Development of a

Beam Pump Energy Audit Tool (BPEAT), Version 1.0

To Assist Oil Field Production Companies
Achieve Reduced Oil Pumping Costs

FINAL REPORT

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Beam Pump Energy Audit Tool (BPEAT), Version 1.0
Reducing Oil Pumping Costs

Design, Assembly and Use of a Beam Pump Energy Audit Tool (BPEAT), Version 1.0
Beam pumps, the most common system for pumping oil in Kansas and most US oil fields, are simple devices with complex behavior. Careful analysis of a few wells has identified energy efficiency measures that may be cost effective for certain wells. This project involved the development of a Beam Pump Energy Audit Tool (BPEAT) based on lessons learned from earlier research. BPEAT is intended to permit the rapid (a few hours to a to a day) non-intrusive evaluation of a beam pumping unit to determine the potential impact and cost effectiveness of individual electrical, mechanical, and control energy efficiency measures. The tool developed is a basic system (Version 1.0) intended to provide the more important data for basic analysis. If use of the tool in the oil field proves successful more comprehensive versions could be developed to evaluate additional energy savings opportunities.

1. Criteria for Preliminary Evaluation of System Pumping Efficiency

- **Determine current well energy performance (kWh/barrel of fluid/1000ft)**
  If pumping energy performance is less than 0.20 kWh/bbl/1,000 feet the unit is already very efficient and little electrical or mechanical performance improvement is likely achievable. If pumping energy performance exceeds 0.50 kWh/bbl/1,000 feet the system may have significant opportunities for improvement. Wells with energy intensity between 0.20 and 0.50 kWh/bbl/1,000 feet may or may not have cost effective energy savings opportunities. Pre-audit data should permit a preliminary estimate for well screening purposes. A more accurate value can be acquired by using the BPEAT tool and the audit process.

- **Determine current well oil pumping economic performance ($/barrel of oil)**
  If the energy cost of lifting oil is less than $2.00 /barrel, cost effective options are not likely to be found. If the lifting energy cost exceeds $4.00/ barrel of oil cost effective improvement opportunities may exist. Wells with pumping costs between $2.00 and $4.00 require specific analysis. Fluid flow and energy use data acquired by the BPEAT tool permits detailed analysis of energy cost per barrel.

2. Electric Utility Rate Analysis

Using the prior 12 months of utility bills can help determine annual pumping cost and serve as a starting point for determining which electric utility rate offers the lowest cost. Rate design review can also identify factors such as annual peak demand ratchets and power factor penalties that can significantly affect cost.

3. Instrument and Analyze Pumping System Electrical and Mechanical Performance

The BPEAT system as developed consists of a pair of meters/data loggers for measurement of energy and fluid flow. Data from the loggers is downloaded in the field to a notebook PC equipped with dual serial ports for analysis in Excel.

BPEAT Design and Operation
The project team evaluated a variety of sensors and data logging systems for acquiring data on energy use and fluid flow. Important criteria were acceptable accuracy and reliability, durability, ease of acquisition and repeatability, and cost. While a "built up" system might have been the least expensive, standard off the shelf equipment from established vendors was selected with the expectation that others seeking to develop their own BPEAT would find it this approach easier. The final system design is described below.

BPEAT System Configuration

Power Measurement and Data Logging
The electric metering system selected is an Amprobe DM-II with the specifications below.

- Single or three phase capable
- AC voltage 5 to 600 volts
- AC current 1 to 1000 amperes
- 3 Channels for voltage measurements and 4 channels for current measurements
- Graphic display 160x160 pixel
- All readings are True RMS
- Power Measurements include: 1- Watts 3- VA
- 2- Vars 4- PF(Power Factor)
- Energy Measurements include: 1- KW-HR's 2-Demand or Non Demand
- User selectable recording rates.
- DM-II View™ software allows downloading data to a personal computer running Windows™ 3.11/95 and NT environment.
- Computer requirements: 486 - 50Mhz, 8Megs of RAM (16Meg recommended).
- Line Operated (120V/60Hz & 240V/50Hz)
- Battery backup protects memory if a power failure occurs and allows recording session to continue.
- Auto Ranging
- Real time clock
- Multi Languages built in: 1- English 2- German 5- French 3- Spanish 4- Italian
- Rugged ABS plastic case with a weather resistant design
- Made in USA
- Inputs: Voltage - Three voltage channels with common (V1, V2, V3 and COM). The test leads are flexible straight sheath banana plugs on each end, rated 1000Vrms and a length of 6 feet (set of four supplied). The alligator clips have a 1 inch jaw opening and are rated at 10A max (set of four supplied).
- Current - Four current channels (I1, I2, I3, I4) DM-CT: 1 to 1000A ±1% of reading (four supplied)

