Right-sizing Pumps for Energy Efficiency - *The 141st Ave Pump Station*

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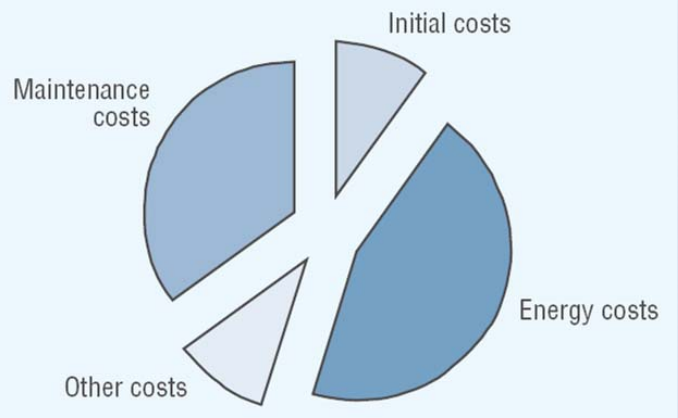
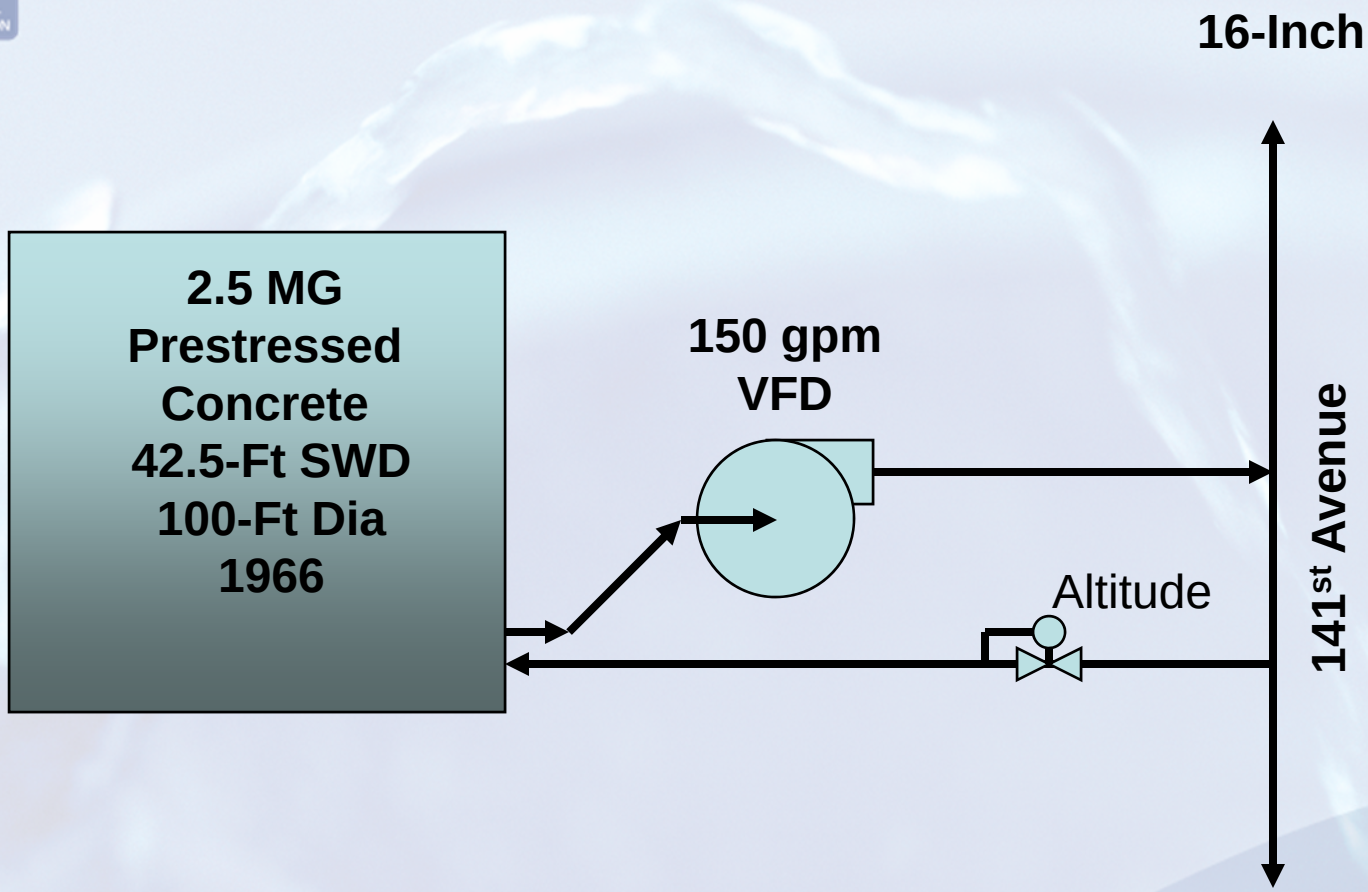
Agenda

- The project
- Pumping
- Pumping efficiency
- Maintain for efficiency



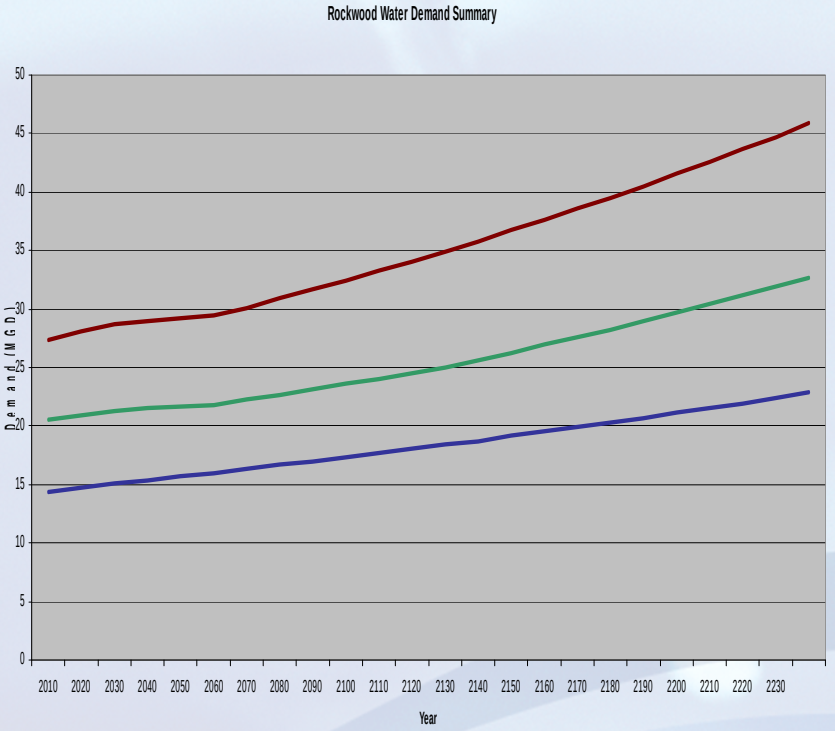
Efficiency doesn't increase after purchase

