

Scattered thoughts on industrial energy assessments (With a focus on pumping systems)

For: BPA Utility Energy Efficiency Workshop

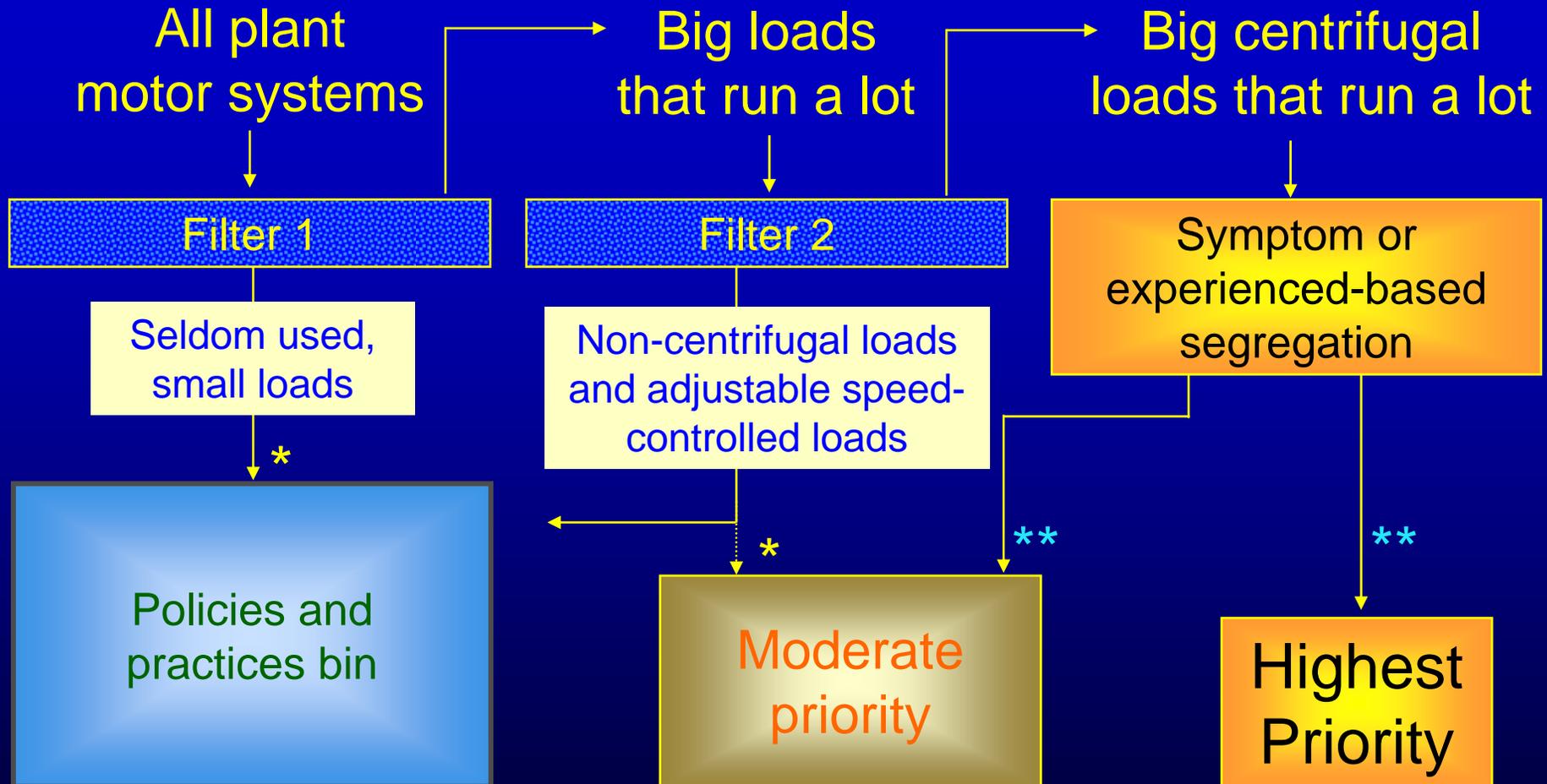
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Subjects sequence

- Prescreening – applying the Pareto Principle
- Non-energy considerations
- Partnering with plant folks
- Measuring – the unappreciated science and art
- Analysis - examples

Prescreening to narrow the field of focus - i.e., to select the VITAL FEW for further review



* Productivity/reliability-critical systems sent to higher priority levels

** Policies & practices also apply to moderate & highest priority applications

Symptoms in pumping systems that indicate potential energy opportunity (and more)

