

Auditing Water System Pumps for Efficient Operation

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City of Vancouver System

- Fourth largest water utility in Washington State
- Service area of 65-square-miles serving about 210,000 people
- Average 10 Billion Gallons Annually
- 40 groundwater wells
- 49 Booster Pumps
- Power Bill = \$1,000,000/yr

Energy Audit Objectives

- Assess all system pumps for efficiency
- Assess system for inefficiencies
- Identify cost effective energy saving projects
- Make modifications for the “low hanging fruit” projects
- Include energy savings projects in the capital budget

Evaluating Pump/Motor Efficiency

- Wire to Water Efficiency
- Calculated Current vs. Measured Current

Flow Meter

- Calibrate first
- One meter per pump is best
- Master station meter
- Ultrasonic meters



Pressure Gauges

- Make sure they are accurate
- Needed to determine total head
- Best to have multiple gauges



Level Meters (Well Pumps)

- Continuous Meters
- Manual Meters



Amp Meter

- Hand Held
- Permanently Mounted



Power Data Logger



995665revA

DM-II™ PRO

DATA LOGGER/RECORDER

LCD CONTRAST CONTROL

DARKER



LIGHTER



SYMBOL	NAME	UNIT
V	TRUE RMS VOLTAGE	VOLT
I	TRUE RMS CURRENT	AMPERE
S	APPARENT POWER	VA
P	REAL POWER	WATT
Q	REACTIVE POWER	VAR
PF	TRUE POWER FACTOR	
WH	ENERGY	WATT HR

