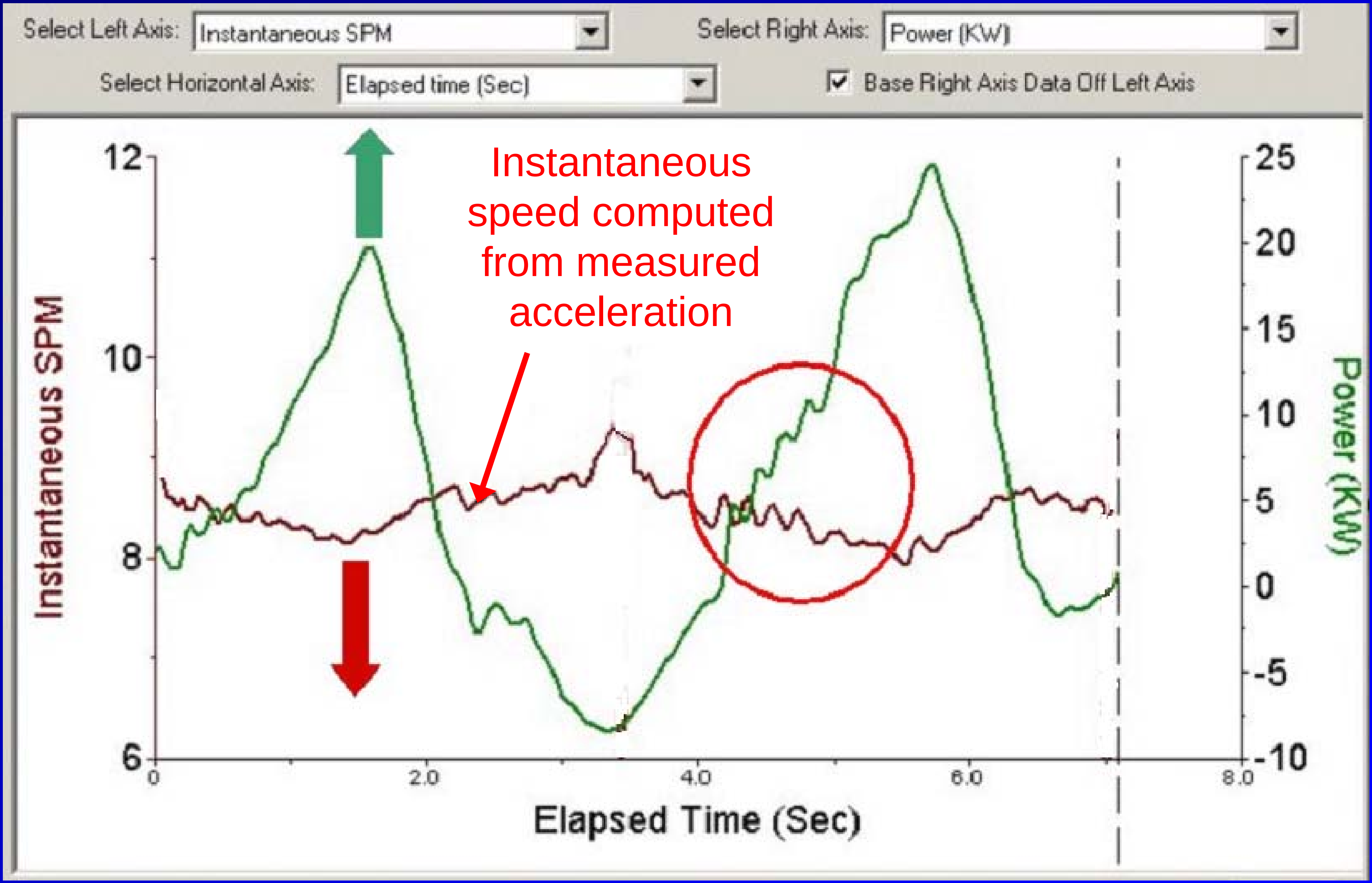


Motor Performance Data NEMA D - 40 HP

Relationship between current drawn and motor speed.