Look for:

- Throttle valve-controlled systems
- Bypass (recirculation) line normally open
- Multiple parallel pump system with same number of pumps always operating
- Constant pump operation in a batch environment or frequent cycle batch operation in a continuous process
- Cavitation noise (at pump or elsewhere in the system)
- High system maintenance

Partnering in multiple domains – you gotta love it



Measuring – it ain't always easy

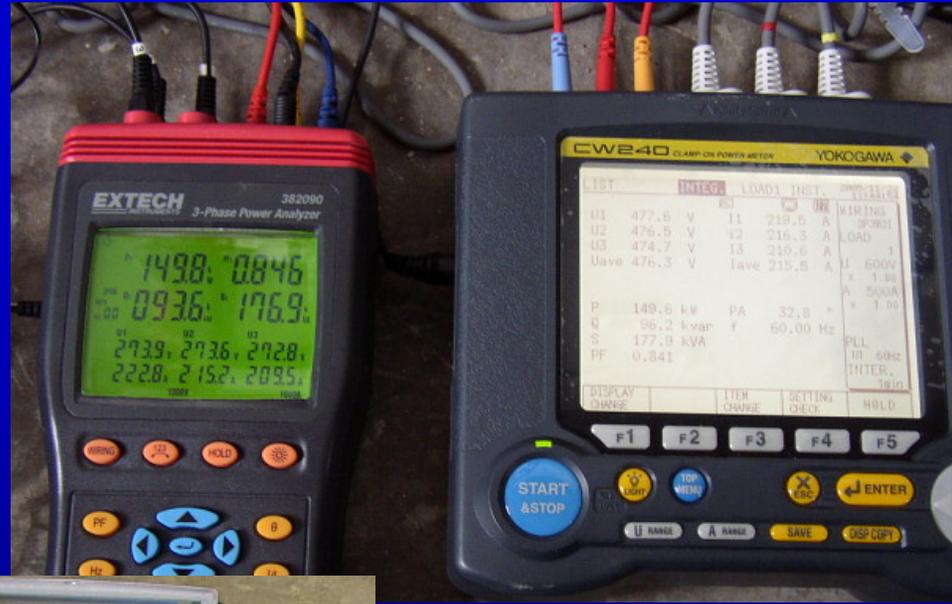


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It ain't always clean

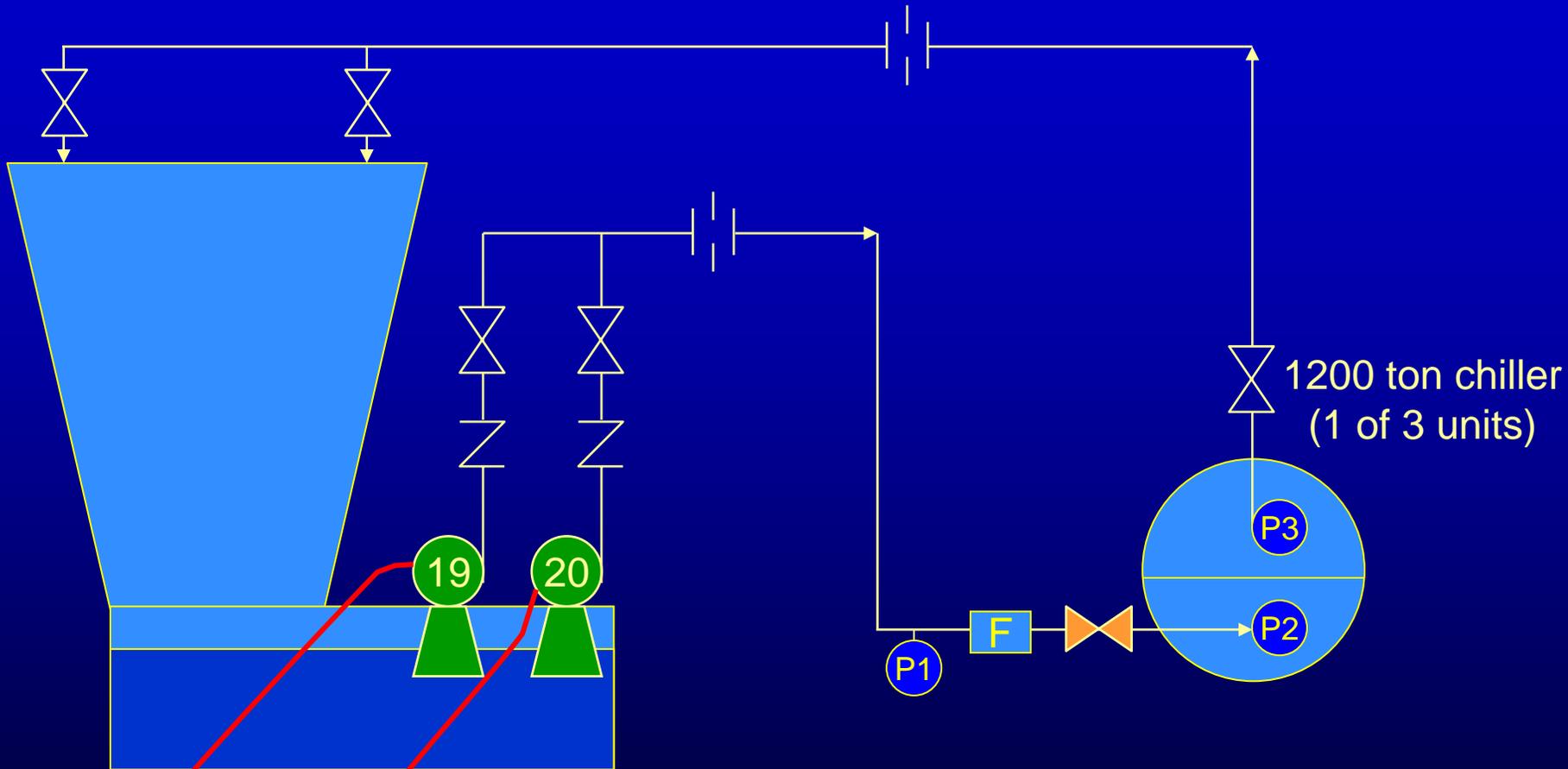


And it definitely ain't cheap (well, maybe on E-bay)



But it is almost always the smart thing to do
in serious industrial settings

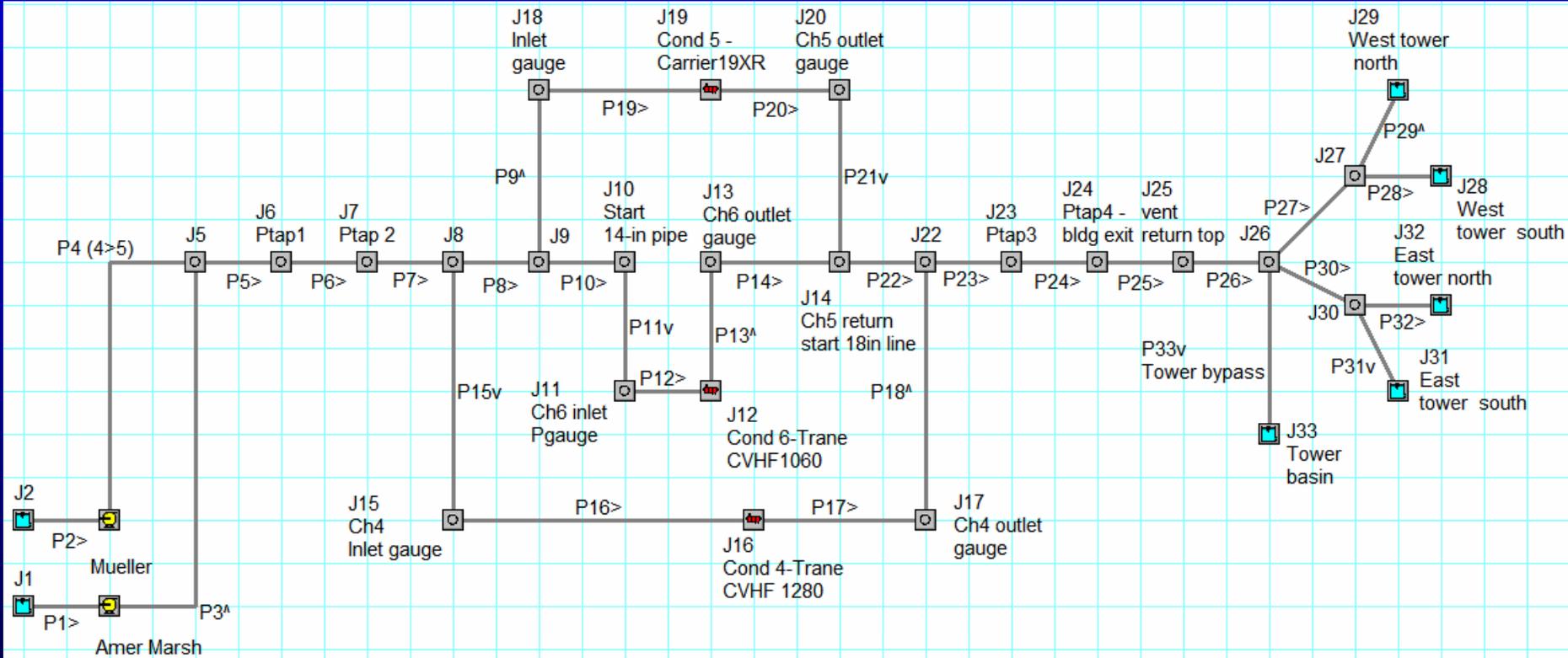
A simplified flow diagram for a system that we'll use as a talking point



