ENERGY CONSERVATION:

Common Sense Methods for Lightening the Load v3.0

PREPARED FOR: New Jersey Water Association 2022 Fall Conference
PRESENTER: David J. Applegate, P.E., T3, W3

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Presentation Outline

- Industry Nomenclature
- Water Industry Energy Usage Overview
- Efficiency Targets
- Pumps
- Motors
- Pipes
- Valves
- Energy Efficiency/Reclamation

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Industry Nomenclature

Industry Nomenclature

- Horsepower (HP)
- Kilowatt (kW)
- 1 HP = 0.746 kW (or, 746 Watts)
- Water Horsepower (WHP)
- KiloWatt Hour (kWh)
- Water-to-Wire Efficiency (%)
- Variable Frequency Drive (VFD) or Variable Speed Drive
- Total Dynamic Head (TDH)
- Cavitation – low/negative pressure implosions on impeller
- Volute – area of the casing that the water is discharged to

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Water Industry Energy Usage Overview

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Water Industry Energy Usage Overview

Drinking Water and Wastewater Systems Account for Approximately 3-4 Percent of Energy Use in the United States, Adding Over 45 Million Tons of Greenhouse Gases

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Water Industry Energy Usage Overview

Drinking Water and Wastewater Plants Are Typically the Largest Energy Consumers of Municipal Governments, Accounting for 30-40 Percent of Total Energy Consumed

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Water Industry Energy Usage Overview

Energy As a Percent of Operating Costs for Drinking Water Systems Can Reach As High As 40 Percent and is Expected to Increase 20 Percent in the Next 15 Years Due to Population Growth and Tightening Drinking Water Regulation

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Water Industry Energy Usage Overview

A University of Michigan Study Projects Electricity Consumption in the U.S. for Supply of Fresh Water to be 36 Billion kWh by 2020 and 46 Billion kWh by 2050

- A 28% increase in electrical consumption over 30 years

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Efficiency Targets

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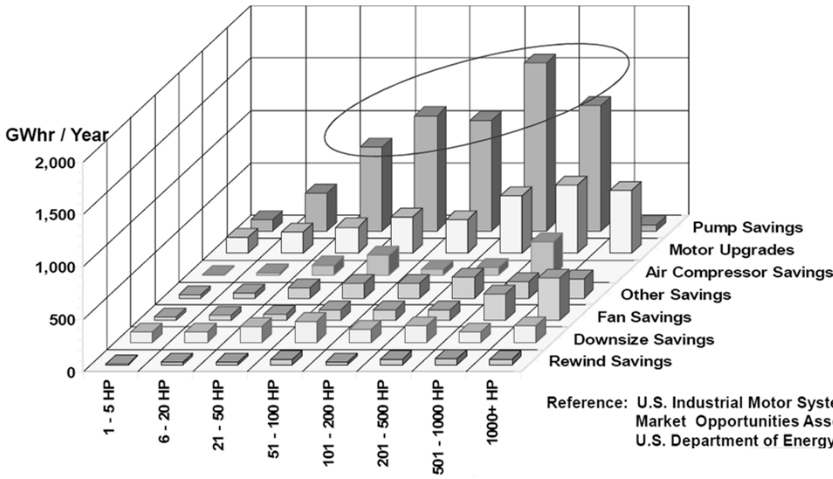
Efficiency Targets



Reference: U.S. Industrial Motor Systems Market Opportunities Assessment, U.S. Department of Energy