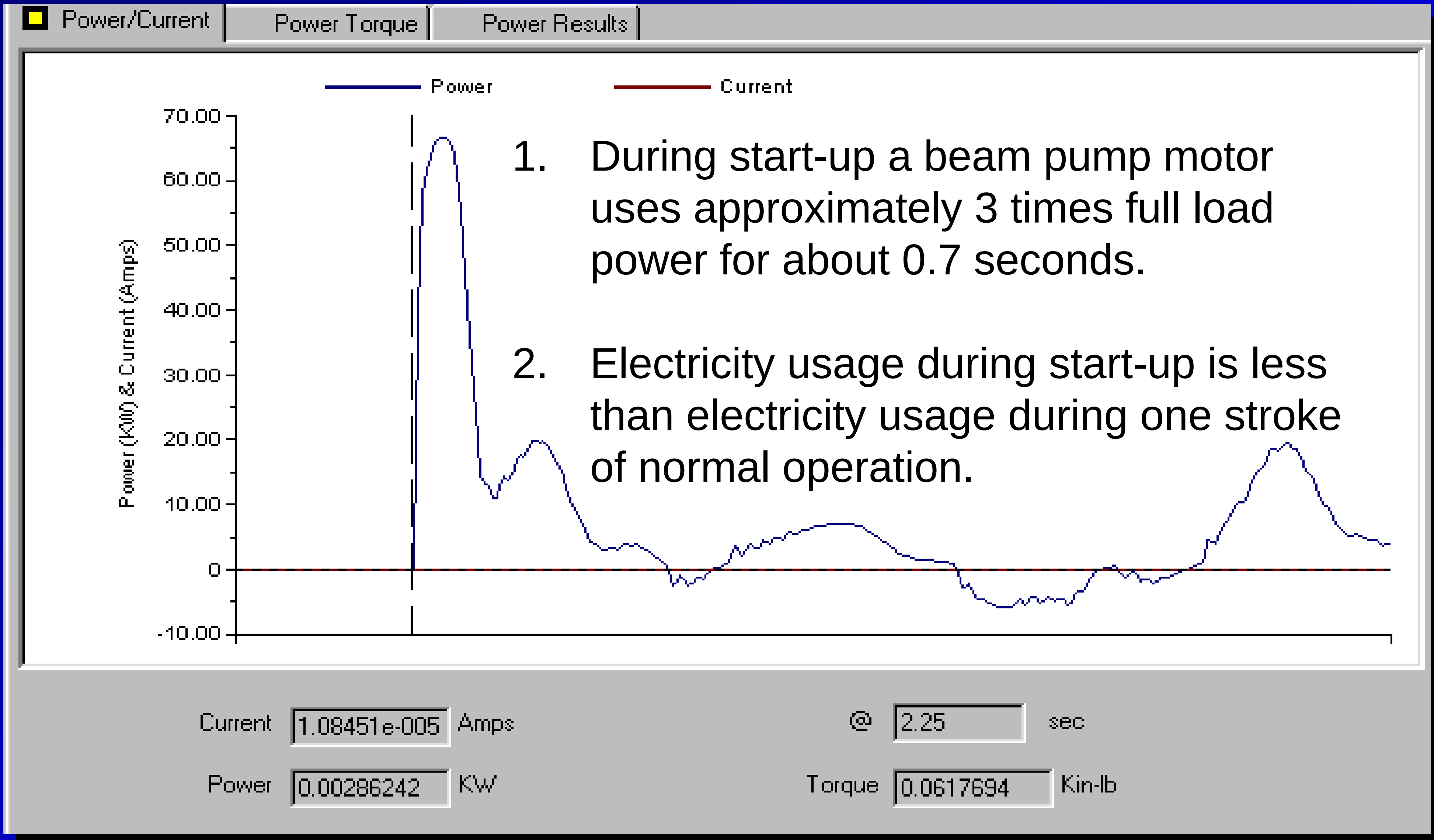
Motor Slip =
(Synch. RPM - Running RPM) / Synch. RPM



INDUCTION MOTORS OBJECTIVES

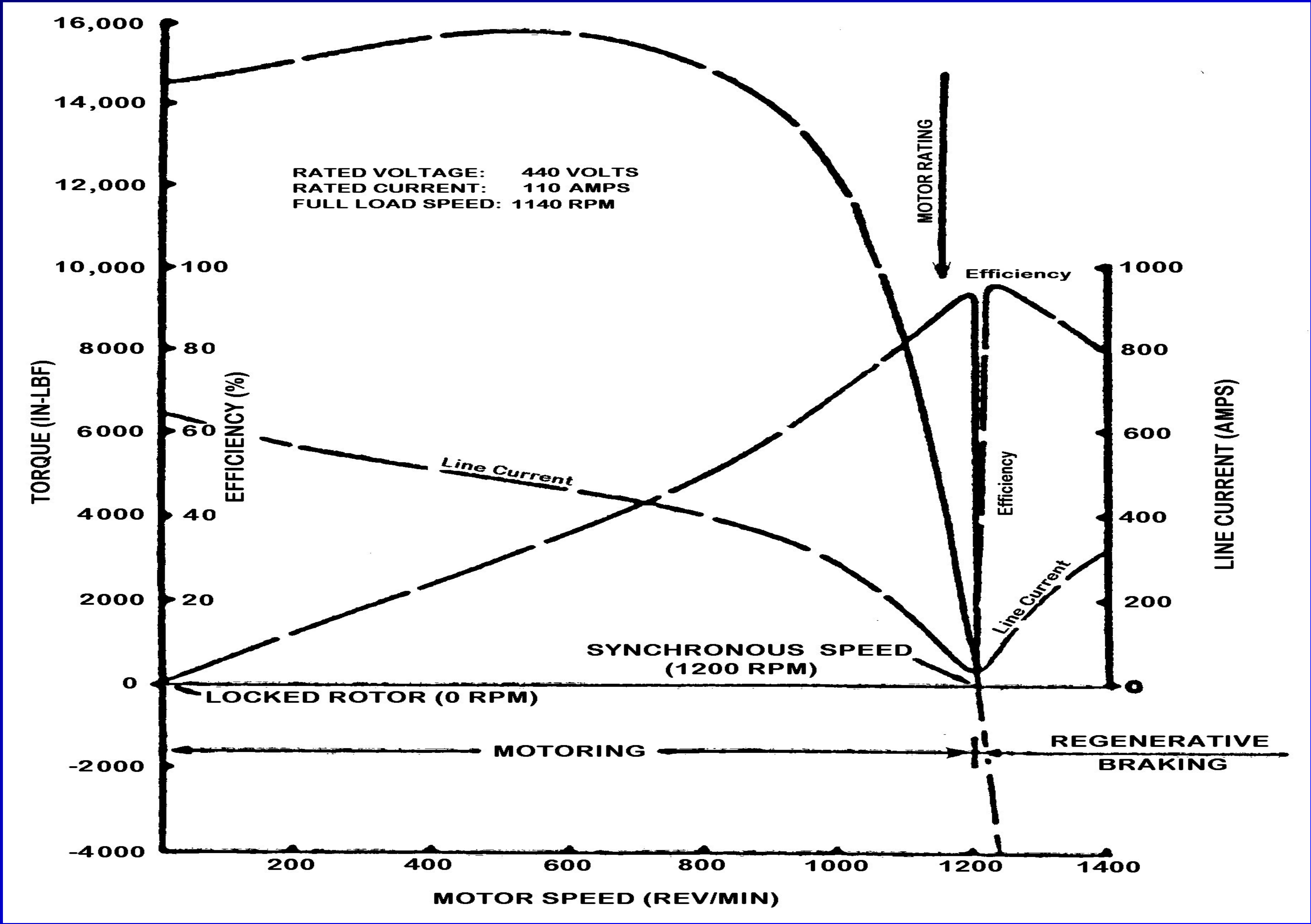
- **Understand the performance characteristics of a typical electric prime mover.**
- **Understand the nature of the load imposed on an electric motor, the torque required from the motor to break away and accelerate a pump jack.**
- **Pumping unit gearbox load presented to the prime mover, and the motor 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.**
- **What the Gearbox demands the motor provides.**
- **Identify and distinguish between an electrically unbalanced and balanced pumping unit.**