- ACF3000: 30A to 300A ±1% of full scale 300A to 3000A ±1% of full scale
- Ranges: AC Voltage measurements (True RMS) 5 to 600 Vrms.
AC Current measurements (True RMS) 1 to 1000 Arms with four supplied DM-CT’s
- Accuracy: Voltage measurements ± 1% of reading +3 LSD's
Current measurements ± 1% of reading +3 LSD's
- Voltage and Current Measurement Selections: True RMS voltage and current, RMS max, RMS min, RMS avg, Peak max
- Power measurement Capabilities: Real Power P (watts), Apparent Volt-amperes S (VA), Reactive Volt amperes Q (VAR), True Power Factor (tPF)
- Energy Measurement Capabilities: Kilowatt Hours (KWH), Demand (KW)
- Programmable Thresholds: User selectable high/low limits for RMS voltage and current.
- Recording Modes/Rates/Intervals: User selectable normal and loop (wrap around) recording modes. User selectable recording rates of 1 sec, 5 sec, 15 sec, 30 sec, 1 min, 5 min, 15 min, 30 min. Recording intervals for Demand (KW) are 15 min and 30 min.
- Memory: Total of 600K RAM memory. The recording session length depends on the recording rate, the number of selections, recording mode, and recording interval. The memory has a lithium battery backup to preserve its contents in the event of the absence of AC power and batteries.
- Real Time Clock: The user programmable real-time clock is displayed in 12/24 hour formats and HH:MM:SS Day month year, daylight savings option, accuracy ±1 min per month.
- System Configuration: Total of four presorted setup configurations for 1Ø and 3Ø systems: 1Ø 2W, 1Ø 3W, 3Ø 3W Straight Delta, and 3Ø 4W Wye.
Note: Any or all parameters of a phase configuration can be recorded.
- PC Interface: Optically isolated RS-232 serial interface. DM-II View™ software for display, analysis, and report generation. User selectable baud rates of 9600, 19200 and 38400 baud.
- Power Requirements: AC line voltage with battery backup operation. The ON/OFF dual color LED indicates the unit’s power source - Green indicates AC line power and Red for battery backup power.
- Designed to Meet: UL3111-1, CE (LVD/EMC/EMI)
- Sample Rate: 130µ sec. (7.68 KHz, 128 samples per cycle per channel, total of 8 channels).
- Case: Material: Injection molded flame retardant ABS911, rugged, water-resistant, and corrosion proof.
- Case dimensions: 17.5” x 11.6” x 7.5”
- Weight: 16 lbs. (7.3 kgs.) includes batteries, 4 CTs, voltage leads and alligator clips.
Pressure relief valve: Important - Be sure the knob located next to the handle is open when encountering atmospheric changes.
- Battery: 6 alkaline “D” cells (not supplied)
- Battery Life: 21 hours continuous with backlight OFF, 1 sec. recording rate, normal recording mode, all parameters selected for 3Ø 4W WYE configuration. *Battery life was*

extended by using rechargeable Lithium-ion D cells.

- Operation Temperature Range: 32 to 122°F (0-50°C) RH<85%

Amprobe technical staff advised us that the unit currently available would not register bi-directional current flow. Since measurement of regenerative current flow was an important part of the audit strategy two units were acquired at a per unit cost of $1,989. The DM-II energy requirements were measured in the lab and found to be 26 Watts at 12 volts. The final unit was configured with a light color plastic weatherproof storage box with a very small DC fan and vent.

Fluid Flow and Data Logging

The flow meter selected is a Greyline PDFM-IV portable combination battery/line powered Doppler flow meter capable of measuring average flow per unit time in various units (gph, barrels/day etc.), and also total flow at the end of the period of measurement. The unit uses a Doppler effect sensor to read the velocity of suspended particles in the material being pumped. A special bracket is supplied for mounting this sensor on the pipe containing the fluid to be measured. It is very important the sensor be mounted inline with the pipe, and that there be no air gaps between surface of the sensor and the pipe. The special gel supplied with the unit must be correctly applied between the pipe and the sensor as spelled out in the manual otherwise inaccurate readings are likely. The unit specifications are listed below.