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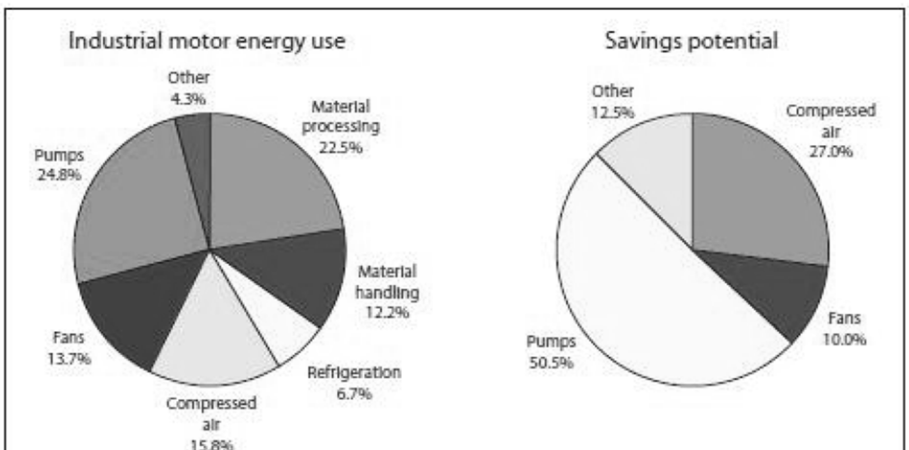
Efficiency Targets



Source – U.S. DOE office of Industrial Technology

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Pumps

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Pumps

- Pump Efficiency Monitoring
  - Ammeter testing (aka Megger Test)
  - Calculate water-to-wire efficiency

- Reduced efficiency means:
  - Compromised impeller (loss of diameter, damage, roughness)
  - Compromised volute (damage (cavitation et al), roughness)

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Pumps

- Mechanical Refurbishing
  - New impellers
  - New casing rings
  - New mechanical seals
  - New packing
  - Shaft alignment(s)
- Coating Rehabilitation
  - Impeller
  - Volute

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Pumps

- Shaft misalignment
  - Can account for 3% to 5% incremental power consumption
- Mechanical openings/wear surfaces
  - Increased internal leakage
  - Loss of efficiency
  - Increased HP consumption

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Pumps

- Interior pump rehabilitation/coating
  - 5% to 10% improvement in efficiency
  - Volute coating accounts for major portion, impeller to a lesser extent
- Best (most talked about) product
  - 2-part ceramic filled epoxy systems
  - Good for both new and old pumps
  - Belzona 1321, or equal

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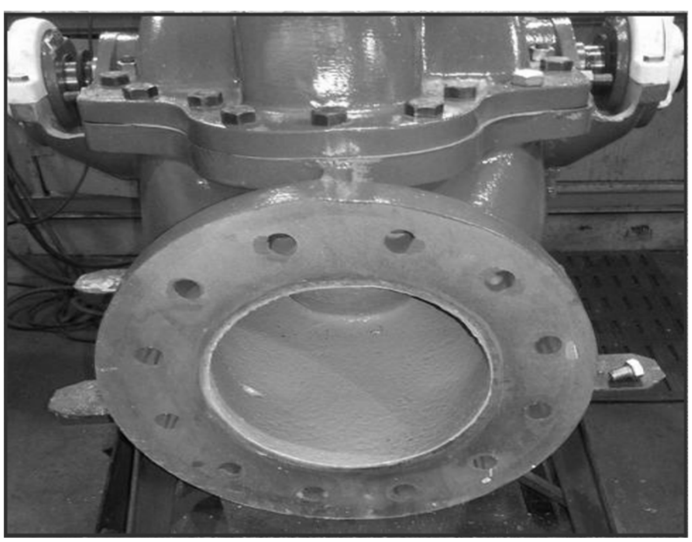
Pumps



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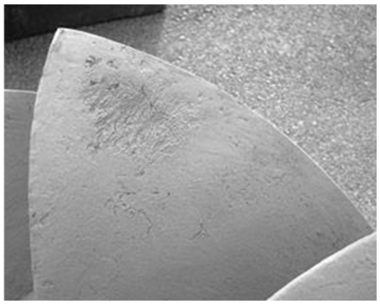
Pumps



Before

After

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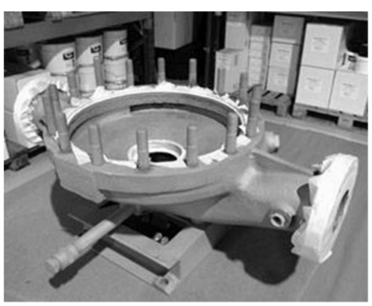
Pumps



Before

After

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Pump and Motor Selection

- When possible, always choose lower rpm pump/motor combination
- For VFD interaction, need motor that is inverter duty ready