Startup Motor Power Consumption



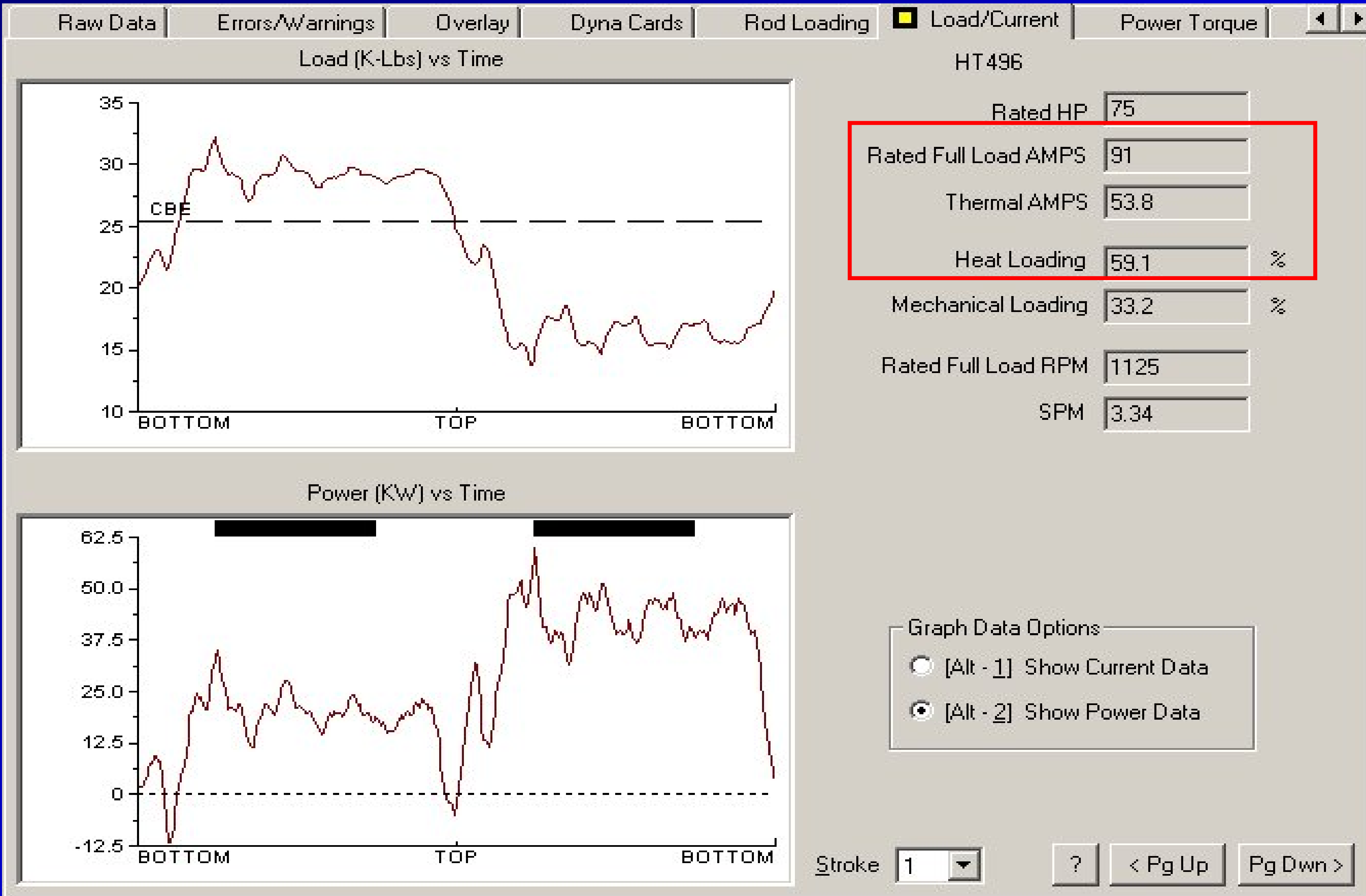
Starting a beam pump motor once each 15 minutes affects the demand charge less than 0.2 % compared to continuous operation.