Existing system

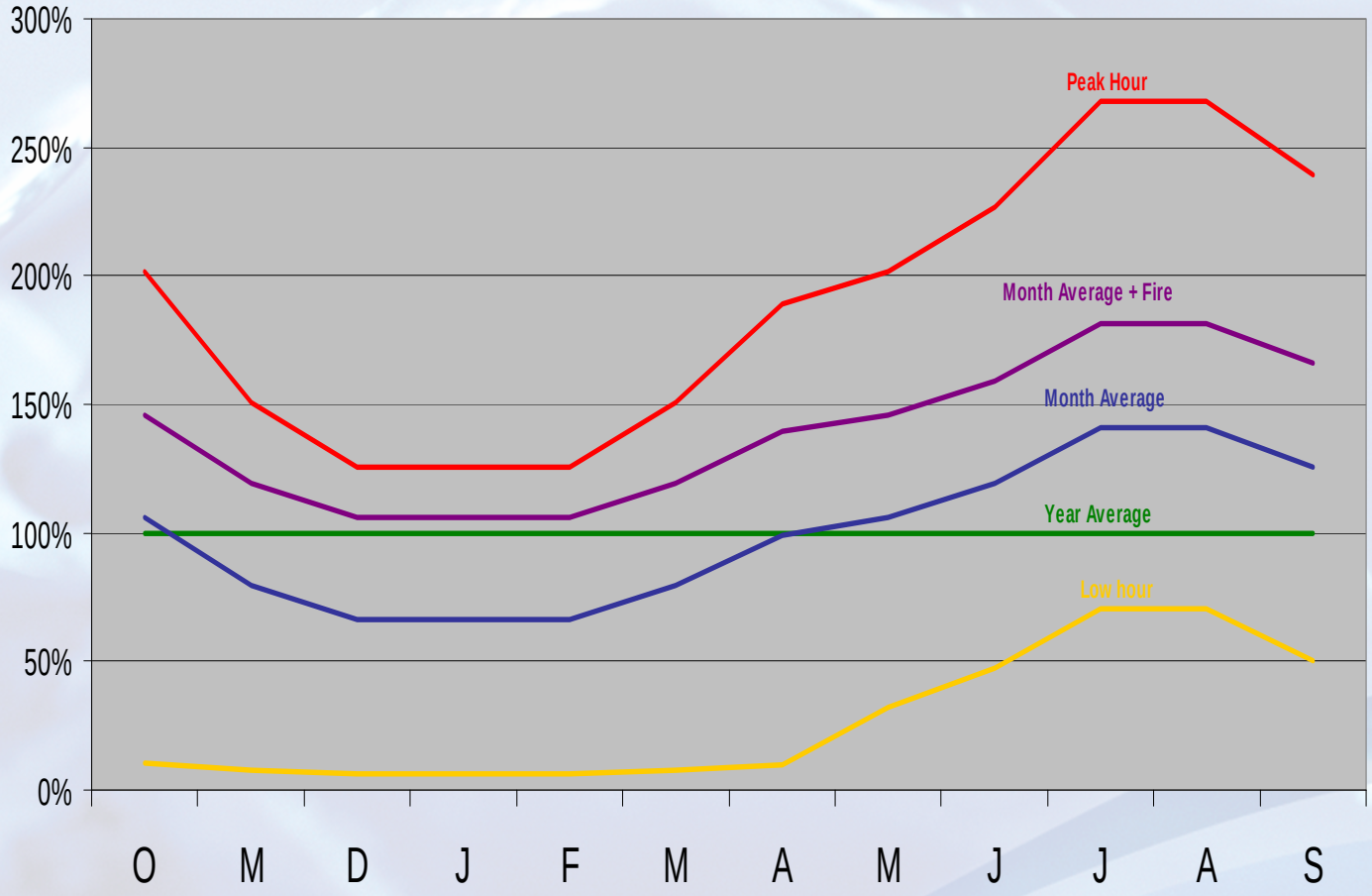


141st pump station

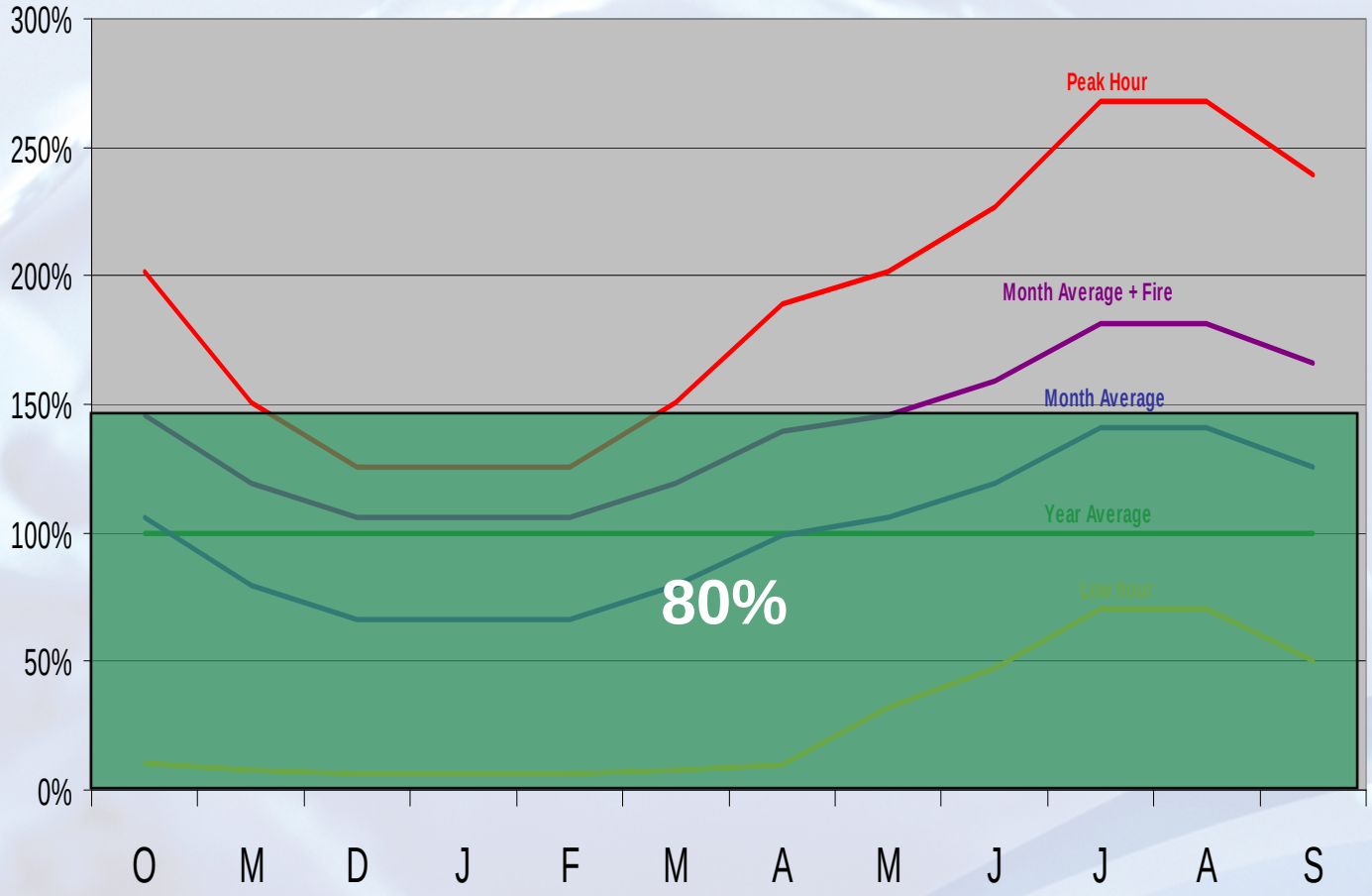
- **Planned - 9,600 gpm at 150 ft TDH**
- **Existing - 150 gpm**



“Typical” duty cycle



% of pumping


300%
250%
200%
150%
100%
50%
0%
Peak Hour
Month Average + Fire
Month Average
Year Average
Low hour
80%
O
M
D
J
F
M
A
M
J
J
A
S

Energy conversion

Power

Prime mover

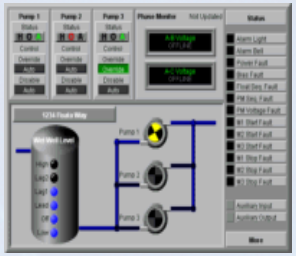
VFD

Pump

Piping & control valves

System

SCADA

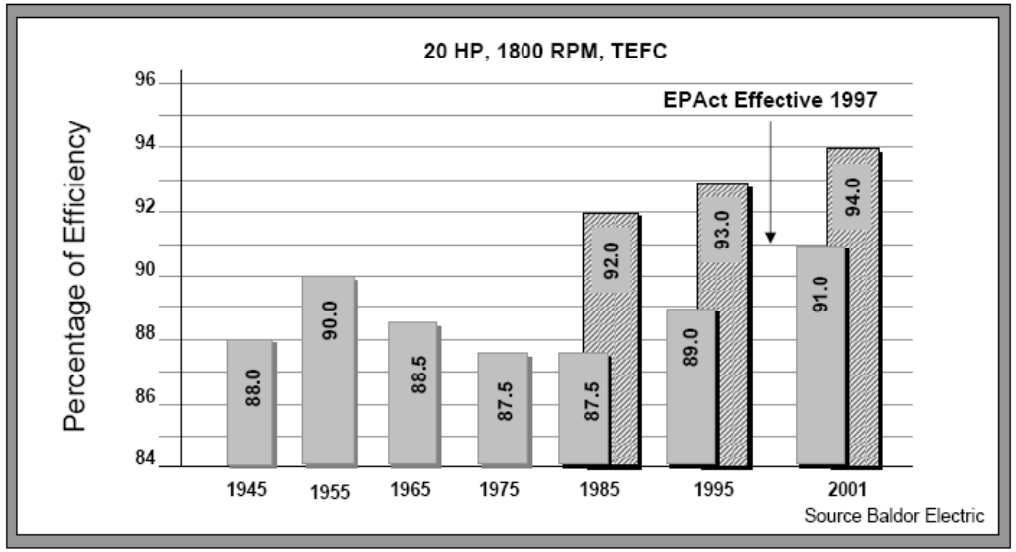


Wire to water

- Hydraulic power/input power
  - **Case 1**
    - **94% motor * 89% pump = 84%**
  - **Case 2**
    - **97% VFD * 94% motor * 89% pump = 81%**
  - **Case 3**
    - **97% VFD * 94% motor * 80% pump = % Total 73%**
  - **Case 4**
    - **88% motor * 80% pump = 70%**
  - **Case 5**
    - **88% motor * 50%* pump = 44%**

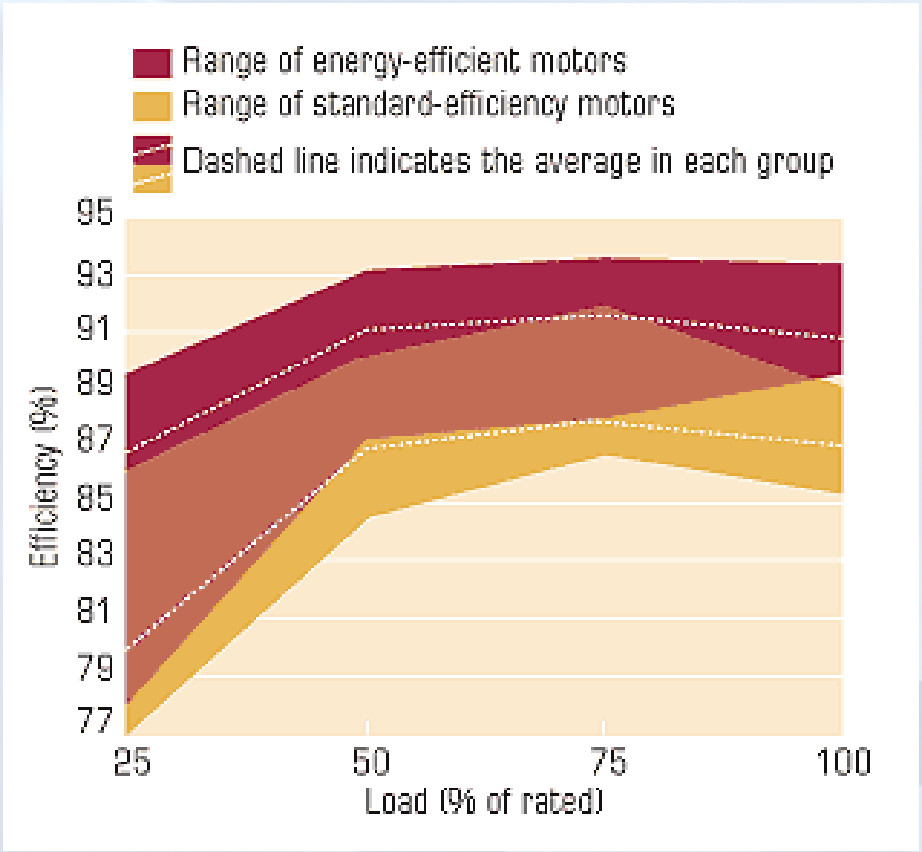
Premium motors

- **Application**
  - 50% duty
  - $0.06/kWh
- **Pre-EPAct**
  - 88% efficiency
  - 100 hp electrical power
    - $22,200/ year
    - $444,400/20 years
- **Premium efficiency**
  - 95.4% efficiency
  - 1-- hp electrical power
    - $20,500/year
    - $410,000/20 years