- Sensor - strap-on, single head ultrasonic for 1/2" - 180" (12.5 mm - 4.5 m) ID pipes
- Sensor cable - 12ft / 3.5m shielded coaxial pair
- Installation - sensor coupling compound and stainless steel Sensor mounting clamp for 0.6 - 32 in. (15-800 mm) OD pipes
- Enclosure - portable, aluminum (non-rated) in foam lined Cordura™ carry-case
- Displays - Flow Rate: large 4-digit LCD - Totalizer/Menu/Status: 16-digit alphanumeric
- Calibration - built-in 3-key programmer
- Damping - keypad adjustable
- Sensitivity - keypad adjustable with signal strength indication
- Power input - built-in battery with internal charger - switch select 100-160VAC 50/60Hz or 200-260VAC 50/60Hz - 12 VDC (from external battery)
- Outputs - 4-20mA, RS232C with programmable baud rates up to 19,200
- Data logger - 50,000 point with multi-session and flow report capability

- PC software for data log retrieval by direct serial connection, or by dial-up connection with modems and telephone lines
- 1 set cables and plugs - AC power, 4-20mA, 12VDC, RS232
- Accuracy of ±2% of full scale on most wastewater applications. Have linearity of ±0.5% and repeatability of ±0.1%.
- Operates on liquids with entrained particles or gases of 100 microns or larger and minimum concentrations of 75 ppm.
- Operates on the following pipe materials: carbon steel, stainless steel, ductile iron, copper, PVC, FRP, ABS and other selected engineering materials.
- Operates on AC/DC power. Include an internal 12VDC gel type rechargeable battery with minimum capacity for 16 hours continuous battery operation. Recharge and operate with power input of 100-160VAC and 200-260VAC 50-60Hz, and 12VDC.
- Has a single-head, strap-on transducer with twin piezo-electric ceramic transmit and receive crystals encapsulated in epoxy resin and a stainless steel housing.
- The transducer is solid state and transformer isolated, and designed to meet intrinsic-safe requirements.
- The transducer is waterproof and operate continuously at temperatures from -10°F to 200°F (-23°C to 93°C), and withstand accidental submersion to 10 psi.
- The transducer is designed to install on pipes with inside diameter ranging from 1/2" to 180" (12.5 mm to 4.5 m).
- Has a 12 ft (3.6 m) long flexible, shielded coaxial pair cable extending from the transducer to the electronics.
- Include Manufacturer's recommended sensor coupling compound and adjustable stainless steel sensor mounting clamp.
- Portable aluminum enclosure in a padded Cordura™ carrying case with shoulder strap. Total weight shall be less than 10 lbs. (4.5 kg).
- Electronics designed for continuous operation at temperatures from -10° to 140°F (-23° to 60° C).
- Built-in 3-key calibrator with operator selection of parameters through visual prompts from a Menu calibration system. Systems requiring calibration by Parameter codes, BCD switches or external calibrators shall not be accepted.
- Continuous 4-digit LCD display indicating flow in user-selected engineering units. Have a 16-digit alphanumeric display indicating totalized flow, units of calibration, and/or signal strength.
- Flow proportional 4-20mA output rated to maximum resistive load of 500 ohms.
- Built-in 50,000 point data logger, RS232C serial output and connecting cables. Data logger shall support time and date-stamped logging and generate formatted flow reports including total, average, minimum, maximum and times of occurrence.
- Includes Windows software for data log retrieval, graphing and export.

- Keypad adjustable sensitivity which modifies the received signal strength to reduce interference. Have automatic signal strength monitoring to drive the flow reading to zero at low signal threshold.
- Battery status indicator with automatic low battery shut off and battery overcharge protection.
- The Model PDFM-IV Portable Doppler Flow Meter as manufactured by Greyline Instruments Inc. is warranted against defects in materials and workmanship for one year.

Signal generation for the Doppler flow meter requires significant energy. Power consumption was measured at approximately 26 watts. To accommodate 24 hour operation the PDFM-IV unit is placed in a weatherproof plastic box with a small dc fan and vent. A 1000 amp-hour deep cycle lead acid battery placed in a separate plastic weatherproof box sits adjacent to the meter box, connected by a battery cable and plug adapter unique to the flow meter. Cost of the flow meter was $3,818.45.