Performance Curve 100 HP NEMA D Motor (After Gibbs, SPE 1987)



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

MOTOR LOADED?

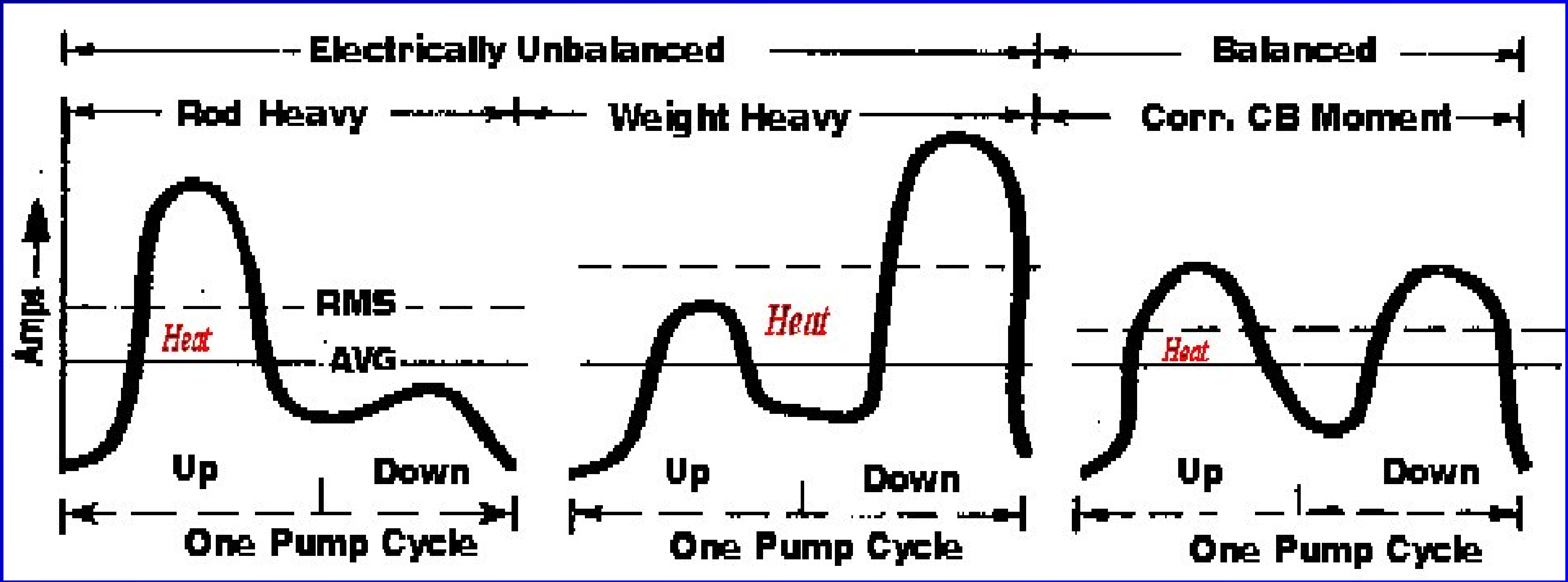


Cyclic Loading on Motor

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.