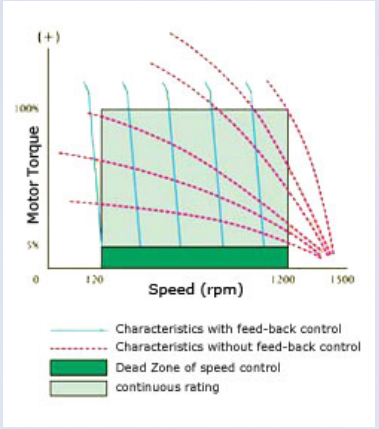


Motor efficiency vs size & load

Enclosure	Speed	Horse Power	Volt	Old NEMA	NEMA EPACT	IEEE 841	NEMA Premium
TEFC	1800	1	460	80.0	82.5	84.0	85.5
TEFC	1800	1.5	460	81.5	84.0	85.5	86.5
TEFC	1800	2	460	82.5	84.0	85.5	86.5
TEFC	1800	3	460	84.0	87.5	88.5	89.5
TEFC	1800	5	460	85.5	87.5	88.5	89.5
TEFC	1800	7.5	460	87.5	89.5	90.2	91.7
TEFC	1800	10	460	87.5	89.5	90.2	91.7
TEFC	1800	15	460	88.5	91.0	91.7	92.4
TEFC	1800	20	460	90.2	91.0	91.7	93.0
TEFC	1800	25	460	91.0	92.4	93.0	93.6
TEFC	1800	30	460	91.0	92.4	93.0	93.6
TEFC	1800	40	460	91.7	93.0	93.6	94.1
TEFC	1800	50	460	92.4	93.0	93.6	94.5
TEFC	1800	60	460	93.0	93.6	94.1	95.0
TEFC	1800	75	460	93.0	94.1	94.5	95.4
TEFC	1800	100	460	93.6	94.5	95.0	95.4
TEFC	1800	125	460	93.6	94.5	95.0	95.4
TEFC	1800	150	460	94.1	95.0	95.4	95.8
TEFC	1800	200	460	94.5	95.0	95.4	96.2
TEFC	1800	250	460		95.0	95.0	96.2
TEFC	1800	300	460		95.4	95.4	96.2
TEFC	1800	350	460		95.4	95.4	96.2
TEFC	1800	400	460		95.4	95.4	96.2
TEFC	1800	450	460		95.4	95.4	96.2
TEFC	1800	500	460		95.8	95.4	96.2



Variable speed drives

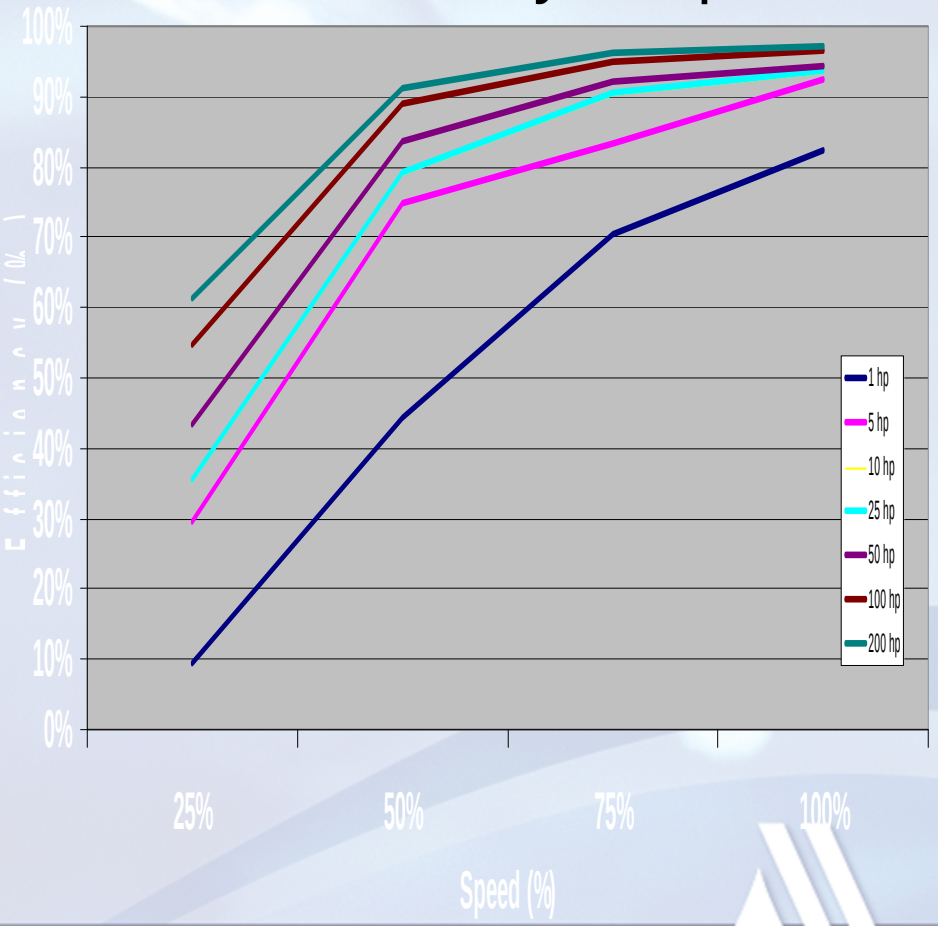


VFD losses

VFD efficiency vs load

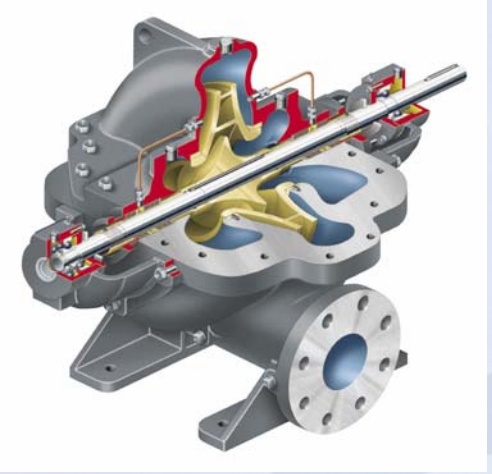
Table 1. PWM ASD Efficiency as a Function of Drive Power Rating[1]							
Variable Speed Drive hp Rating	Efficiency,%						
	Load, Percent of Drive Rated Power Output						
	1.6	12.5	25	42	50	75	100
3	31	77	86	90	91	93	94
5	35	80	88	91	92	94	95
10	41	83	90	93	94	95	96
20	47	86	93	94	95	96	97
30	50	88	93	95	95	96	97
50	46	86	92	95	95	96	97
60	51	87	92	95	95	96	97
75	47	86	93	95	96	97	97
100	55	89	94	95	96	97	97
200	61	91	95	96	96	97	97
400	61	91	95	96	96	97	97

VFD efficiency vs speed

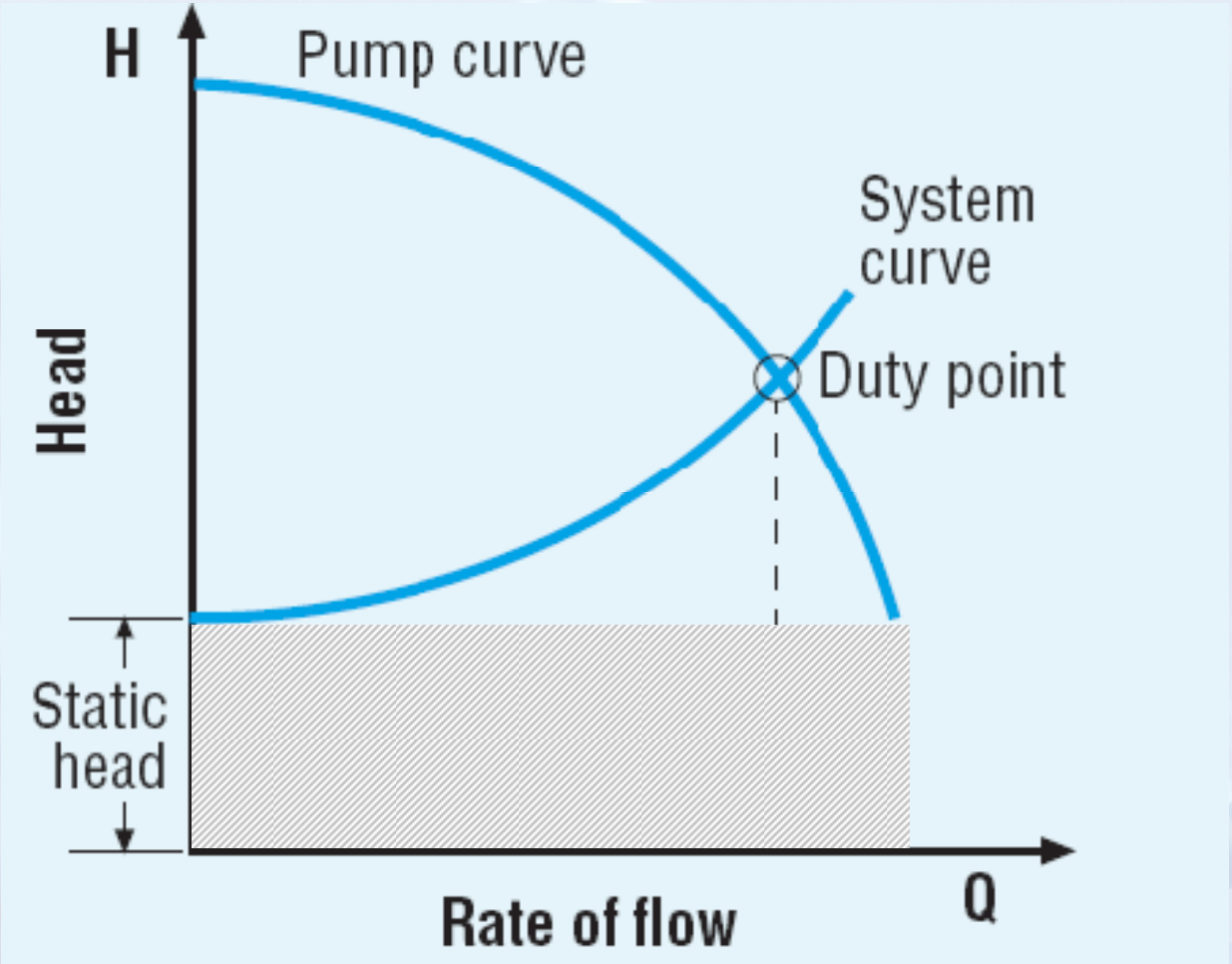


Pumps

- **Most selected for maximum, future demand**
- **But, multiple operating points**