Data Analysis

The Amprobe DM-II and Greyline PDFM-IV units have data collection, logging, and analysis capabilities. Integration of the two data streams for system analysis requires transfer of the processed data via serial port to a notebook PC. The unit acquired is a Dell Inspiron with the specifications listed below.

- 600 Mhz Celeron
- 12.1 inch LCD screen
- 64 MB RAM
- 10 GB hard disk
- 24X CD-ROM
- Internal Modem
- Floppy Drive
- 4-Cell Lithium-Ion Battery
- Windows 98 SE, MS Office 2000 Small Business Edition
- Norton Antivirus 2001

Field use time of the notebook PC is anticipated to be very limited, involving transfer of data from the two logging devices and analysis in the prepare spreadsheet template. No additional power source was provided. In addition to the software unique to the Amprobe and Greyline units, MS Excel™ is used for data analysis. A Quatech RS-232, 2 Port, PCMIA card was installed to permit download of data from both metering systems at the same time. Total PC system cost was $1,263.

System Operation

Following component selection and acquisition the system was set up at the Power Quality Laboratory at Wichita State University for preliminary testing. Contrary to advice received from technical assistance at Amprobe, the DM-II data-logger proved capable of measuring current flow in both directions and one unit was returned for credit. Efforts to evaluate the Greyline PDFM-IV unit under available laboratory conditions proved problematic. The unit's sensor appears to not be capable of consistent measurement of clear water flow. Since this condition does not occur in the field further evaluation of the unit was deferred for field testing.

Field Test Site

Vess Oil Corporation, an oil production company headquartered in Wichita, Kansas had expressed interest in the project. Mr. Bill Horigan of Vess offered to provide access to, and technical assistance at, one of their wells in the El Dorado Field in Butler County, Kansas for testing. The project team met with Steve Darwin, a contract employee for Vess Oil, who serves as field pumper for approximately 300 stripper wells in the El Dorado Field immediately west of El Dorado in Butler County, Kansas. The well selected for test purposes was considered representative of the field. Oil/salt water is produced from a depth of 1,411 feet, with the depth verified with an Echometer. No salt water reinjection occurs in the field and the well fluid level is therefore relatively constant. The oil to water ratio is extremely low with about one barrel of oil for 410 barrels of salt water.

Stapleton No. 1, complete in the Fall of 1915 was the first well in the El Dorado Field.

Stapleton No. 1 is now shut in and serves as an historical marker. The well used for test purposes is located within ¼ mile.

The test well Lufkin pump jack is powered by a rewound 20 hp Baldor motor. Vess Oil takes power at a substation approximately a mile from the well and manages distribution in the field.

Greyline Flow Meter/Data Logger Installation

The oil/water fluid arrives at the surface flows through a horizontal section of 2-3/8 inch o.d. steel pipe before returning below grade enroute to the collection tank. This section of pipe allows access for fluid measurement. The surface of the pipe was rusty and was cleaned using a file to get a smooth surface. The contact gel was applied and the sensor installed and clamped to the pipe with a steel band clamp.

The flow pipe was clean and the flow sensor attached with a hose camp and contact gel.

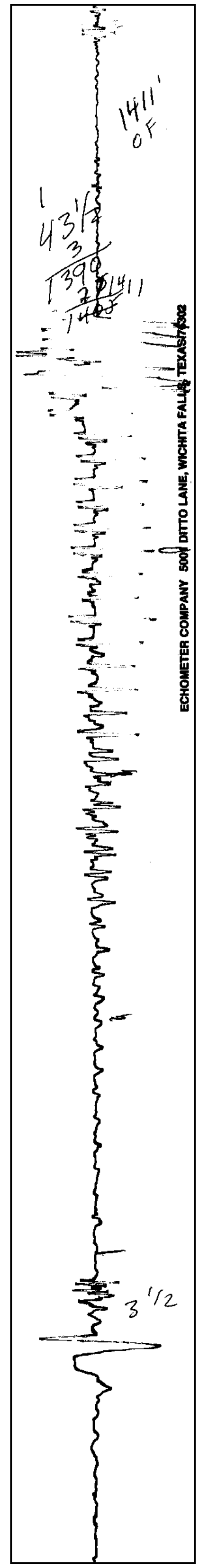
Accurate inside pipe diameter is required to acquire accurate flow data. Plastic lined pipe resists salt corrosion.