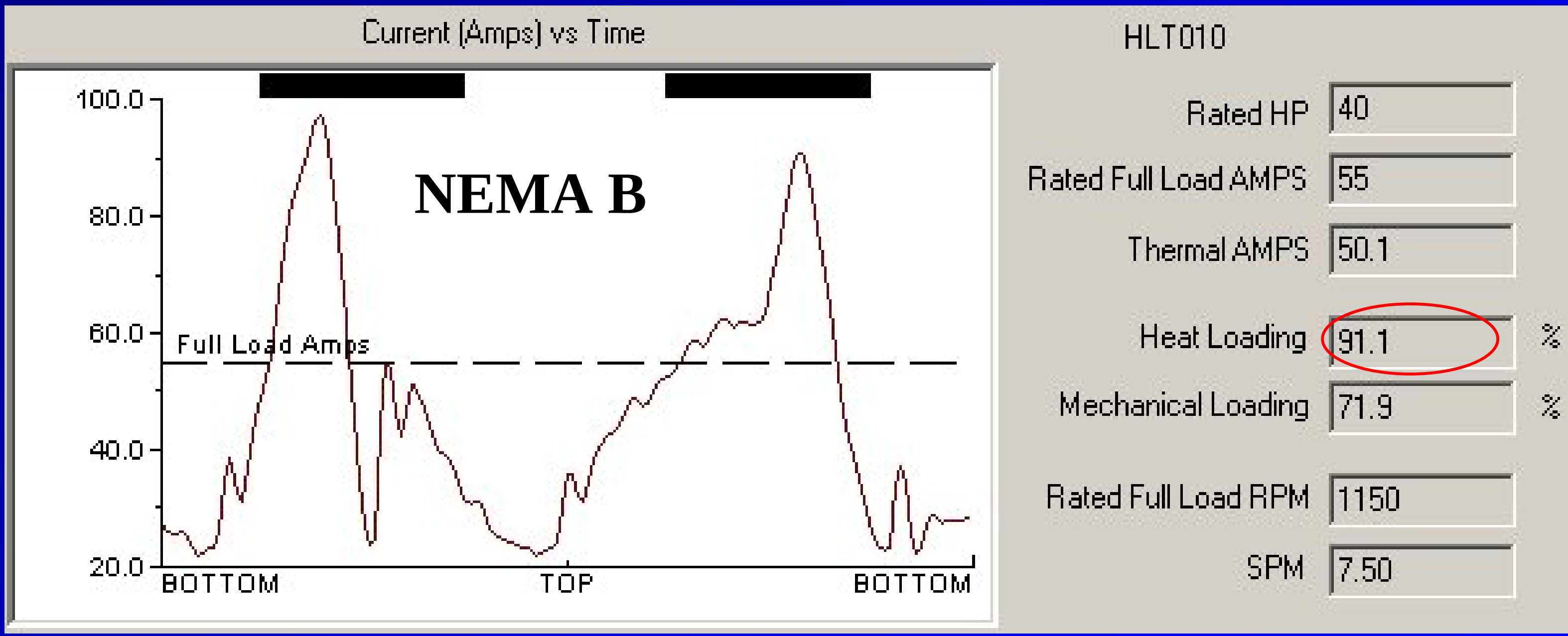


MOTOR CHARACTERISTICS

Same Well with Different Motors

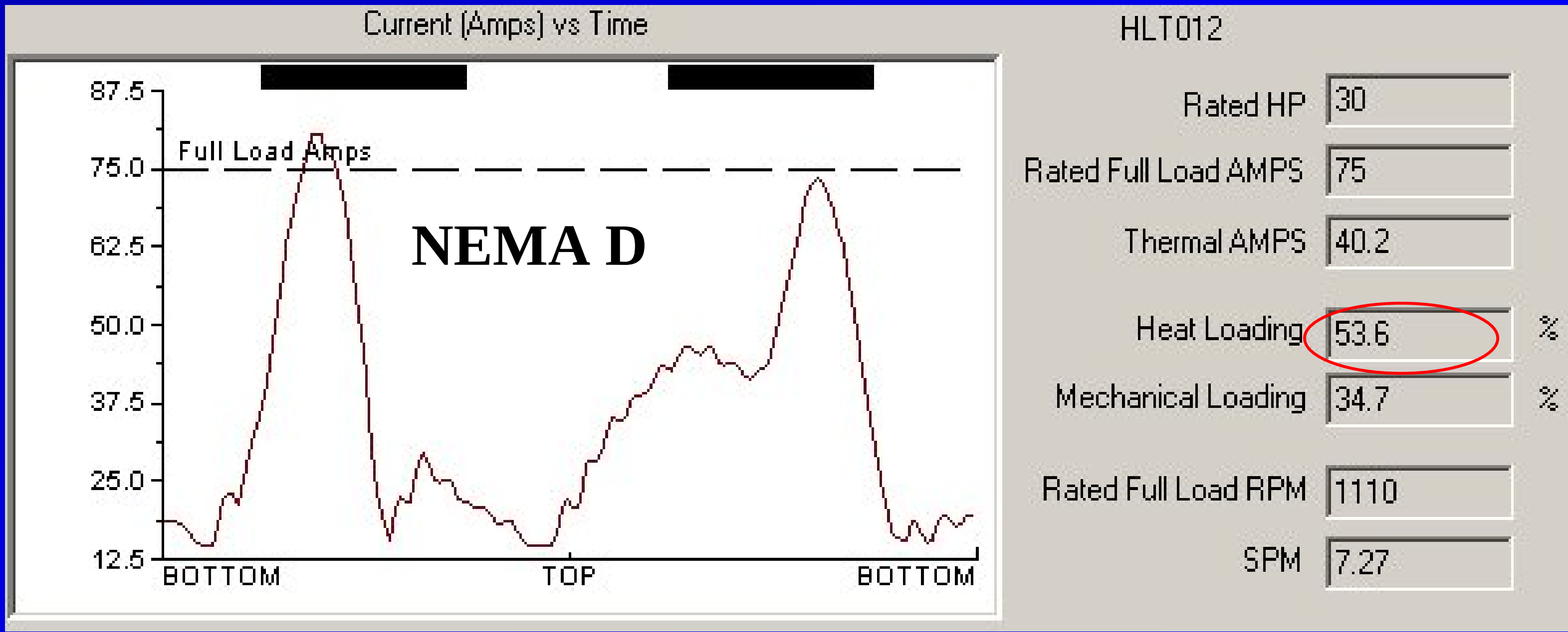
NEMA B

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



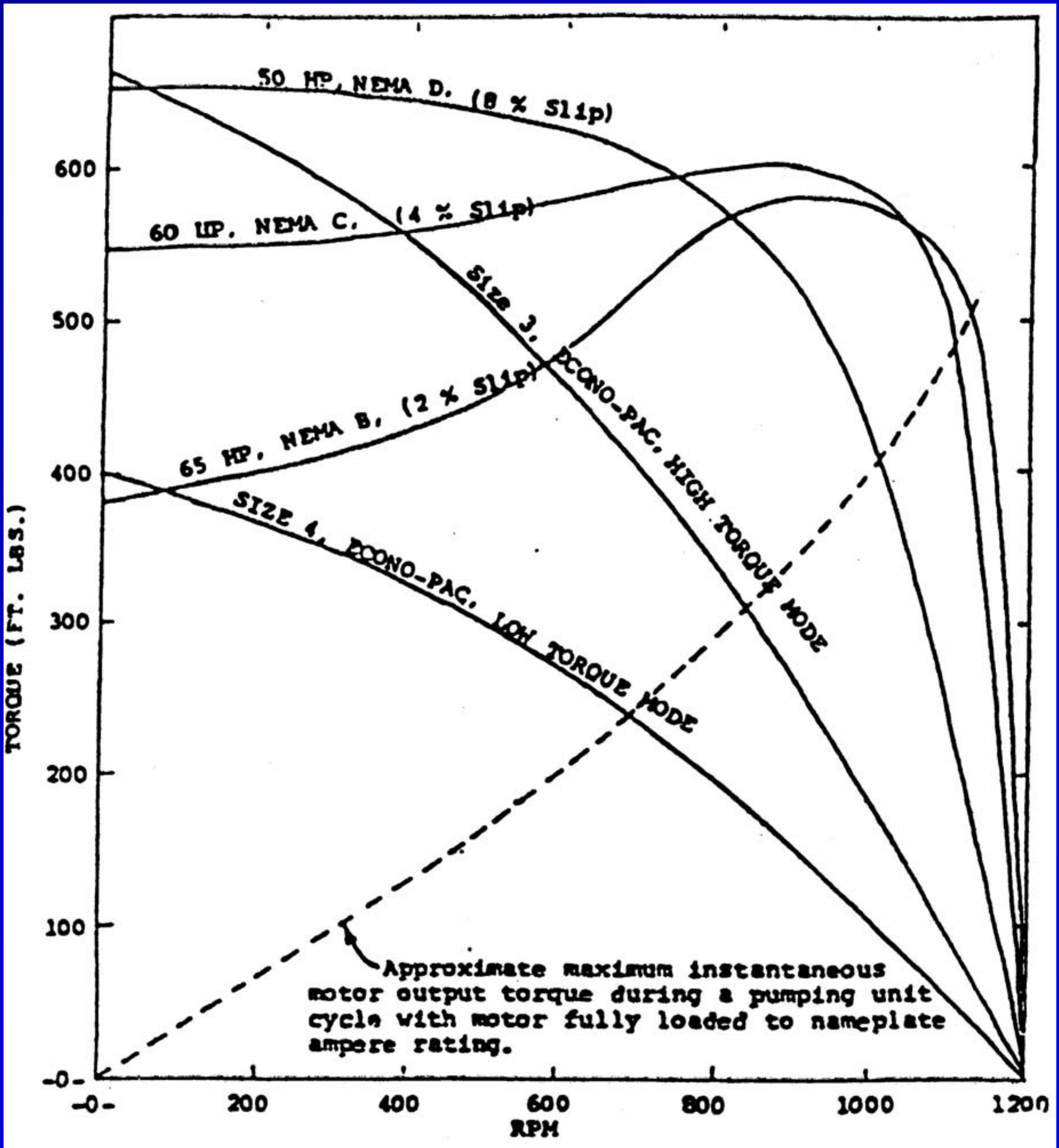
NEMA D

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



Comparison of Motor Performance Data – Speed/Torque Curves for Various Slip Rating

All Motors on this chart have essentially Equal full load capacity on a beam pumping system because of the derating factors necessary for cyclic load operations.



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.

Motor Sizing Criterion

Computer: HP = CLF * PRHP / Unit Effcy

CLF = RMS Current/ Average Current

~ RMS Torque/ Average Torque

~ RMS Power/ Average Power

(don't use CLF based on motor current)

OR:

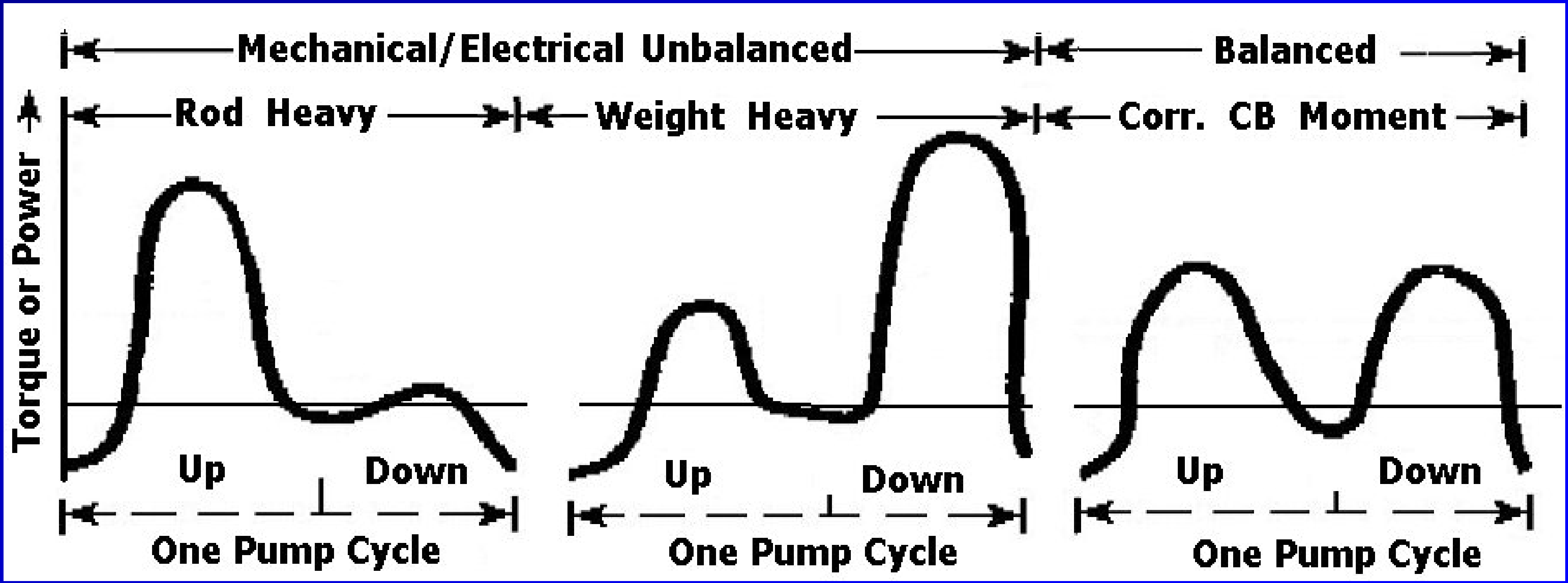
Gault: HP = 2. * PRHP

Balanced versus Unbalanced

Torque (in-lbs) or kW (power) signatures of an electrically or mechanically unbalanced or balanced pumping unit:

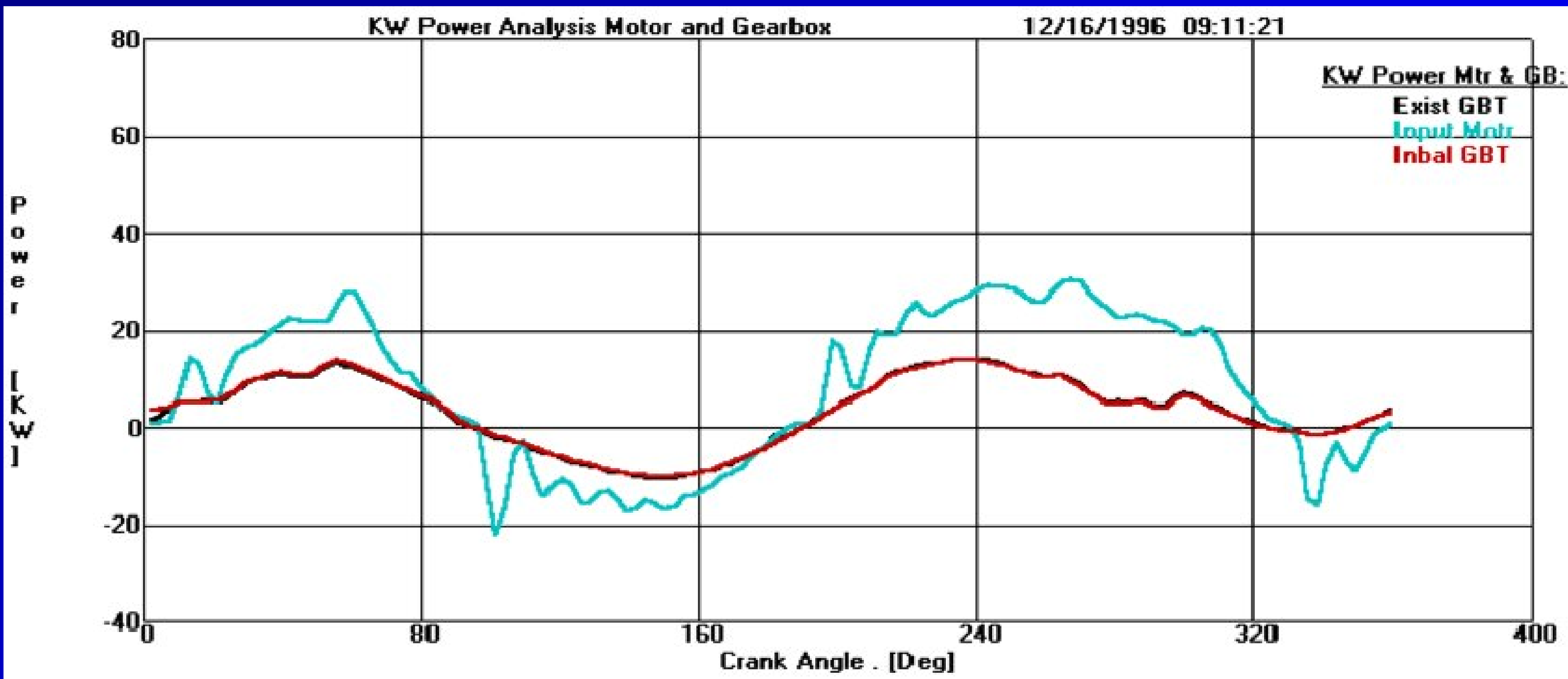
- **upstroke peak is greater,** the unit is under balanced or **rod heavy.**
- **downstroke peak is greater,** the unit is overbalanced or **weight heavy.**