P19 running

F: 3700 gpm (magnetic flow meter)
P1: 29.1 psig (test instrument)
MCC: 87.5 kW, 480V (test instrument)

A hydraulic model for this system



Note: the time required to assemble the model, including getting manufacturer performance data for valves, heat exchangers, and pumps, as well as just tabulating the line sizes and lengths, numbers and types of fittings, etc., was approximately 2 person-days.

Model vs. measured comparisons: there were some devils in the details

<u>Parameter</u>	<u>Model</u>	<u>Actual</u>	<u>Actual/Model</u>
P19 flow rate (gpm)	3683	3700	1.00
Pump head (ft)	54.1	73.1	1.35
Shaft power (hp)	80.8	109.3	1.35
Condenser dP (psid)	5.43	14.3	2.64

Measurement-based observations:

Pump data provided by the supplier was off; actual curve was beyond that provided. Pump was also operating at a higher than rated speed.

The condenser appears to have significant blockage on the inlet side; additional measurements showed that the dP on the second pass of the U-type condenser was normal.

The close matching of predicted and actual flow was basically coincidental

Quantifying the opportunity magnitude through measurement and analysis

- Methods vary from snapshot-based, using tools such as the DOE's PSAT and valve energy loss software programs to more detailed engineering analyses
- Pay attention to details, but keep focus at the system level

Throttling and bypassing in a single application: machine chest to stuff box pumping



Photo by: Diagnostic Solutions, LLC



Photo by: Diagnostic Solutions, LLC

Logging machine chest pump pressures



Photo by: Diagnostic Solutions, LLC

Logging power data, using BPA-supplied equipment



Photo by: Diagnostic Solutions, LLC

PSAT evaluation of Norpac machine chest to stuff box application – at the pump and systems levels

Pumping System Assessment Tool

Condition A

Pump, fluid data End suction stock

Fixed pump specific speed? Yes Speed, rpm: 1180
 No Drive: Direct drive

stages: 1 Specific gravity: 0.983
 Fluid viscosity (cS): 1.00

Motor ratings Motor hp: 200

Existing motor class: Energy efficient
 rpm: 1190 Rated voltage: 575

Motor size margin, %: 15

Duty, cost rate Operating fraction: 0.980
 Electricity cost, cents/kwhr: 4.000

Required or measured data

Flowrate, gpm: 6880
 Head, ft: 79.4
 Load estimation method: Power
 Motor volts: 556 Motor kW: 127.0

	Existing	Optimal
Pump efficiency, %	83.6	87.7
Motor rated power, hp	200	200
Motor shaft power, hp	162.1	154.7
Pump shaft power, hp	162.1	154.7
Motor efficiency, %	95.2	95.2
Motor power factor, %	83.4	83.1
Motor current, amps	158.1	151.4
Motor power, kWe	127.0	121.2
Annual energy, MWhr	1090	1040
Annual cost, \$1,000	43.6	41.6

Annual savings potential, \$1,000: 2.0
 Optimization rating: 95.4

Condition B

Pump, fluid data End suction stock

Fixed pump specific speed? Yes Speed, rpm: 1180
 No Drive: Direct drive

stages: 1 Specific gravity: 0.983
 Fluid viscosity (cS): 1.00

Motor ratings Motor hp: 200

Existing motor class: Energy efficient
 rpm: 1190 Rated voltage: 575

Motor size margin, %: 15

Duty, cost rate Operating fraction: 0.980
 Electricity cost, cents/kwhr: 4.000

Required or measured data

Flowrate, gpm: 4553
 Head, ft: 20.2
 Load estimation method: Power
 Motor volts: 556 Motor kW: 127.0