The flow meter is easily configured in the field. Key settings are pipe i.d., time interval, and units. Note the sensor on the pipe. For 24 hour logging the unit is placed in a weatherproof vented box.

Unit calibration was then done to select the sample interval (in this case the minimum value of 10 second sample intervals was used). The inner pipe diameter must be set accurately in order to get an accurate total volume flow in the pipe. Vess Oil uses a high quality pipe designed to resist salt water corrosion. The 2-3/8 inch steel pipe is lined with a thin layer of cement and an inner plastic coating reducing true inside diameter to 2-5/8 to 2- 11/16 inch.

Fluid flow rates were compared to a manual calibrated measurement system. All fluid flow is diverted to a tank for a period of two minutes. A calibrated site glass provides a reading in barrels per day. The Greyline unit was within 2% of the manual reading.

The Greyline unit has a built in time/date clock which must be set to the same time as the Amprobe meter for correlation of fluid flow and input pump power for analysis purposes. A complete copy of the pdf file of the ***USER'S GUIDE: Installation & Operation Instructions, Portable Doppler Flow Meter, Model PDFM-IV, Series A.1,*** accompanies this report.



Echometer depth output.

The Greyline portable Doppler flow meter in operation, providing accurate well fluid flow measurement without drilling or cutting the pipe.

Amprobe Power Meter/Data-Logger Installation

The next task was setting up the Amprobe DM-II data-logger, which is also a battery/line powered unit used for collecting input 3-phase parameters for the pump drive motor (power factor, phase voltages/currents, total input true power, etc.). In this case the sample interval was set at the minimum value 1 sample/second in order to capture the best picture of the dynamic load on the motor, including negative power flow on the down stroke of the pump. An important point to note is the connection of the clamp-on CT's used for current measurement. The CT's have polarity markings which must all toward the load to get proper polarity of input power flow; if they are backwards, total energy flow will be negative. A pdf file of the ***Amprobe DMII™ PRO Data Logger Recorder User's Manual*** accompanies this report.

The split-ring current transformers (CTs) and voltage leads are installed at the pump jack electrical panel. Sensor leads are connected to the Amprobe and the unit is field configured.

At this point, both units were both put in data collection mode and allowed to run for a period of about half an hour.

The laptop was connected to each unit (flow meter and Amprobe), one at time in order to download the data into respective software data bases for each unit. (Software supplied with each unit was installed prior to data collection).

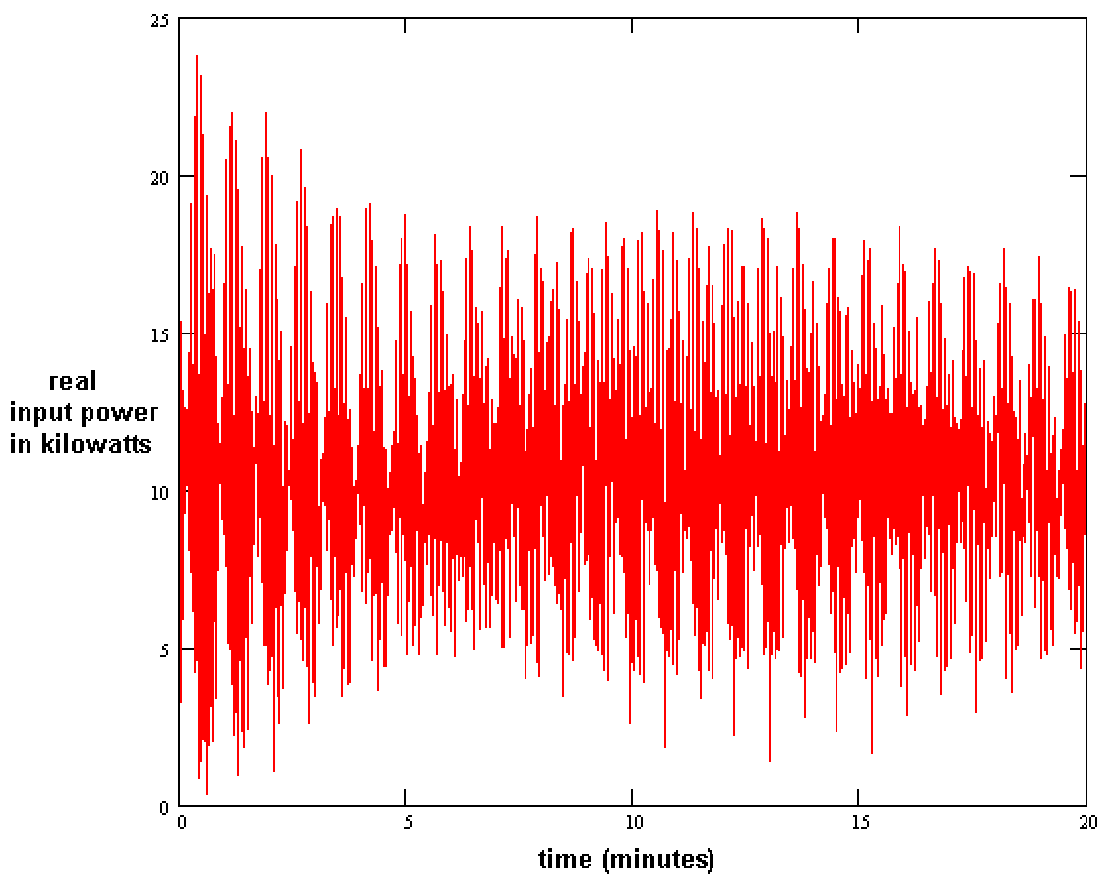
Both software packages have the capability of converting the collected data into forms readable with spreadsheets such as Excel; the resulting download data was converted to this format, with the only remaining task being data analysis.