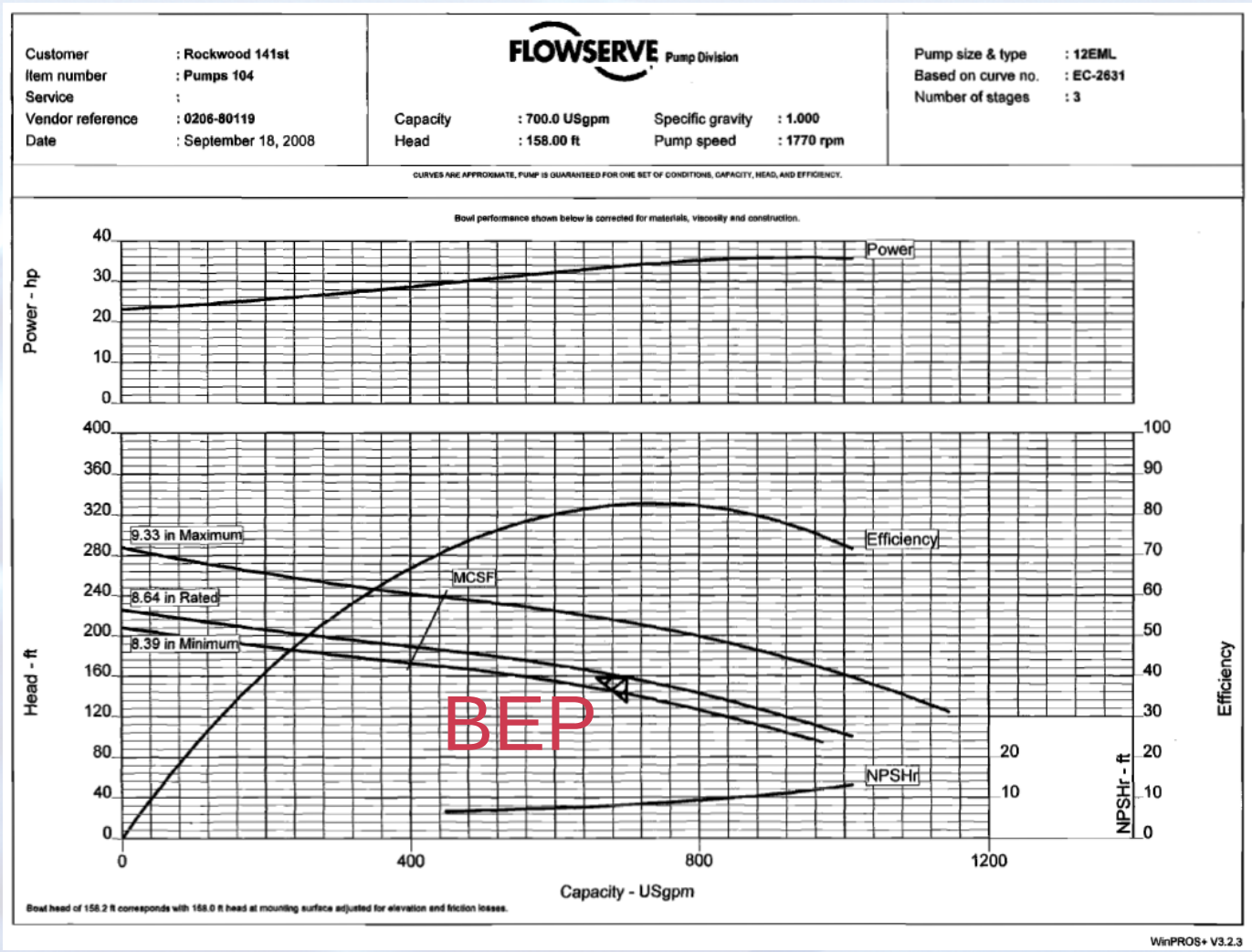


Pump and system curves

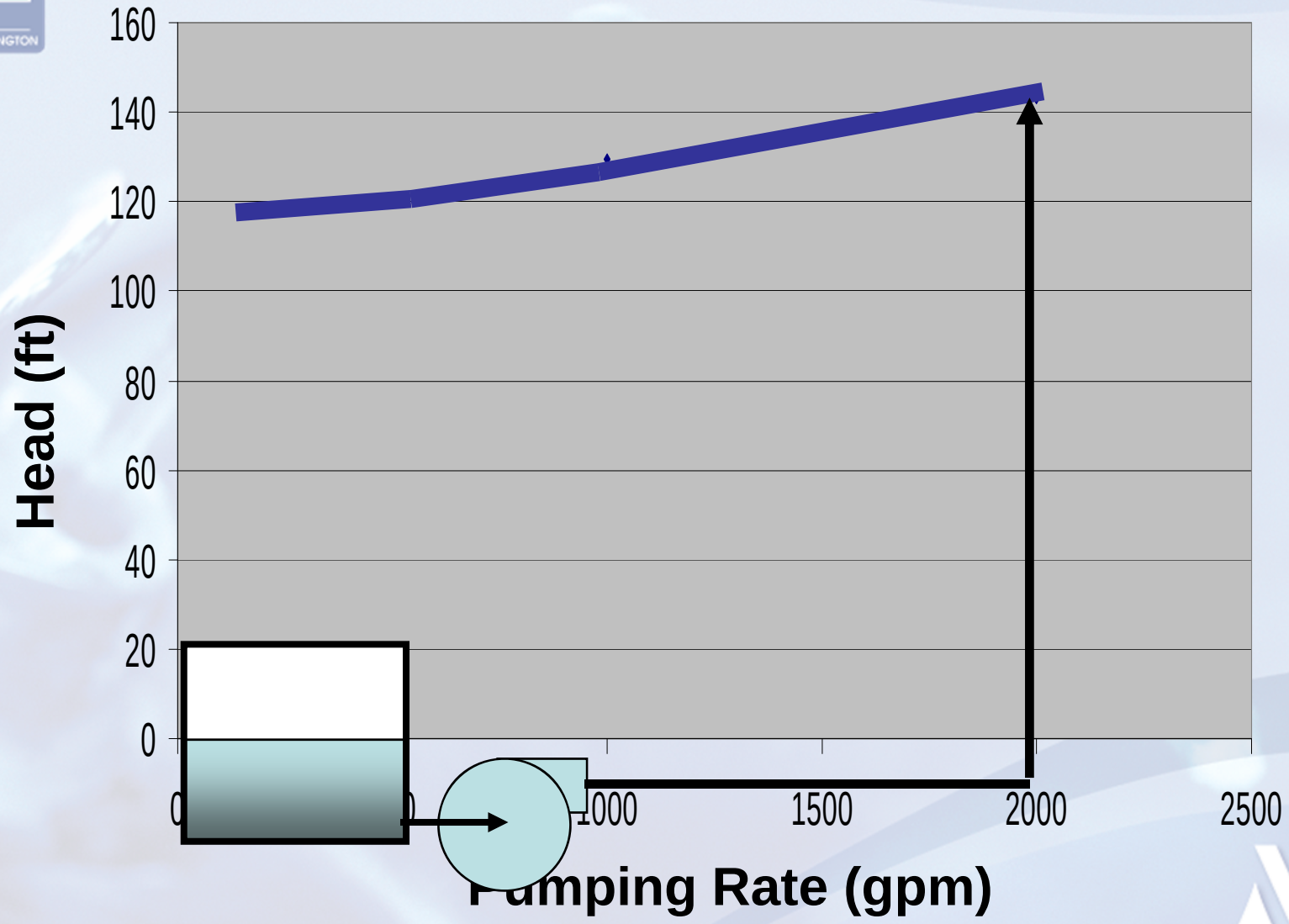


Source: Hydraulic Institute I Pump Life Cycle Costs

700 gpm pump curve



141st Ave system curve



The affinity police

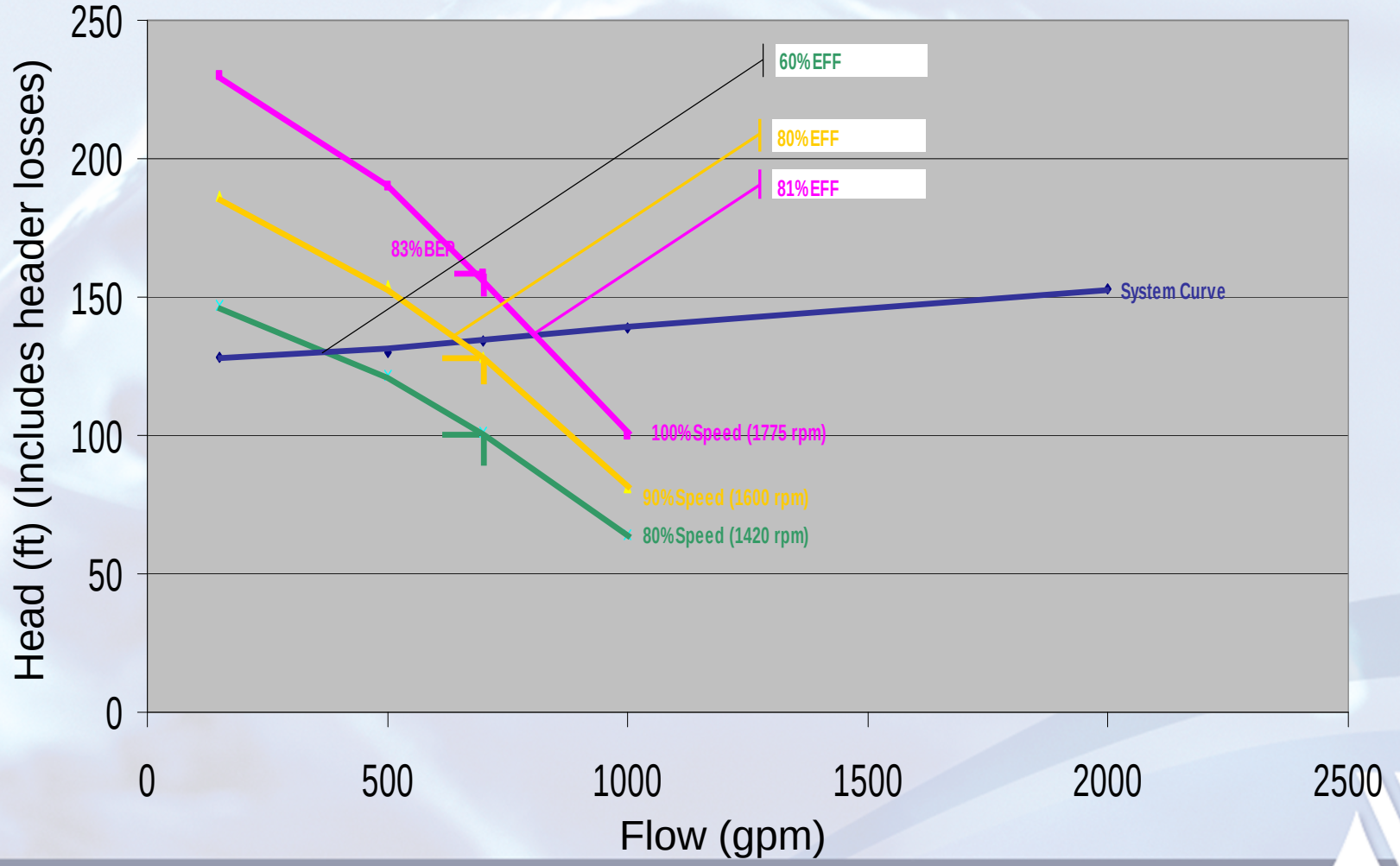
- For centrifugal pumps with no static lift
- $Q_{Speed\ 2} = Q_{Speed\ 1} * (Speed\ 1/Speed\ 2)$
- $H_{Speed\ 2} = H_{Speed\ 1} * (Speed\ 1/Speed\ 2)^{\wedge 2}$

Formulas for Refiguring Pump Performance with Impeller Diameter or Speed Change

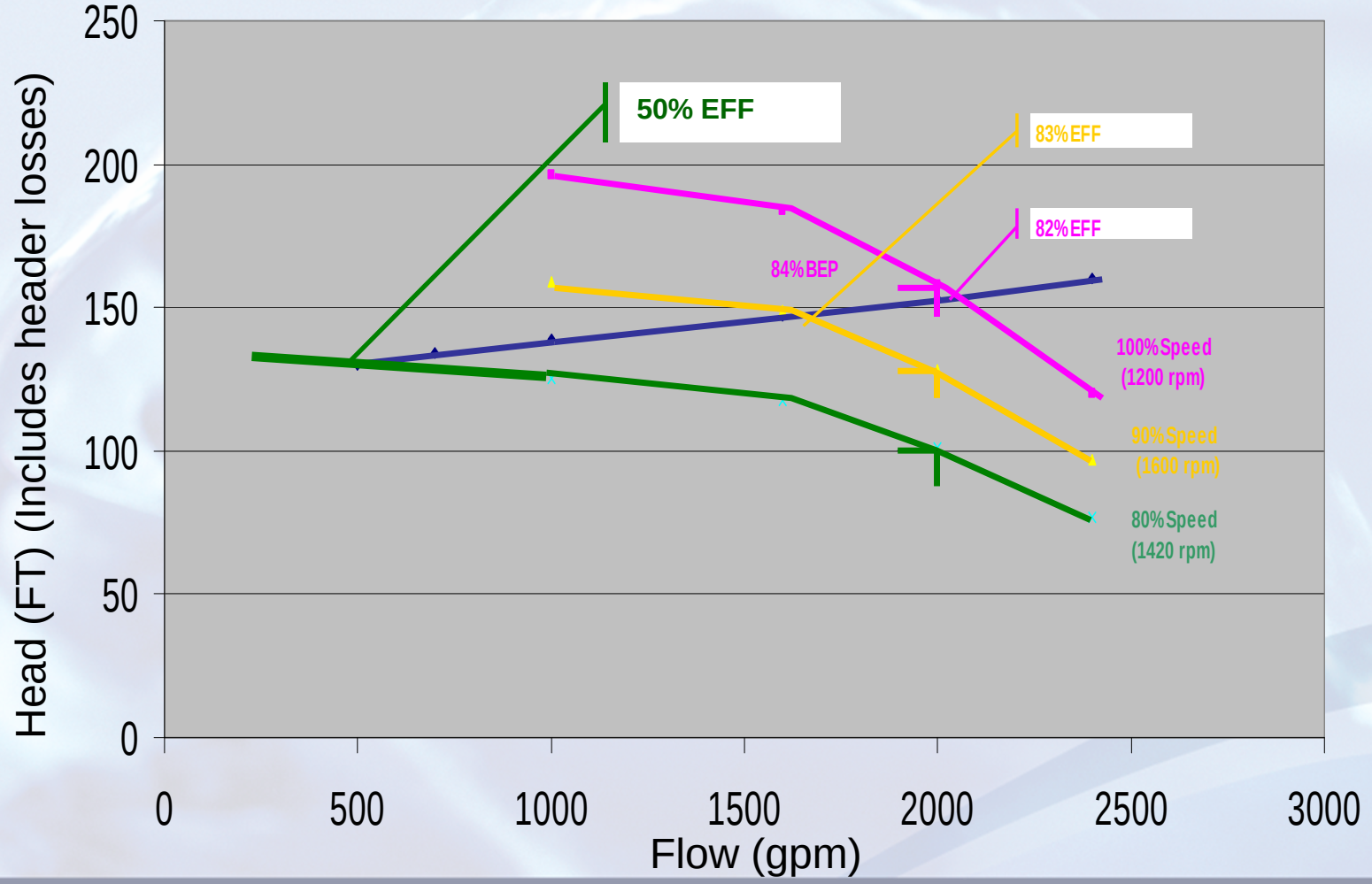
Diameter Change Only	Speed Change Only	Diameter and Speed Change
$Q_2 = Q_1\left(\frac{D_2}{D_1}\right)$	$Q_2 = Q_1\left(\frac{N_2}{N_1}\right)$	$Q_2 = Q_1\left(\frac{D_2}{D_1} \times \frac{N_2}{N_1}\right)$
$H_2 = H_1\left(\frac{D_2}{D_1}\right)^2$	$H_2 = H_1\left(\frac{N_2}{N_1}\right)^2$	$H_2 = H_1\left(\frac{D_2}{D_1} \times \frac{N_2}{N_1}\right)^2$
$bhp_2 = bhp_1\left(\frac{D_2}{D_1}\right)^3$	$bhp_2 = bhp_1\left(\frac{N_2}{N_1}\right)^3$	$bhp_2 = bhp_1\left(\frac{D_2}{D_1} \times \frac{N_2}{N_1}\right)^3$

Q_1, H_1, bhp_1, D_1, and N_1 = Initial capacity, head, brake horsepower, diameter, and speed.