	Existing	Optimal
Pump efficiency, %	14.1	86.4
Motor rated power, hp	200	40
Motor shaft power, hp	162.1	26.4
Pump shaft power, hp	162.1	26.4
Motor efficiency, %	95.2	93.8
Motor power factor, %	83.4	80.5
Motor current, amps	158.1	27.1
Motor power, kWe	127.0	21.0
Annual energy, MWhr	1090	180.4
Annual cost, \$1,000	43.6	7.2

Annual savings potential, \$1,000: 36.4
 Optimization rating: 16.5

Documentation section

Log file controls:

Log current data | Retrieve Log data | Select a file for individual log deletion | Background information | Print this panel

Summary file controls:

Create new or append existing summary file: CREATE NEW

Condition A Notes

Facility: Norpac System: PM2 machine chest
 Application: Pump and motor only perspective
 Date: July 24, 2006 Evaluator: Don Casada

General comments:
 Flow rate is the July 24 snapshot gross flow rate, including stuff box overflow. Head is actual pump head.

Condition B Notes

Facility: Norpac System: PM2 machine chest
 Application: System-level perspective
 Date: July 24, 2006 Evaluator: Don Casada

General comments:
 Flow rate is the net delivered to the machine during July 24 snapshot; head is actual minus losses across the stuff box level control and basis weight valves.

STOP

Collecting pressure and valve information to use with the valve tool included with PSAT



Photo by Diagnostic Solutions, LLC



Photo by Diagnostic Solutions, LLC

Time	Pump discharge psig	Post-valve psig
5/16 11:00:00	71.60	11.73
5/16 11:00:20	71.60	11.61
5/16 11:00:40	71.30	11.68
5/16 11:01:00	69.80	10.60
5/16 11:01:20	71.50	12.24
5/16 11:01:40	72.10	12.67
5/16 11:02:00	72.20	12.52
5/16 11:02:20	71.60	11.82
5/16 11:02:40	71.50	12.57
5/16 11:03:00	70.90	12.11
5/16 11:03:20	71.00	11.91
5/16 11:03:40	71.70	12.77
5/16 11:04:00	71.90	12.55
5/16 11:04:20	72.00	12.85
5/16 11:04:40	71.20	11.89
5/16 11:05:00	70.00	11.50
5/16 11:05:20	70.00	11.15
5/16 11:05:40	70.80	12.05
5/16 11:06:00	71.30	12.40
5/16 11:06:20	71.70	12.86
5/16 11:06:40	71.50	12.70
5/16 11:07:00	70.20	11.21

The electrical power related to valve throttling, and the associated annual energy cost are calculated

Valve head and energy calculations 2005

File Edit Operate Windows Help

Available data selector
 Flow rate from delta-P, Cv

Specific gravity
 1.000

Calculated flow rate, gpm
 1238

Operating fraction 1.000
 Average electrical cost rate, cents/kWh 5.00
 Pump efficiency, % 70.0
 Motor efficiency, % 95.0

Head loss, ft 109.38
 Frictional loss, hp 34.2
Frictional electrical power, kW 38.3
Annual cost of friction, \$ 16790