For conclusions, it was noted that, in spite of rust and pitting on the pipe used for measurement, the flow meter readings were very stable. Nothing eventful was noted with regard to power flow measurement other than the fact that the negative (regenerative) power on the down stroke of the pump was visible as expected.

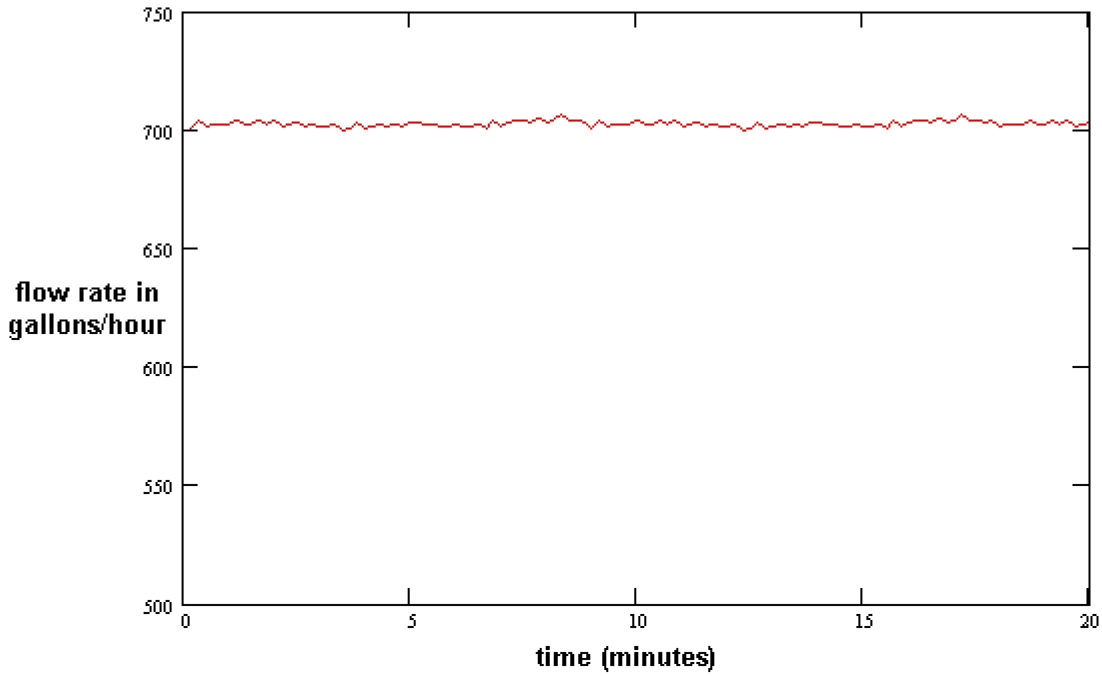
The Amprobe unit logging data. For 24 hour operation the unit is placed in a weatherproof plastic container with a small fan and vent.