Q_2, H_2, bhp_2, D_2, and N_2 = New capacity, head, brake horsepower, diameter, and speed.

700 gpm pump and system curves

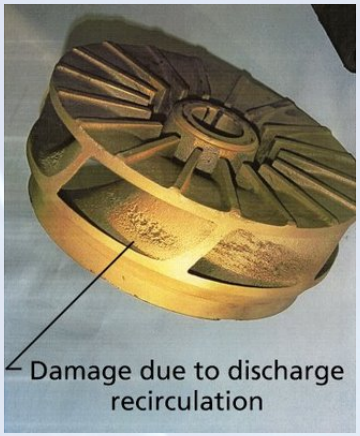


2000 gpm pump and system curves



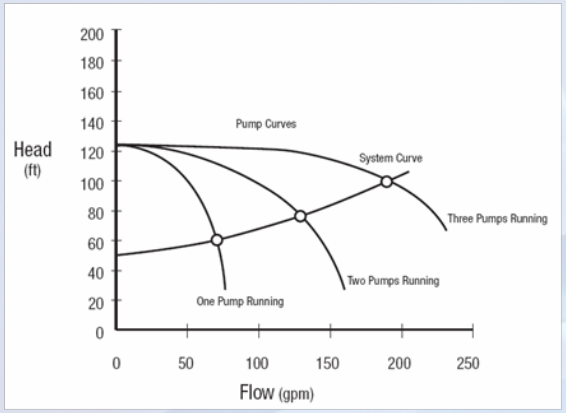
Pump inefficiency

- **Energy available to damage pump**
- **Types**
  - Cavitation
  - Recirculation
  - Mechanical – Bearings and seals
  - Wear ring clearances
  - Heat
  - Noise
  - Vibration
  - Poor flow control – Drooping curves
  - MTBF
  - Leakage
  - Shaft deflection
  - Anchorage



Check capacity range

- **ASD**
  - Good for friction losses
  - Evaluate for high static heads
- **Multiple pumps - Good for high static heads**
- **Pony pumps**
- **Trim impeller**

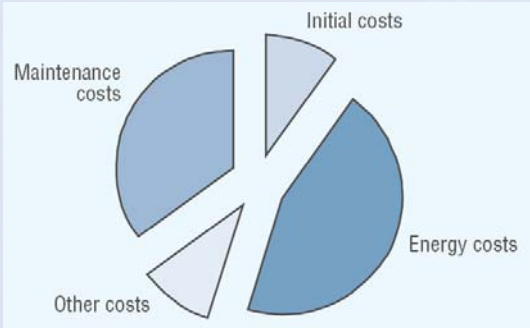


Selecting pumps

- **Understand service requirements**
  - Flow and pressure: Peak, average, low
- **Match to Best Efficiency Point**
- **Complicated**
- **Tendency to oversize**
  - Uncertainties, fouling, future capacity increases, avoiding blame
- **Symptoms of oversizing**
  - Noise
  - Throttled valves
  - Bypass lines
  - Bearing replacement
  - Pump cycling