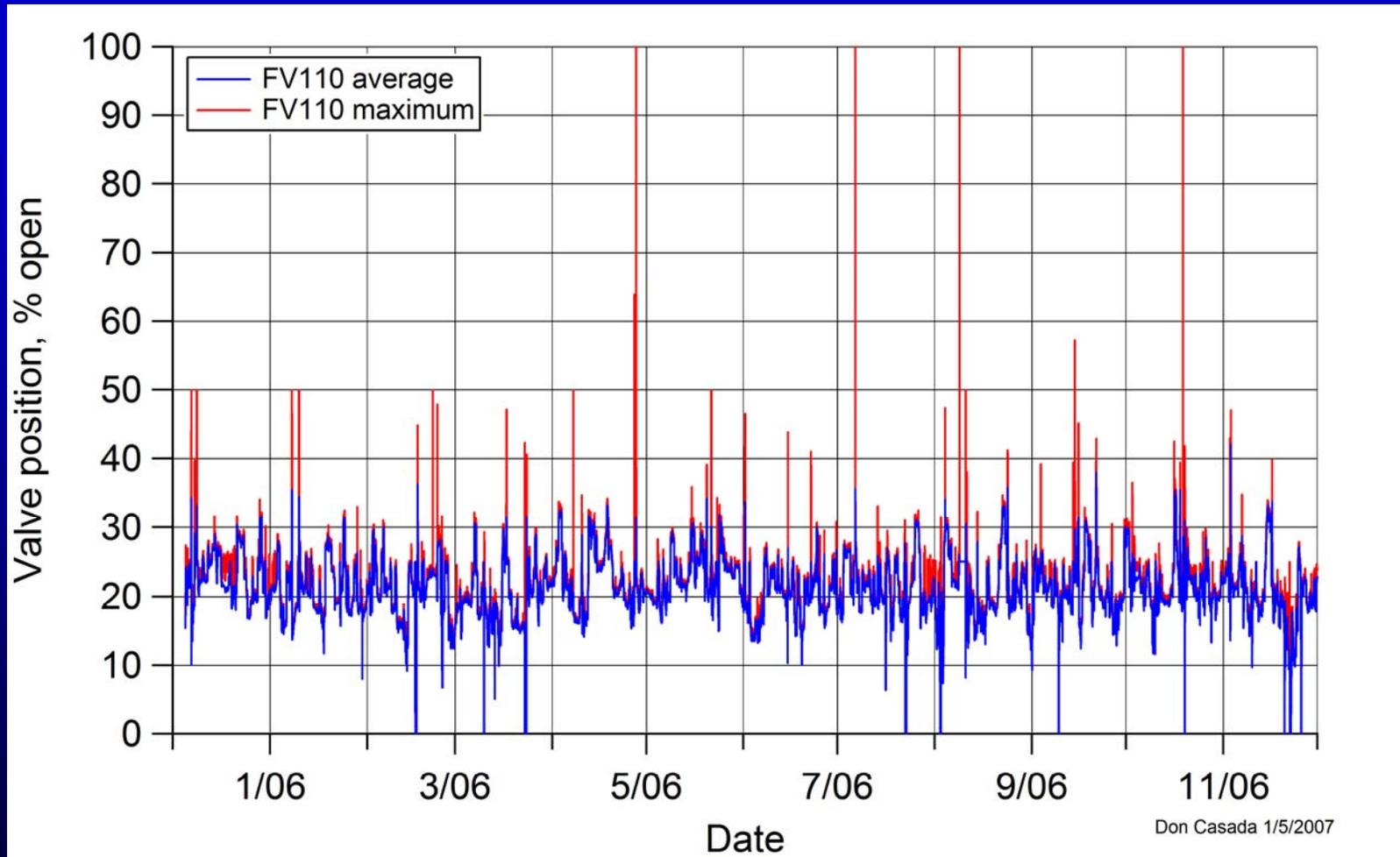
Upstream pressure, psig 70.9
 Upstream pipe ID, inches 14.00
 Upstream gauge elevation, ft 5.0
 Upstream velocity, ft/s 2.6