Well Energy Performance Analysis

The BPEAT system was used at the test well to verify system performance capabilities outlined in the original proposal. The chart below shows power consumption by the test well for a twenty minute period.



The chart below shows fluid flow for the same time period.



Analysis of the energy and flow data indicated 0.43 kWh/bbl/1000 feet net energy use with regenerative energy of only about 0.01 kWh/bbl/1000 feet. This is a reasonably efficient well, although the extreme oil to water ratio means the pumping cost per barrel of oil is very high.

- **Measure well fluid depth**
  Accurate knowledge of well fluid depth is required to evaluate well pumping energy performance. In some wells, particularly those in areas with significant water flooding, fluid depth may vary with time, requiring continuous monitoring for accurate measurement. For BPEAT Version 1.0 fluid depth will be measured using a shot/echo device provided by the production company. Future versions could incorporate continuous fluid depth monitoring.

- **Fluid flow**
  Measurement of fluid flow is required to evaluate system efficiency and percent of barrel fluid fill. Version 1.0 uses a passive non-intrusive flow meter for continuous fluid flow measurement. The fluid flow data is logged at 10 second intervals.

- **Oil fraction**
  The fraction of total fluid that is actually oil must be recorded to evaluate economic performance of potential retrofit measures. Oil fraction will be measured by visual inspection of the collection tank.

- **Electrical current and voltage (in and out)**
  Measuring electrical current alloys calculation of energy and power. Recording data for

relatively short time intervals allows other variables to be evaluated. The energy use data is logged at one second intervals.

- **Power factor, and power quality**
  Power factor is calculated from measured data automatically by the Amprobe DM-II unit. Power quality measurements are limited to single point values and are done with additional specialized instruments that are beyond the scope of the BPEAT device. Such measurements are only done if the previously recorded data suggests a potential harmonic problem, such as sustained current levels above the current rating of the pump motor indicating possible magnetic saturation of the motor frame. There were no indications of power quality problems in the field tests and as such no extra measurements were made.

- **Rod strain**
  Rod strain is a useful method of measuring pump barrel fill. Since fluid flow will be measured continuously rod strain will not be measured in version 1.0 but may be in later versions.

4. Evaluation of Electrical Performance Improvement Measures

Using the data collected as outlined above, evaluate the potential energy, cost savings, and payback for each of the measures listed below. The table provides a snapshot of data collected by the Amprobe unit at one second logging interval.

Time	VAB RMS	IA RMS	VBC RMS	IB RMS	VCA RMS	IC RMS	3Ø Real Power	3Ø Reactive Power	3Ø Apparent Power	3Ø True PF
	Volts	Amps	Volts	Amps	Volts	Amps	KW	VAR	VA	PF
13:22:58	478.8	13.1	476.8	20.3	477.4	20.3	13.8	5.22	14.8	0.94
13:22:59	486.6	8.41	484.9	13.1	485.9	13	7.45	6.07	9.61	0.78
13:23:00	467.9	18.4	466	28.4	466.3	28.5	19.5	5.77	20.4	0.96
13:23:01	492.8	6.82	491	10.5	492	10.3	3.3	7.04	7.78	0.42
13:23:02	481	12.8	479.2	20	479.9	19.8	13.4	5.66	14.6	0.92
13:23:03	484.4	8.02	482.7	12.5	483.7	12.3	6.76	6.07	9.09	0.74
13:23:04	461.5	24.5	459.9	37.8	460.2	37.7	25.7	7.43	26.7	0.96
13:23:05	493.8	6.68	491.9	10.3	493	10.2	2.65	7.2	7.67	0.35
13:23:06	478.5	13.5	476.6	21	477.1	20.8	14.2	5.58	15.2	0.93
13:23:07	490.4	7.02	488.8	10.9	489.8	10.7	4.39	6.71	8.02	0.55
13:23:08	464.1	22.4	462.3	34.7	462.5	34.6	23.6	6.86	24.6	0.96
13:23:09	500	10.2	498.2	15	499.3	14.8	-4.1	10.8	11.6	-0.35
13:23:10	479.7	12.4	478.1	19.3	478.8	19.2	12.9	5.56	14	0.92

- **Conductor loss**
  Conductor losses from the utility transformer to the well motor service panel were evaluated to determine if increasing conductor size would be cost effective. In the field test the voltage at the well disconnect was found to be approximately 477 V. This

indicates that the conductors supplying power to this well are adequately sized and that no serious voltage drop occurs in the conductors.