141st Avenue

- **9,600 gpm; 4,000 gpm; 3,300 gpm**
- **Five VLT pumps, oversize pedestals and piping**
- **Smaller initial capacities**
  - 2 - 150 gpm @ 126 ft
  - 1 - 300 gpm @ 158 feet
  - 1 - 700 gpm @ 158 feet
  - 1 - 2,000 gpm @ 158 feet
- **Future replacement**
  - 3 - 700 gpm @ 158 feet
  - 2 - 2,000 gpm @ 158 feet



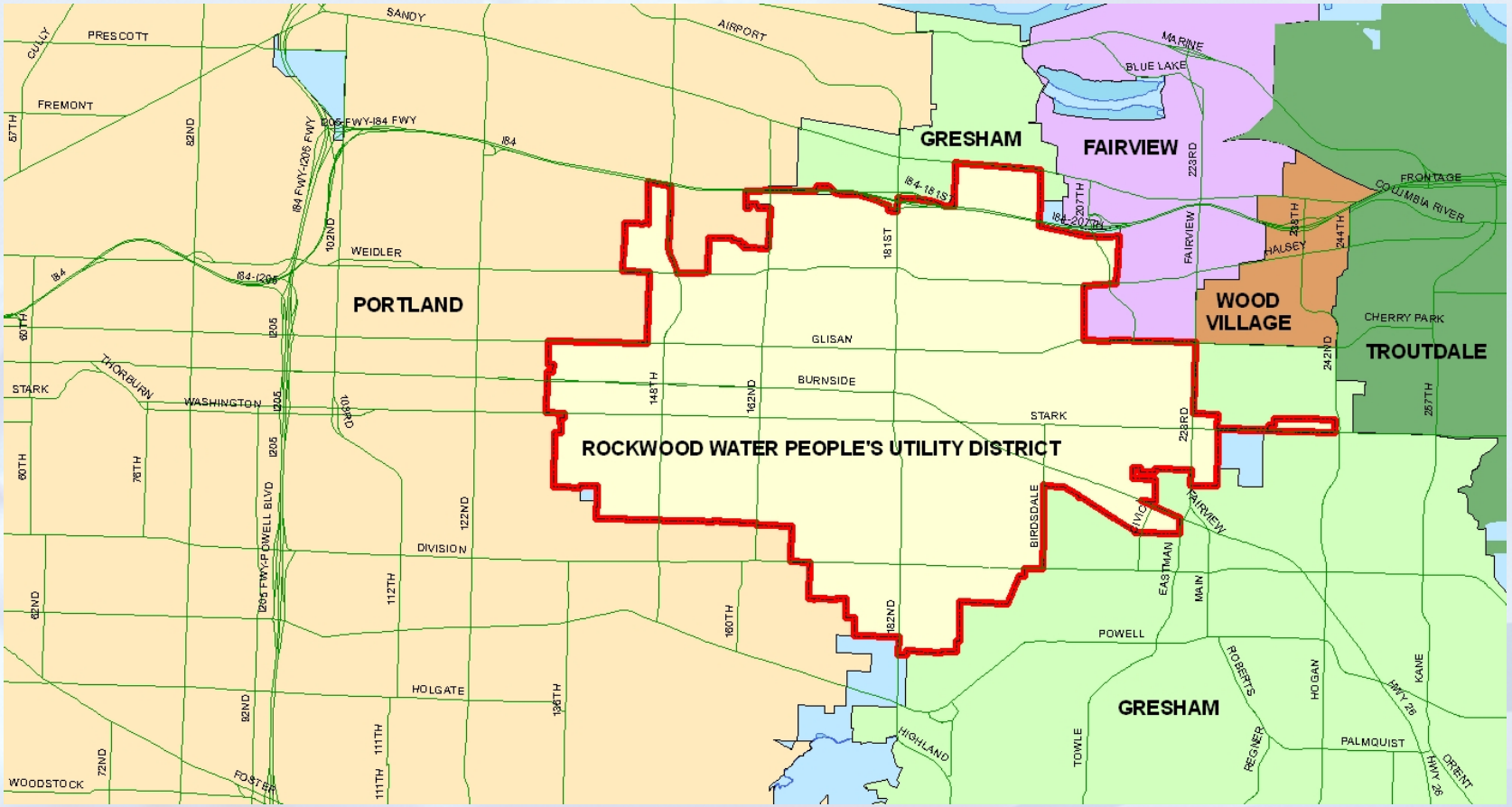
O&M for pump efficiency

- ***Maintenance and repair is a significant component of pumping system life cycle costs and an effective maintenance program can minimize these costs.***

Rockwood Water PUD

- Rockwood Water District - 1925
- Rockwood Water People's Utility District - 1990
- 10 square miles in Portland, Gresham and Fairview
- 140 miles of waterline
- 2 groundwater wells (a third is under construction)
- Surface water from the Bull Run Watershed, purchased from Portland
- Four reservoirs, combined storage of 21 MG
- 53,000 customers, 12,600 meters