Specified valve Cv 180.0
 Valve size, inches 12.00
 Valve velocity, ft/s 3.5

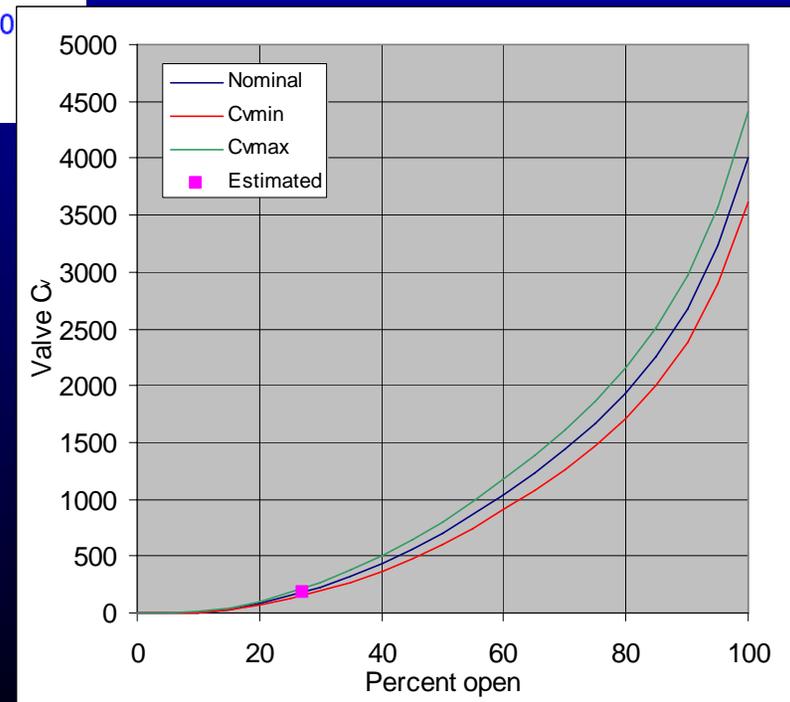
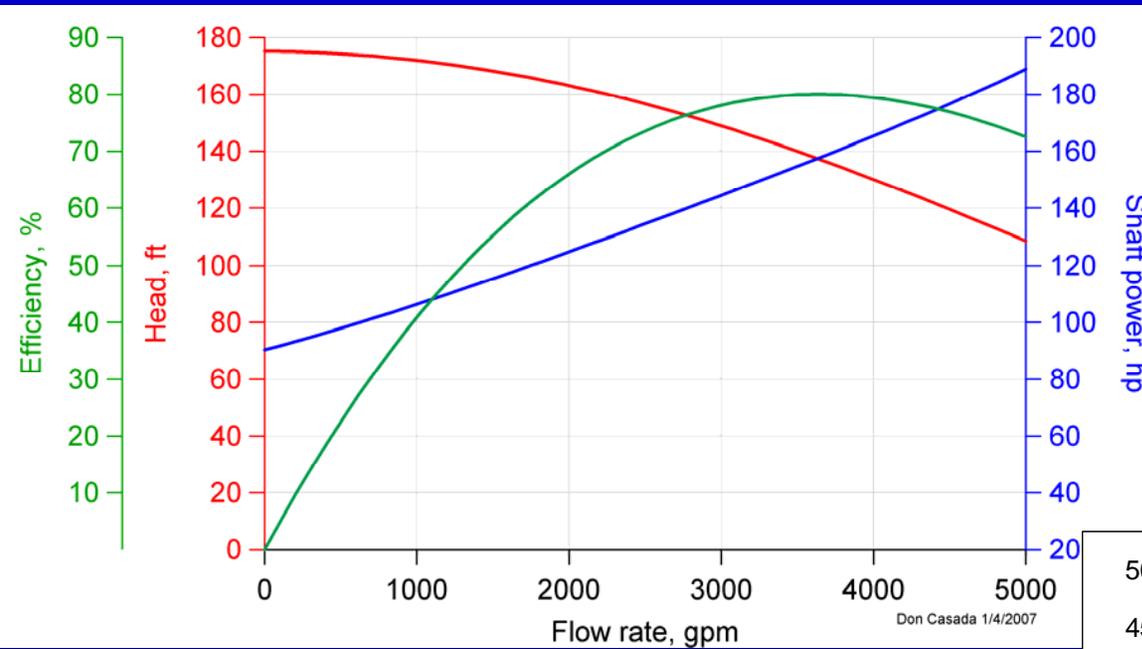
Downstream pressure, psig 31.5
 Downstream pipe ID, inches 14.00
 Downstream gauge elevation, ft 31.5
 Downstream velocity, ft/s 2.6