ON/OFF POWER LED
GREEN-LINE OPERATED
RED - BATTERY OPERATED

FOR TECHNICAL ASSISTANCE
CALL 1-800-327-5060

 **AMPROBE®**
3 ϕ METER

V _{AB}	482	V _{RMS}
I _A	325	A _{RMS}
V _{BC}	484	V _{RMS}
I _B	384	A _{RMS}
V _{CA}	482	V _{RMS}
I _C	374	A _{RMS}

TOTAL

SETUP

METER

RECORD

VIEW



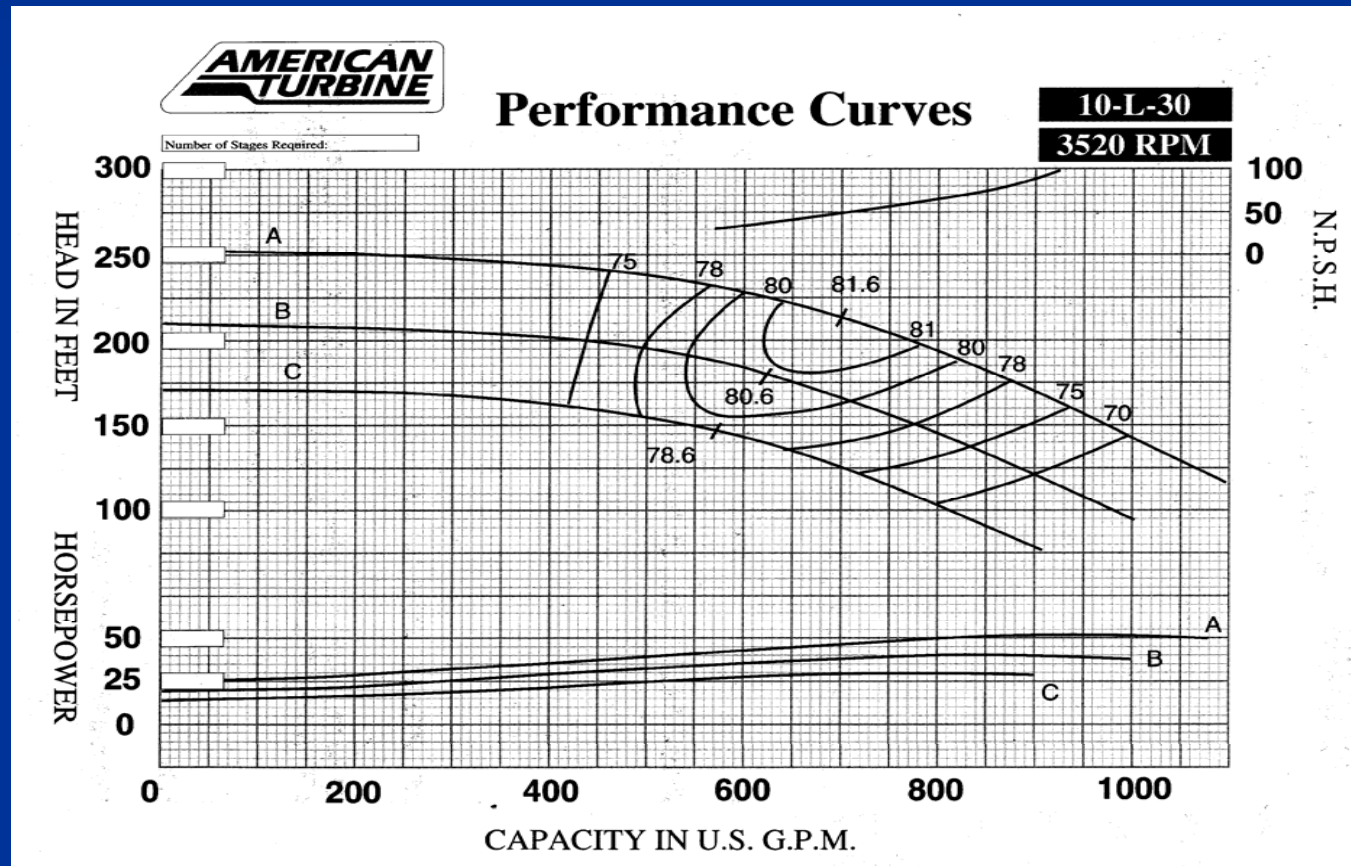
ON/OFF



INSP.

Pump Curve

- Flow rate and Total Dynamic Head (TDH) used with pump curve to determine pump efficiency



Motor Efficiency Data

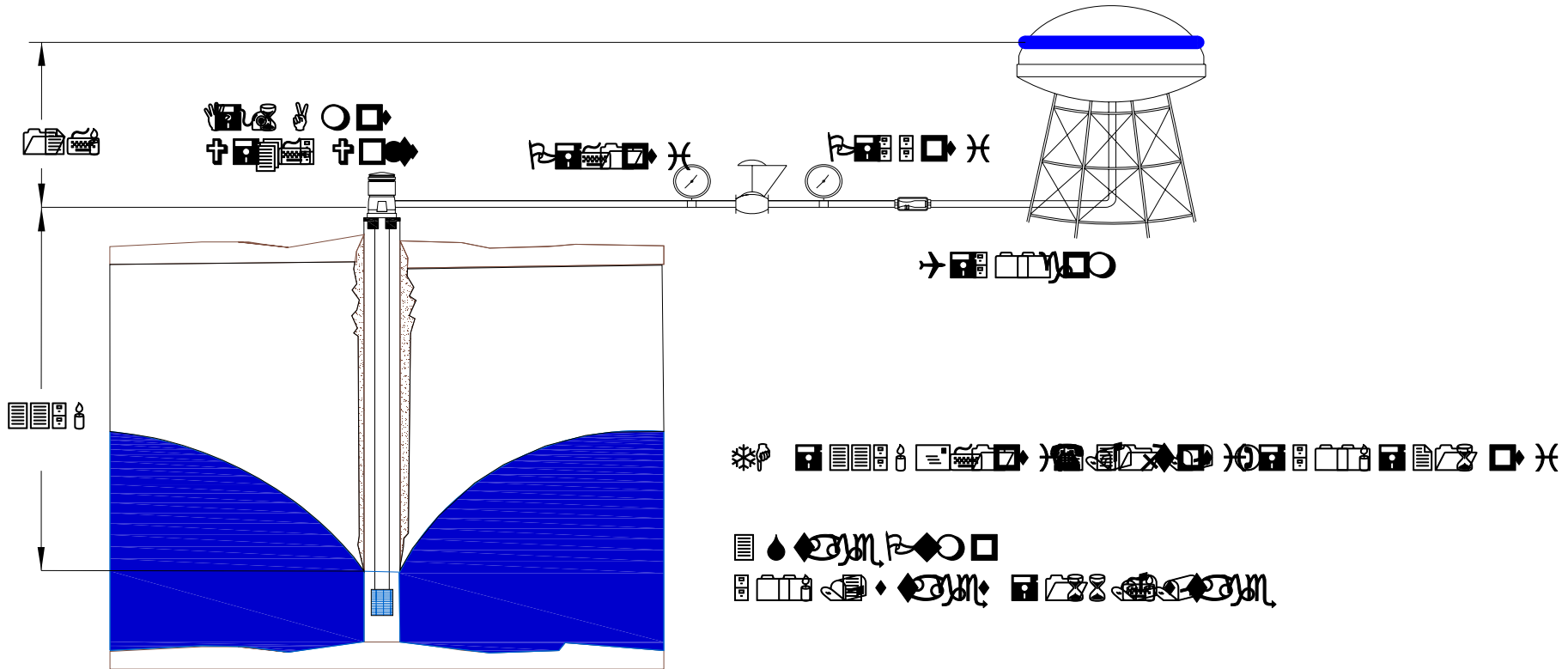
- Motor Manufacturers provide spec sheets showing efficiency at certain loads