RWPUD service area

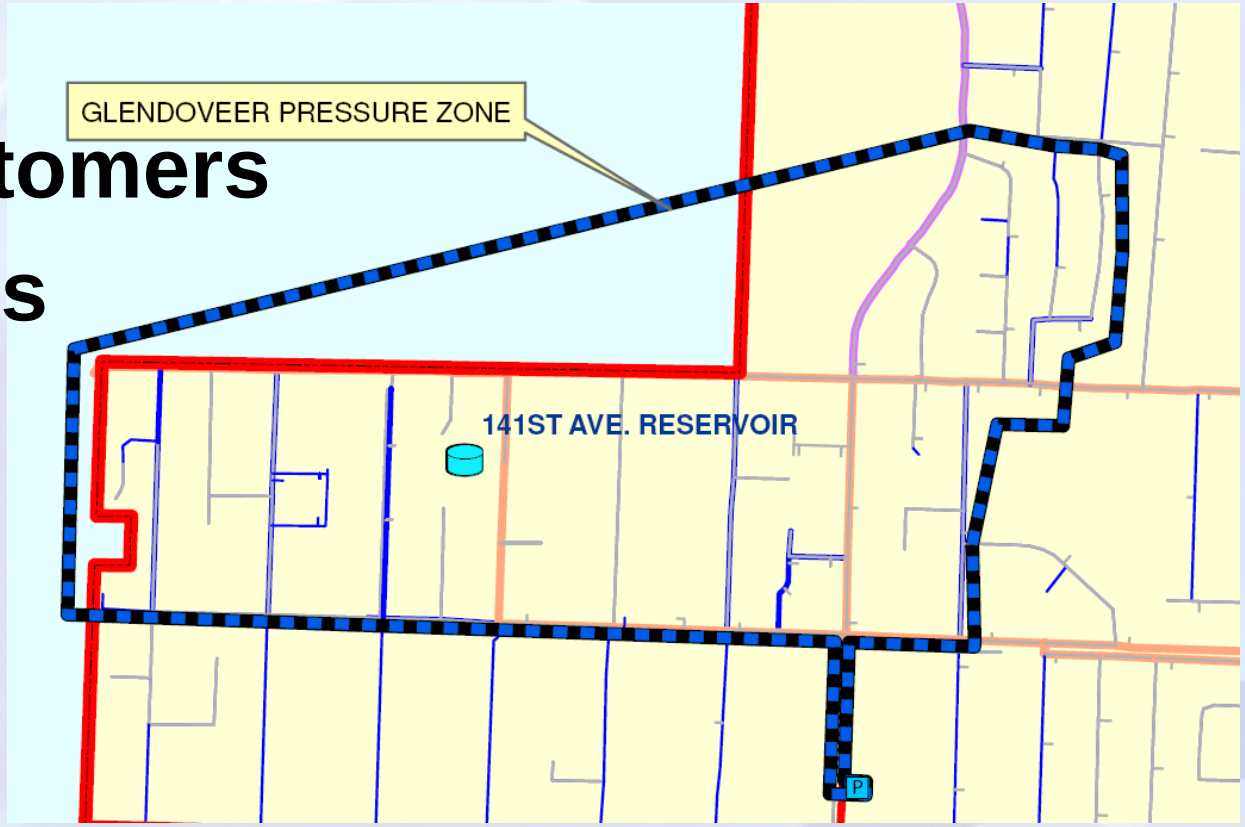


Memory loss

- **Baker & Lindsey**

Glendoveer pressure zone

- 215 acres
- 3,500 customers
- 700 meters



141st Avenue Pump Station

Original Pump Station

Time for a remodel

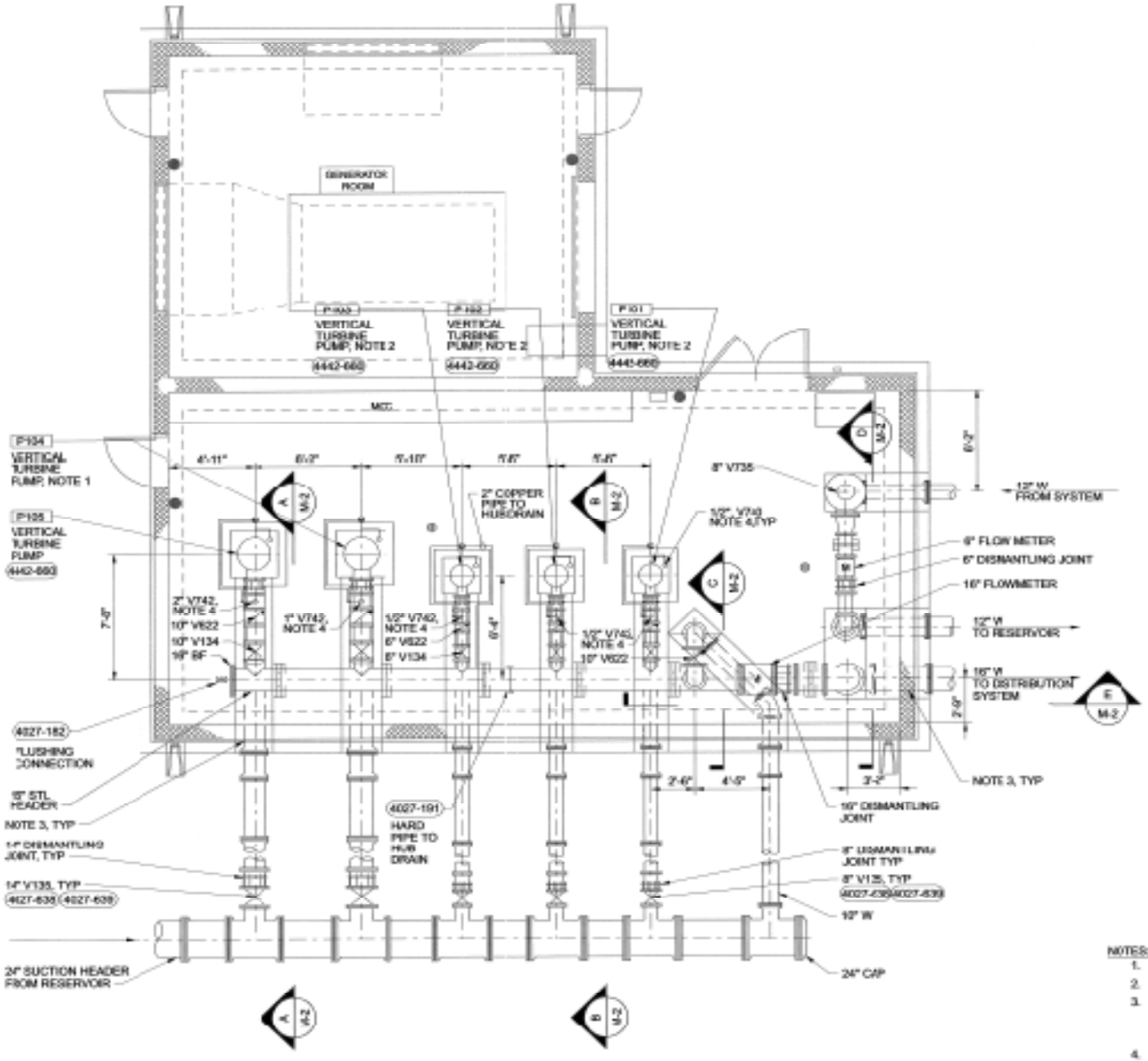
Day 1 of the remodel

Operating & maintaining for efficiency

- **Components**
  - Prime Mover
  - VFD
  - Pump
  - Control Valves
  - I & C
  - Emergency Power

Fishing after work

Under construction



NOTES:

1. SITE OF FUTURE 2000 GPM PUMP.
2. SITE OF FUTURE 700 GPM PUMP.
3. TAPE WRAP FIRST JOINT WITH SYSTEM NO. 7 AS SPECIFIED IN 09 90 00 PAINTING AND PROTECTIVE COATINGS BETWEEN BELL AND 12" INTO THE CONCRETE ENCASEMENT.
4. HARD PIPE AIR RELEASE VALVES TO HUB DRAINS.

FLOOR PLAN

1/4"=1'-0"

N

Prime mover

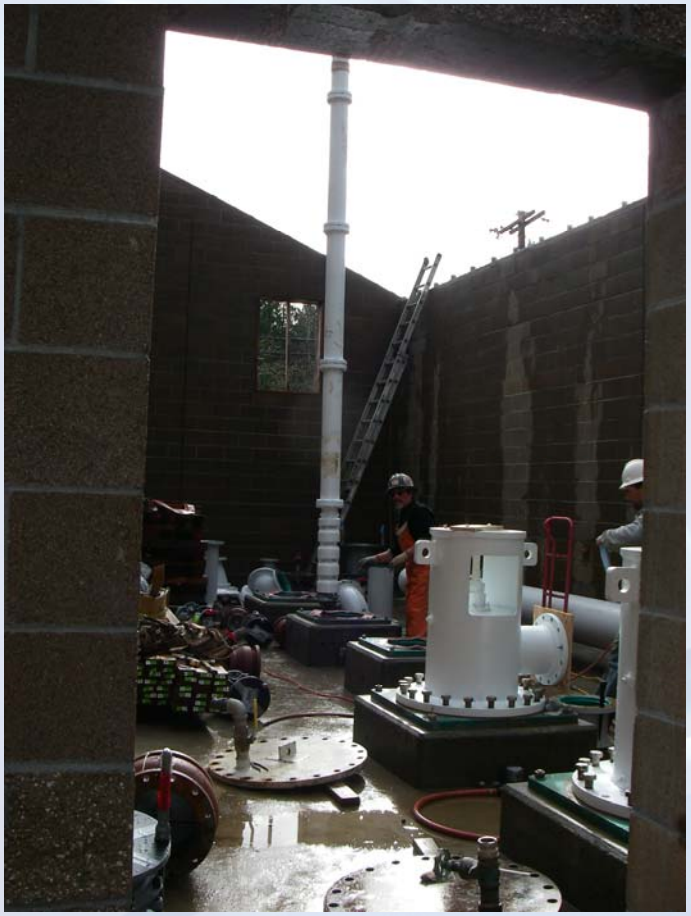
Motor

Adjustable speed drive

- VFD

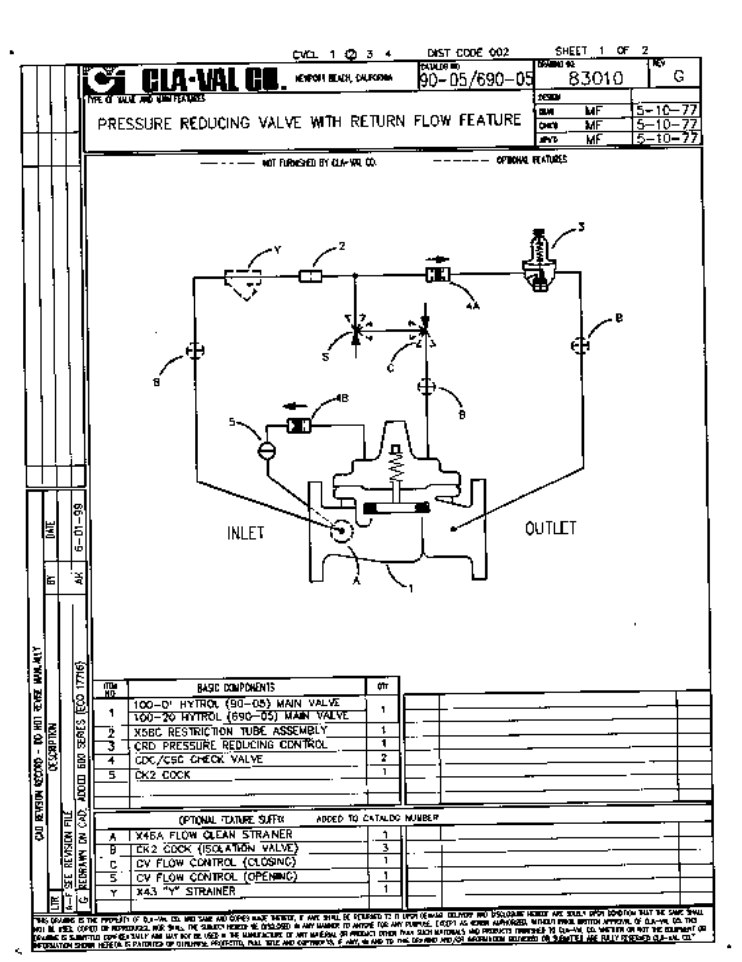
Pumps

One piece install



Control valves

Keeping records



CLA-VAL CO. NEWPORT BEACH, CALIFORNIA

PRESSURE REDUCING VALVE WITH RETURN FLOW FEATURE

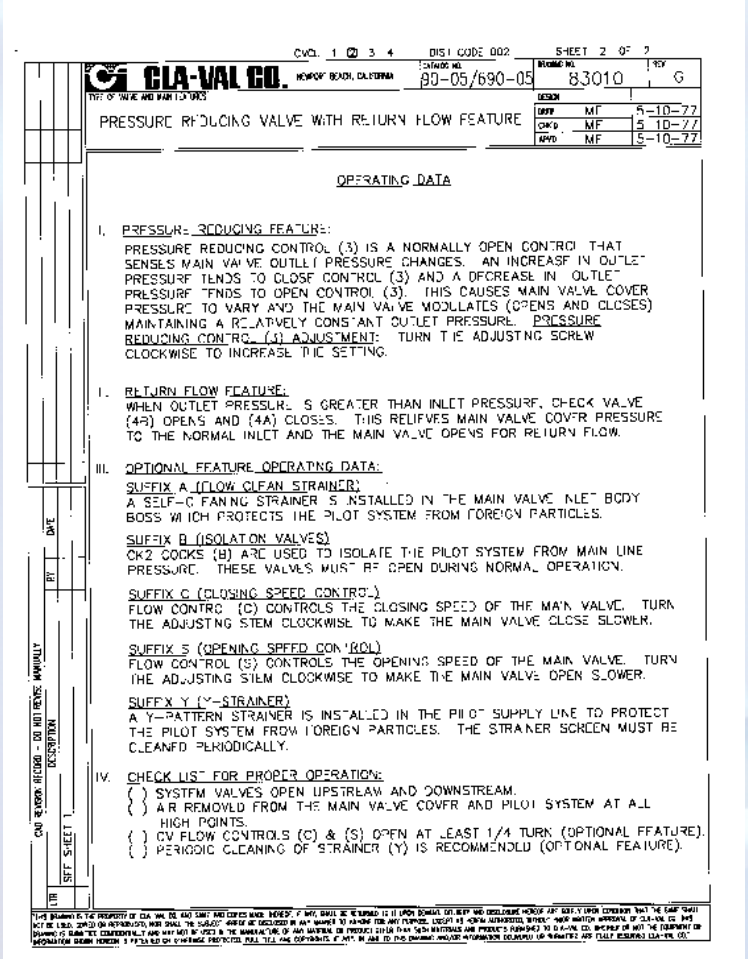
90-05/690-05 | 83010 | G

INLET

OUTLET

ITEM NO	BASIC COMPONENTS	QTY
1	100-01 HYTROL (90-05) MAIN VALVE 100-20 HYTROL (690-05) MAIN VALVE	1
2	X58C RESTRICTION TUBE ASSEMBLY	1
3	CRD PRESSURE REDUCING CONTROL	1
4	CDC/CSC CHECK VALVE	2
5	CK2 COCK	1