0.38 K_reducer & expander
 1056.54 K_valve
 1056.92 K_total

The same techniques can be applied to long-term, varying condition data



Equipment performance curves are often used in conjunction with field data



Historical data supports detailed estimates of losses

DWG #	15-N-5001B	15-N-5001B												
	TMP and DI to blend flow	TMP and DI to blend FCV												
	gpm	% open												
time	15-FIC-0110	15-FIC-0110.COI	Nominal Cv	Max Cv	Nominal dP	Nominal valve whp	Max Cv whp	Pump bhp	Pump head (Q)	Pump eff	Pump whp, no recirc	Motor kW	Nominal valve kW	Max Cv kW
12/5/05 1:00	504.8	15.4	57.8	69.6	76.2	22.4	15.48	98.2	174.4	22.7	22.2	77.9	78.6	54.2
12/5/05 2:00	605.6	17.2	68.7	82.2	77.8	27.5	19.18	99.9	174.1	26.7	26.6	79.2	81.8	57.1
12/5/05 3:00	874.2	21.9	100.5	118.9	75.6	38.5	27.56	104.4	172.9	36.6	38.2	82.9	83.7	59.8
12/5/05 4:00	1012.9	24.3	117.6	138.4	74.2	43.8	31.63	106.8	172.1	41.2	44.0	84.8	84.4	60.9
12/5/05 5:00	826.6	20.9	93.5	110.9	78.1	37.7	26.82	103.6	173.1	34.9	36.1	82.2	85.7	61.0
12/5/05 6:00	766.8	19.9	86.7	103.0	78.2	35.0	24.78	102.6	173.4	32.7	33.6	81.4	84.8	60.1
12/5/05 7:00	747.3	19.6	84.7	100.7	77.9	33.9	24.01	102.3	173.5	32.0	32.7	81.1	84.1	59.5
12/5/05 8:00	766.3	19.9	86.7	103.0	78.1	34.9	24.74	102.6	173.4	32.7	33.6	81.4	84.7	60.0
12/5/05 9:00	740.9	19.4	83.4	99.2	79.0	34.1	24.11	102.1	173.5	31.8	32.5	81.1	85.2	60.2
12/5/05 10:00	738.3	19.4	83.4	99.2	78.4	33.8	23.87	102.1	173.6	31.7	32.4	81.0	84.6	59.8
12/5/05 11:00	744.1	19.5	84.0	99.9	78.4	34.0	24.06	102.2	173.5	31.9	32.6	81.1	84.7	59.8
12/5/05 12:00	749.4	19.6	84.7	100.7	78.3	34.2	24.21	102.3	173.5	32.1	32.8	81.2	84.6	59.8
12/5/05 13:00	744.6	19.6	84.7	100.7	77.3	33.6	23.74	102.2	173.5	31.9	32.6	81.1	83.5	59.0
12/5/05 14:00	732.8	19.3	82.7	98.4	78.5	33.6	23.70	102.0	173.6	31.5	32.1	81.0	84.6	59.7
12/5/05 15:00	727.7	19.2	82.0	97.7	78.7	33.4	23.57	101.9	173.6	31.3	31.9	80.9	84.7	59.8
12/5/05 16:00	696.4	18.7	78.1	93.2	79.4	32.3	22.70	101.4	173.7	30.1	30.6	80.5	85.0	59.8
12/5/05 17:00	765.8	20.0	86.7	103.0	78.0	34.8	24.68	102.6	173.4	32.7	33.5	81.4	84.6	59.9
12/5/05 18:00	1012.3	23.8	113.8	134.1	79.1	46.7	33.67	106.8	172.1	41.2	44.0	84.8	90.1	64.9
12/5/05 19:00	949.8	22.8	107.1	126.4	78.7	43.6	31.29	105.7	172.5	39.1	41.4	83.9	88.4	63.5
12/5/05 20:00	933.3	22.5	104.9	123.9	79.2	43.1	30.90	105.4	172.6	38.6	40.7	83.7	88.7	63.6
12/5/05 21:00	939.6	22.6	104.9	123.9	80.3	44.0	31.53	105.5	172.5	38.8	40.9	83.8	90.0	64.5
12/5/05 22:00	991.7	23.5	111.5	131.5	79.1	45.7	32.91	106.5	172.2	40.5	43.1	84.5	89.6	64.5
12/5/05 23:00	1015.9	23.9	115.3	135.8	77.6	46.0	33.16	106.9	172.1	41.3	44.1	84.8	88.4	63.7
12/6/05 0:00	1008.6	23.8	113.8	134.1	78.6	46.2	33.30	106.7	172.1	41.1	43.8	84.7	89.3	64.3
12/6/05 1:00	1020.4	24.0	115.3	135.8	78.3	46.6	33.60	107.0	172.1	41.5	44.3	84.9	89.2	64.3
12/6/05 2:00	1038.1	24.3	118.4	139.3	76.9	46.6	33.63	107.3	171.9	42.0	45.1	85.1	88.0	63.5
12/6/05 3:00	1064.7	24.7	121.5	142.9	76.8	47.7	34.49	107.7	171.8	42.9	46.2	85.5	88.3	63.8
12/6/05 4:00	1061.1	24.7	120.7	142.0	77.3	47.8	34.58	107.7	171.8	42.8	46.0	85.4	88.8	64.2
12/6/05 5:00	979.3	23.4	110.8	130.6	78.2	44.6	32.11	106.2	172.3	40.1	42.6	84.3	88.3	63.5
12/6/05 6:00	865.5	21.3	96.3	114.1	80.8	40.8	29.08	104.3	172.9	36.2	37.8	82.8	89.3	63.7
12/6/05 7:00	858.0	21.2	95.6	113.2	80.6	40.3	28.73	104.1	173.0	36.0	37.5	82.7	88.9	63.4
12/6/05 8:00	893.7	21.8	99.1	117.3	81.3	42.4	30.27	104.8	172.8	37.2	39.0	83.1	90.4	64.6

Observation from many miles traveled on the industrial circuit:
BPA's industrial energy program is – BY FAR –
the best in the country; take advantage of it!

Todd, I'm pretty sure I see some savings trying to hide down there