Load Characteristics of a 200 HP motor, 460 V, 60 Hz

% of Rated Load	25	50	75	100	125	150	S.F.
Efficiency	93.3	95.8	96.3	96.2	95.9	95.4	96
Speed (rpm)	1797	1794	1791	1787	1783	1778	1785
Line Amperes	86.3	126.4	174	224	279.6	339.2	257.4



Well Example

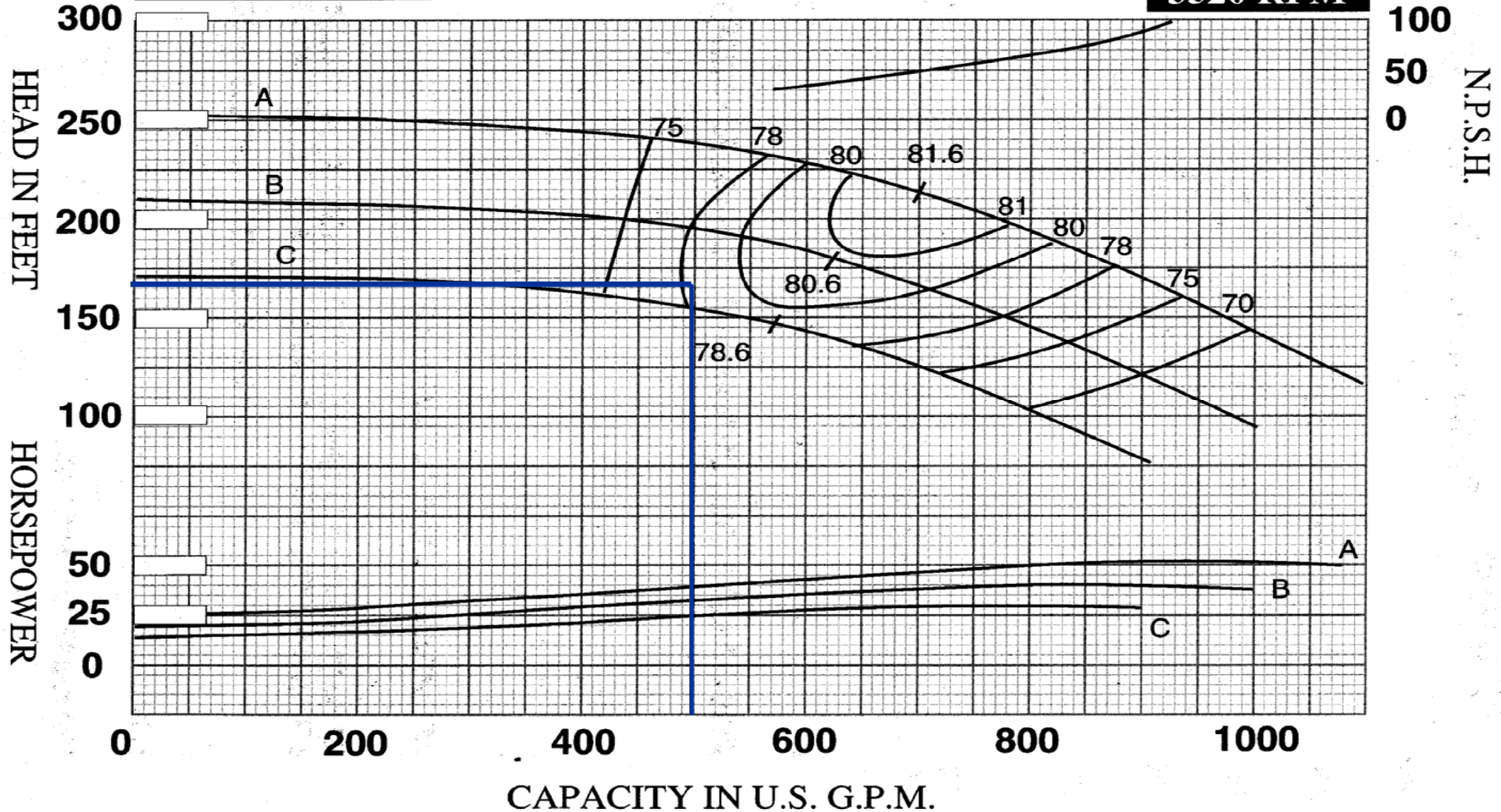




Performance Curves

10-L-30
3520 RPM

Number of Stages Required:



$$Power = \frac{(BHP)(0.746)}{(MotorEfficiency)} = \frac{(80)(0.746)}{(0.92)} = 65kW = \frac{(500gpm)(216psi)}{(0.78)(1714)} = 80hp$$

Calculated Current

$$BrakeHorsePower(BHP) = \frac{(Flow)(TDH)}{(PumpEfficiency)(1714)} = \frac{(500gpm)(216psi)}{(0.78)(1714)} = 80hp$$

$$MotorInputPower = \frac{(BHP)(0.746)}{(MotorEfficiency)} = \frac{(80hp)(0.746)}{(0.92)} = 65kW$$

$$CalculatedCurrent = \frac{(Power)(1000)}{(Voltage)(1.732)(PowerFactor)} = \frac{(65kW)(1000)}{(475V)(1.732)(0.95)} = 83Amps$$

Calculated Current = 83 Amps

Measured Current = 96 Amps

Efficiencies NOT Correct

$$BrakeHorsePower(BHP) = \frac{(Flow)(TDH)}{(PumpEfficiency)(1714)} = \frac{(500gpm)(216psi)}{(0.78)(1714)} = 80hp$$

What If Currents Don't Match?

- Use judgment to determine if motor or pump is operating inefficiently
- If motor is new, then probably a pump problem
- Modify efficiency until measured current matches calculated current

$$BrakeHorsePower(BHP) = \frac{(Flow)(TDH)}{(PumpEfficiency)(1714)} = \frac{(500gpm)(216psi)}{(0.68)(1714)} = 93hp$$

$$MotorInputPower = \frac{(BHP)(0.746)}{(MotorEfficiency)} = \frac{(93hp)(0.746)}{(0.92)} = 75kW$$

$$CalculatedCurrent = \frac{(Power)(1000)}{(Voltage)(1.732)(PowerFactor)} = \frac{(75kW)(1000)}{(475V)(1.732)(0.95)} = 96Amps$$