OPTIONAL FEATURE SUFFIX	ADDED TO CATALOG NUMBER	
A	X45A FLOW CLEAN STRAINER	1
B	CK2 COCK (ISOLATION VALVE)	3
C	CV FLOW CONTROL (CLOSING)	1
S	CV FLOW CONTROL (OPENING)	1
Y	X43 "Y" STRAINER	1



CLA-VAL CO. NEWPORT BEACH, CALIFORNIA

PRESSURE REDUCING VALVE WITH RETURN FLOW FEATURE

90-05/690-05 | 83010 | G

OPERATING DATA

I. PRESSURE REDUCING FEATURE:
PRESSURE REDUCING CONTROL (3) IS A NORMALLY OPEN CONTROL THAT SENSES MAIN VALVE OUTLET PRESSURE CHANGES. AN INCREASE IN OUTLET PRESSURE TENDS TO CLOSE CONTROL (3) AND A DECREASE IN OUTLET PRESSURE TENDS TO OPEN CONTROL (3). THIS CAUSES MAIN VALVE COVER PRESSURE TO VARY AND THE MAIN VALVE MODULATES (OPENS AND CLOSES) MAINTAINING A RELATIVELY CONSTANT OUTLET PRESSURE. PRESSURE REDUCING CONTROL (3) ADJUSTMENT: TURN THE ADJUSTING SCREW CLOCKWISE TO INCREASE THE SETTING.

II. RETURN FLOW FEATURE:
WHEN OUTLET PRESSURE IS GREATER THAN INLET PRESSURE, CHECK VALVE (4B) OPENS AND (4A) CLOSES. THIS RELIEVES MAIN VALVE COVER PRESSURE TO THE NORMAL INLET AND THE MAIN VALVE OPENS FOR RETURN FLOW.

III. OPTIONAL FEATURE OPERATING DATA:

SUFFIX A (FLOW CLEAN STRAINER)
A SELF-CLEANING STRAINER IS INSTALLED IN THE MAIN VALVE INLET BODY BOSS WHICH PROTECTS THE PILOT SYSTEM FROM FOREIGN PARTICLES.

SUFFIX B (ISOLATION VALVES)
CK2 COCKS (B) ARE USED TO ISOLATE THE PILOT SYSTEM FROM MAIN LINE PRESSURE. THESE VALVES MUST BE OPEN DURING NORMAL OPERATION.

SUFFIX C (CLOSING SPEED CONTROL)
FLOW CONTROL (C) CONTROLS THE CLOSING SPEED OF THE MAIN VALVE. TURN THE ADJUSTING STEM CLOCKWISE TO MAKE THE MAIN VALVE CLOSE SLOWER.

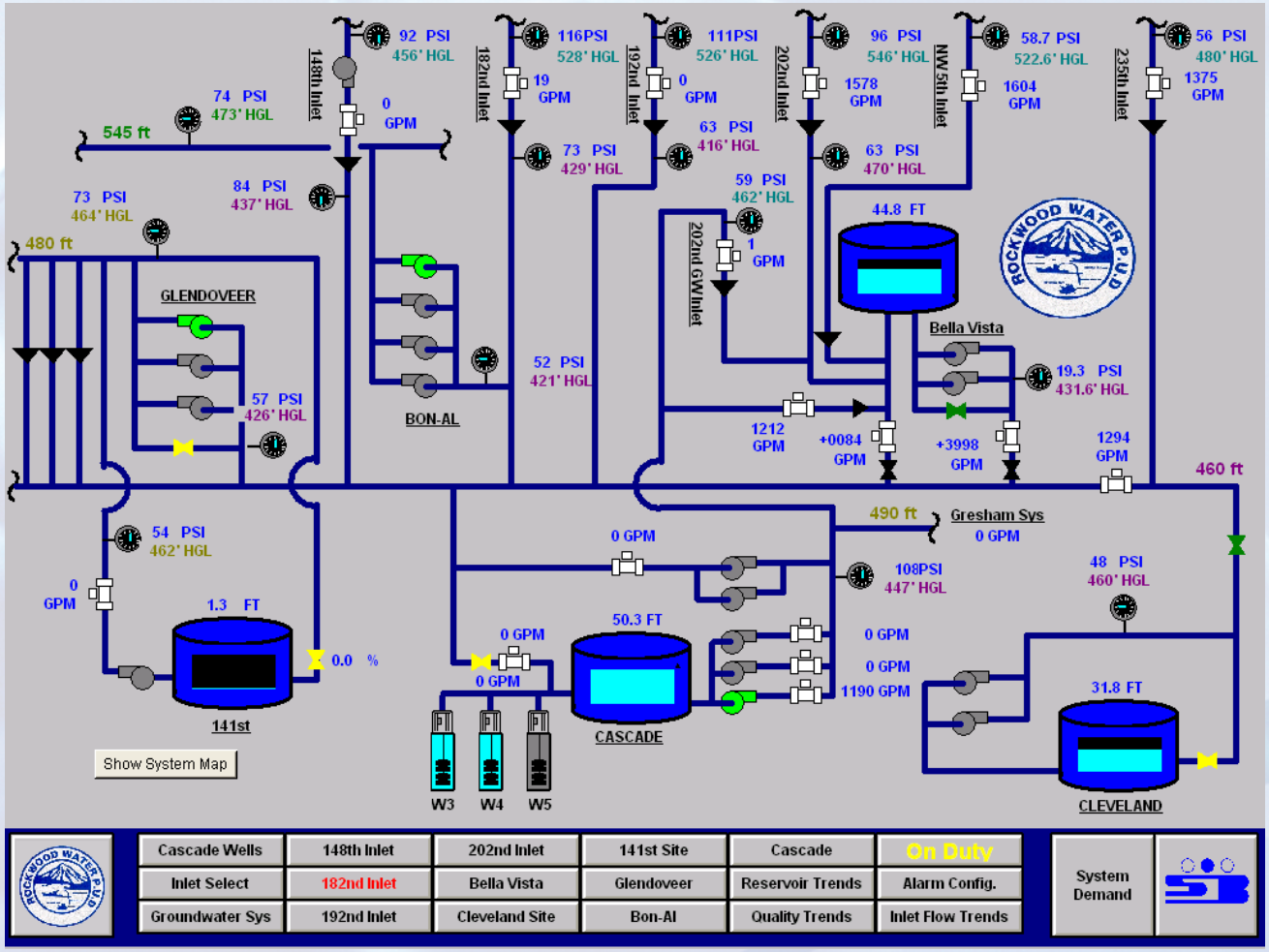
SUFFIX S (OPENING SPEED CONTROL)
FLOW CONTROL (S) CONTROLS THE OPENING SPEED OF THE MAIN VALVE. TURN THE ADJUSTING STEM CLOCKWISE TO MAKE THE MAIN VALVE OPEN SLOWER.

SUFFIX Y (Y-STRAINER)
A Y-PATTERN STRAINER IS INSTALLED IN THE PILOT SUPPLY LINE TO PROTECT THE PILOT SYSTEM FROM FOREIGN PARTICLES. THE STRAINER SCREEN MUST BE CLEANED PERIODICALLY.

IV. CHECK LIST FOR PROPER OPERATION:
( ) SYSTEM VALVES OPEN UPSTREAM AND DOWNSTREAM.
( ) AIR REMOVED FROM THE MAIN VALVE COVER AND PILOT SYSTEM AT ALL HIGH POINTS.
( ) CV FLOW CONTROLS (C) & (S) OPEN AT LEAST 1/4 TURN (OPTIONAL FEATURE).
( ) PERIODIC CLEANING OF STRAINER (Y) IS RECOMMENDED (OPTIONAL FEATURE).

Instrumentation and control

SCADA



Pressure spike!

12” Steel Main Break

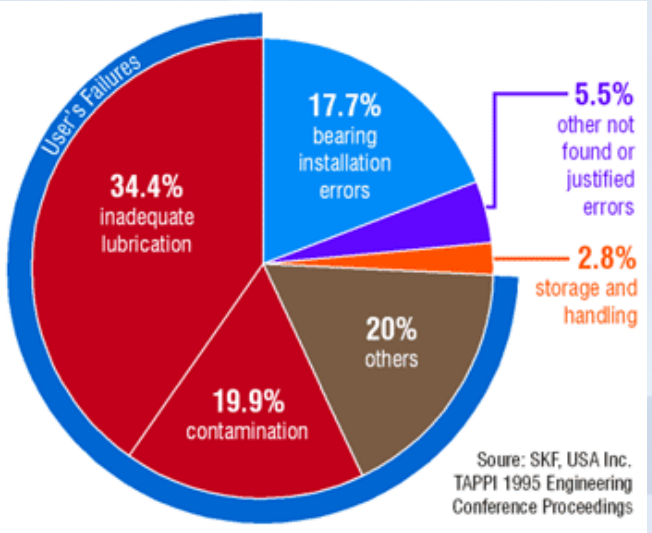
Emergency power
Diesel engine-generator

Last slide!

- **Components of Pump and Motor Maintenance**
  - Prime mover
  - VFD
  - Pump
  - Control valves
  - I & C
  - Emergency power

Bearing failures

- Almost ½ of motor failures
- L10
- Wrong replacement bearings
- Incorrect lubricant
- Excessive lubricant
- Incorrect interval
- Contaminated lubricant
- Excessive vibration
- Misaligned couplings
- Power quality



Summary - Minimize life cycle costs

- Consider all relevant costs
- Buy LCC
- Pump duty points
- Match equipment to system
- Match pump type to intended duty
- Don’t oversize
- Match driver type to duty
- High efficiency motors
- Match power transmission equipment to duty
- Evaluate system effectiveness
- Monitor and sustain the pump and system to maximize benefit
- Consider the energy wasted using control valves
- Utilize auxiliary services wisely
- Optimize preventative maintenance
- Maintain the internal pump clearances
- Follow available guidelines regarding the rewinding of motors
- Analyze existing pump systems for improvement opportunities