- **Stray voltage loss**

Losses within the service panel and at the motor were evaluated to determine if high impedance connections need correction to reduce stray voltage losses. Analysis of the motor current data taken during the field test shows that the current in phase “A” of the motor circuit is consistently lower than the current in the other two phases. This suggests a possible high impedance connection in the motor or disconnect circuit in the test well. This item would be one of the things brought to the attention of the operator after the BPEAT unit had run its tests.

- **Power factor correction**

The economic potential for power factor correction capacitors based on actual power factor, the utility rate, and actual utility billing practices was evaluated. In this case, the oil producer who operated the test well performs power factor correction at the meter point instead of on each individual well. Since the test well was one of 280 operating wells in the field that were all served by a common metering point, no attempts at power factor correction were or felt to be warranted in the test case.

- **Oversized motors**

Pumping energy requirements were evaluated to determine if the motor is oversized and can be economically replaced. The data taken by the Amprobe DM-II device indicated that the 20 Hp motor on the test well was operating at or slightly above its rated value. It was therefore determined that the motor was properly sized for the well.

- **Replace low efficiency motor**

Replacement of low efficiency motors with higher efficiency units was considered in conjunction with motor downsizing. The motor on the test well appeared to be in good condition and was recently rebuilt by a reputable motor rewind shop. It was not considered economically feasible to replace this motor at the current time, given the relatively low oil production of the test well.

- **Regenerated energy**

When the beam pump counterweight falls driving the motor above past synchronous speed it becomes a generator. Depending on how well balanced the unit is regeneration is generally assumed to produce energy equal to 20 – 35% of a well consumption, although good data on the actual amount have not been found. Meters are detented (will not turn backwards) but not shunted to ground (the energy goes back into the grid). When several wells are connected to one meter this energy may flow to other wells on the circuit rather than to the utility, but with single meter wells the power flows to the utility grid. Short time interval energy data will be evaluated to determine if regenerative power is sufficient to consider strategies for better management. Data from the test well taken by the Amprobe DM-II indicated that the peak power consumption by the test well was approximately 26 kW and the peak regenerated power was approximately 4 kW. This suggested that the test well was fairly well balanced (see below) and since the test well was one of 280 wells connected to the same electric meter the investigators felt that the well operator was already using the regenerated power advantageously.

5. Evaluation of Mechanical Performance Improvement Measures

- **Balance pumping unit**

  Short time interval motor amperage was used to create the equivalent of a dynamometer card that was used to determine whether the units is in need of rebalancing. Based on the field data taken by the investigators the test well appeared to be nearly in balance. It was determined that the test well did not need rebalancing.

- **Gear box replacement**

  Gear box performance will not be measured in version 1.0 but may be in later versions.

- **Gear box lubricants**

  Gear box lubricant performance will not be measured in version 1.0 but may be in later versions.

- **Drive belt**

  Drive belt performance will not be measured in version 1.0 but may be in later versions.

6. Pumping System Control Measures

- **Pump on/off or variable speed control**

  On/off or variable speed control can achieve demand reduction, depending on the electric utility rate design, and full pump barrel filling. A partially filled pump barrel degrades energy performance since the same weight of rod string and pump must be lifted for a lesser amount of fluid. Barrel fill can be evaluated from the fluid flow measurement or a strain gage located on the polishing rod.

All indications are that the hardware and software perform as planned. Use of standard industry measurement devices should permit easy replication by others interested in developing such a system.

Experience gained from evaluating multiple wells will be required to fully refine the operation of the BPEAT hardware and software.

BPEAT Field Use

The BPEAT tool was developed by Dr. Bob Egbert, PE, and Dr. Doug Warner of Wichita State University and Joe King, AIA, of Coriolis[1]. It is being turned over to Dr. Lynn Watney of the Kansas Geological Survey KGS and Rodney Reynolds, Director of the Petroleum Technology Transfer Council North MidContinent Resource Center (PTTC) in Lawrence, Kansas through an in field training process.

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[1] Dr. Egbert and Joe King were principal investigators for recent projects focusing on beam pump energy performance in Kansas.

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