Appendix A

Energy Cost from Pump Operation

Power Cost Winter: \$0.0391

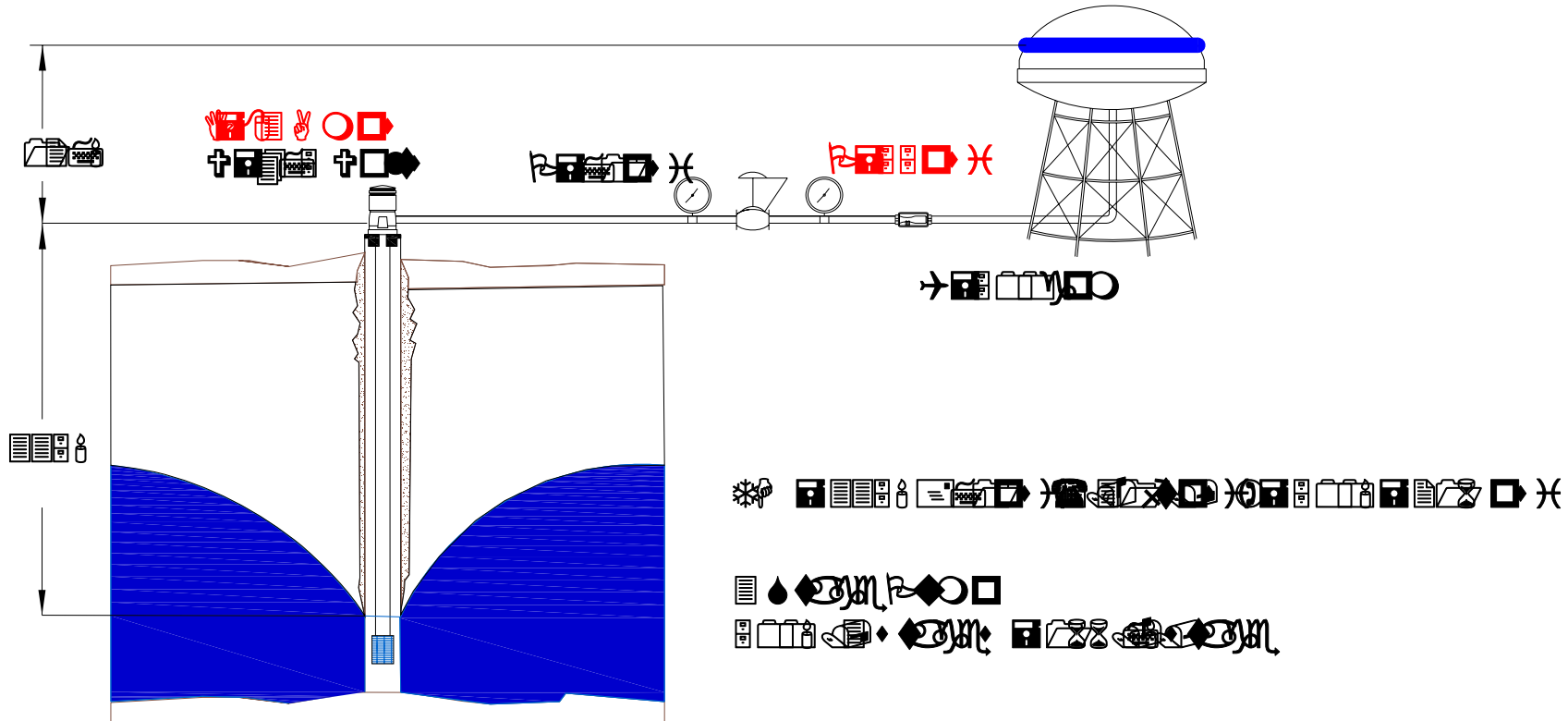
Power Cost Summer: \$0.0441

Pump ID	Flow reqm't (gpm)	Head (psi)	Pump Efficiency	Brake Horse Power (BHP)	Motor Efficiency	Power (kW)	Power Factor	Calculated Current (Amps)	Measured Current (Amps)	Required Motor (hp)	Observed Motor (hp)	Power Cost Summer	Power Cost Winter	% Op Summer	% Op Winter	Cost/yr w/ 4% tax	Cost/MG Pumped
Station 15																	
Well 1	515	140	0.8	52.6	0.900	43.6	0.95	55.2	67	58.4	100	\$0.0391	\$0.0441	0.768	0.680	\$11,917	\$61.40
Well 2	500	140	0.8	51.1	0.900	42.3	0.95	53.6	No	56.7	100	\$0.0391	\$0.0441	0.000	0.000	\$0	#DIV/0!
Well 3	500	140	0.83	49.2	0.920	39.9	0.95	50.5	56	53.5	100	\$0.0391	\$0.0441	0.060	0.000	\$359	\$54.08
Well 4	500	140	0.65	62.8	0.920	50.9	0.95	64.5	No	68.3	100	\$0.0391	\$0.0441	0.000	0.000	\$0	#DIV/0!
													Calculated Pump Cost/yr			\$12,275	
													Demand Cost/yr			\$5,494	
													Demand + Calc. Pump Cost/yr			\$17,769	
													CPU Bill for 2003			\$22,506	
Ellsworth																	
Well 1	2100	226	0.72	384.6	0.958	299.5	0.98	367.6	375	401.4	350	\$0.0391	\$0.0441	0.995	0.988	\$113,544	\$103.81
Well 2	2400	245	0.78	439.8	0.958	342.5	0.95	433.6	430	459.1	450	\$0.0391	\$0.0441	0.036	0.552	\$45,930	\$108.53
Well 3	3000	208	0.79	460.8	0.958	358.9	0.95	454.4	450	481.0	500	\$0.0391	\$0.0441	0.995	0.436	\$89,779	\$84.98
Boost 1	2200	86	0.8	138.0	0.940	109.5	0.95	138.6	142	146.8	150	\$0.0391	\$0.0441	0.945	0.811	\$36,159	\$36.08
Boost 2	2200	86	0.8	138.0	0.940	109.5	0.95	138.6	142	146.8	150	\$0.0391	\$0.0441	0.484	0.057	\$9,378	\$34.34
Boost 3	2200	86	0.8	138.0	0.940	109.5	0.95	138.6	141	146.8	150	\$0.0391	\$0.0441	0.449	0.373	\$16,870	\$36.04
Boost 4	2200	86	0.8	138.0	0.940	109.5	0.95	138.6	142	146.8	150	\$0.0391	\$0.0441	0.675	0.481	\$23,319	\$35.88
Boost 5	2200	86	0.8	138.0	0.940	109.5	0.95	138.6	132	146.8	150	\$0.0391	\$0.0441	0.000	0.000	\$0	#DIV/0!
													Calculated Pump Cost/yr			\$334,979	
													Demand Cost/yr			\$117,874	
													Demand + Calc. Pump Cost/yr			\$452,853	
													CPU Bill for 2003			\$470,069	