- **balanced if peak upstroke torque equals peak downstroke torque.**



KW Power Analysis Motor and Gearbox Plot
kW_{IN} and Torque are Directly Proportional

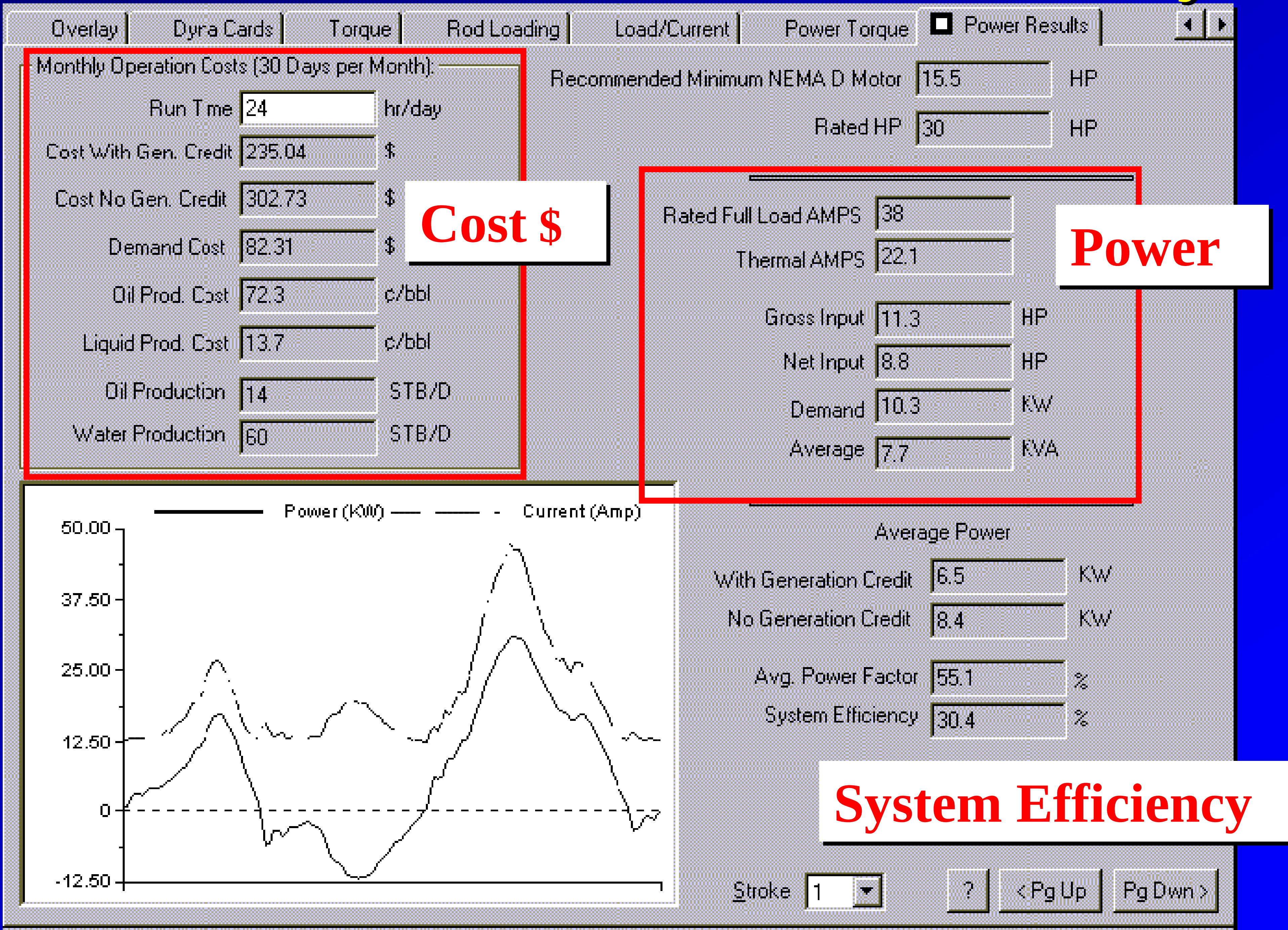
Torque = 84450 x Efficiency x KW / RPM



Analyze Motor Power and Current to Determine:

1. Overall system efficiency
2. Proper motor sizing
3. Motor loading and generation
4. Motor speed variation
5. Gearbox loading
6. Gearbox balancing
7. Electricity cost

Motor Power and Electrical Analysis



Electrical cost is one of the highest expenses in operating a well.

1. The power measurement system is designed to give instantaneous power values within 5% of actual values.
2. Through use of the power probe the Artificial Lift Technician will become proficient at reducing electrical cost.