Bad Pumps Can Be Placed Into Two Categories

- No longer behaving as designed
- Behaving as designed, but are used inappropriately

Well Example





CLARK-WALKER CO.
PAT'S PEND





$$\text{BrakeHorsePower}(BHP) = \frac{(Flow)(TDH)}{(PumpEfficiency)(1714)} = \frac{(500\text{ gpm})(216\text{ psi})}{(0.78)(1714)} = 80\text{ hp}$$

Control Valve Cost

Example 1:

$$\$ / yr = \frac{(Flow)(ValveHeadloss)(ElectCost)(Use\%)}{(PumpEfficiency)(MotorEfficiency)} = \frac{(500\text{ gpm})(40\text{ ft})(\$0.04 / kWh)(0.50)}{(0.78)(0.92)} = \$557 / yr$$

Example 2:

$$\$ / yr = \frac{(Flow)(ValveHeadloss)(ElectCost)(Use\%)}{(PumpEfficiency)(MotorEfficiency)} = \frac{(2500\text{ gpm})(65\text{ ft})(\$0.04 / kWh)(0.50)}{(0.70)(0.96)} = \$4800 / yr$$

Contact Electrical Utility

- Request past bills
 - Compare bills to calculated values
- Determine what billing schedule you are on
 - Use rates to evaluate your energy cost
 - Do they have peak time rates that can be avoided
 - Demand charges

Demand Charges

- Pay utility to size system large enough for generation, transmission and distribution
- Calculate cost based on max 30 minute average kW usage for month
- 95% of monthly bill (\$2,500)

Operations Cost Table

Height High	Cost/MG
WS 8 → HH	\$51.50
WS 14 → HH	\$54.10
WS 9 → HH	\$56.00
WS 15 → HH	\$60.50
WS 7-1 → HH	\$71.13
WS 7-2 → HH	\$96.51
WS 1 → St John's → HH	\$98.89
WS 1 → WS 5 → HH	\$103.69
WS 1 → 49th → HH	\$104.81
WS 4 → WS 5 → HH	\$109.19
WS 1 → WS 5 → Ells → HH	\$116.81
WS 4 → Ells → HH	\$122.31
Ells → WS 5 → HH	\$122.46
Ellsworth → HH	\$131.20

$$\text{BrakeHorsePower(BHP)} = \frac{(Flow)(TDH)}{(PumpEfficiency)(1714)} = \frac{(500\text{gpm})(216\text{psi})}{(0.78)(1714)} = 80\text{hp}$$

What City of Vancouver Done

- Installed VFD at booster station
- Found open valves
- Budgeted smaller pump installation at one booster
- Budgeted for VFD installation at large booster station
- Replace four old motors with high efficiency
- Installed soft starts to decrease demand
- Reduced pump starts to decrease demand charges
- Replace oversized pumps when rebuild required

$$\text{BrakeHorsePower(BHP)} = \frac{(\text{Flow})(\text{TDH})}{(\text{PumpEfficiency})(1714)} = \frac{(500\text{gpm})(216\text{psi})}{(0.78)(1714)} = 80\text{hp}$$

Savings

- VFD install saved \$9,000/yr
- Reduced pump starts saved \$18,000/yr
- High efficiency motor installs \$4,600/yr for 4 motors
- Future pump replacements \$9,000/yr
- Future VFD install save \$12,500/yr

$$\text{BrakeHorsePower(BHP)} = \frac{(\text{Flow})(\text{TDH})}{(\text{PumpEfficiency})(1714)} = \frac{(500\text{gpm})(216\text{psi})}{(0.78)(1714)} = 80\text{hp}$$

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