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Motors

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Motors

- Motor Efficiency Monitoring
  - Ammeter testing (aka Megger Test)
  - Calculate water-to-wire efficiency
- Reduced efficiency means:
  - Old motor
  - Winding damage
  - Moisture intrusion

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Motors

- VFD Usage
  - Reduces (multiple) start up amperage spikes
  - Typically NOT ideal for potable water production wells
  - IDEAL for booster pumps, sanitary sewage pumps, large HP motors

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Motors - Electricity Primer

- For DC motors:
  P = i V
- For AC polyphase motors:
  P = i V (PF) (1.73)

Where:

P = Power (Watts)
i = Current (amps)
V = Electromotive Force (Volts)
PF = Power Factor (usually 0.9 for standard 3-phase motors)

» Given same Power, P, LARGER V equates to a smaller i

746 Watts = 1 Horsepower (HP)

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Motors - Electricity Primer

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Motors – Horsepower Primer

WHP = Q (gpm) x TDH (feet) / 3960

BHP = Q (gpm) x TDH (feet) / (3960 x Efficiency of Pump, E_p)

MHP = Q (gpm) x TDH (feet) / (3960 x E_p x Efficiency of Motor, E_m)

$E_{TOTAL} = E_p \times E_m$

E_p Generally Ranges from 40% to 75%
E_m Generally Ranges from 90% to 95%

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Hypothetical Working Example

<u>Situation:</u>

Vertical turbine pump (VTP) has experienced diminished pumping capability over time

<u>Knowns:</u>

100 HP motor

480 Volts

1,800 rpm

Motor Efficiency: 90% (new)

Pump Efficiency: 70% (new)

Design Point: 1,000 gpm @ 250 feet TDH

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Hypothetical Working Example (cont'd)

Measured:

- When at full speed, average ammeter reading on all three legs reads 80 amps
- Discharge pressure gauge reading of 87 psi (200 feet)

Therefore, P (Watts) = 80 x 480 x (0.9) (1.73) = 59,789 Watts

HP = 59,789 Watts/746 Watts/HP = 80 HP

$HP_{measured}$ 80 vs. HP_{design} 100 = Δ of 20 HP

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Hypothetical Working Example (cont'd)

A Second Check:

MHP = Q (gpm) x TDH (feet) / (3960 x E_{TOTAL})

80 HP = Q x 250 feet /(3960 x 0.63)

Q = 80 x (2,495)/250 = 798 gpm

Conclusions

- ❑Pump impeller probably diminished in diameter or damaged
- ❑Motor windings old and/or damaged
- ❑Volute tuberculated or damaged

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Hypothetical Working Example (cont'd)

What would have been the proper ammeter reading for a pump/motor combination running at their design points?

100 amps

Know your equipment. Know their service settings.

- ❑HP
- ❑Amperage draw
- ❑TDH
- ❑gpm

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Pipes

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Pipes

- Pipe Cleaning/Maintenance
  - Force mains:
    - Pigging stations
    - Chemical feed/scrubbing
  - Water mains:
    - Chemical balance (Langlier Index)
    - Cleaning and lining
    - Replacement

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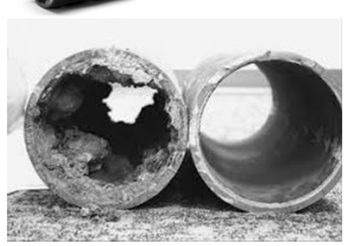
Pipes

Pigs

Before and After



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Pipes – Friction Loss Calculation

Hazen-Williams Formula

$H_f = ((147.85 \times Q)/(C \times D^{2.63}))^{1.852}$ per 1,000 feet of pipe

Where:
H_f = friction head, in feet
Q = flow, in gallons per minute (gpm)
C = Hazen-Williams friction factor
D = pipe diameter, in inches

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Pipes – Friction Loss Calculation

- Calculating friction losses in closed conduit piping
  - Hazen-Williams friction coefficient, “C”
  - Darcy-Weisbach formula, using Reynolds number
  - Good Reference Material: Cameron Hydraulic Tables

- Most common modeling and design criteria use “C”
  - Use C = 80 (or less) for old, heavily tuberculated piping
  - Use C = 100 for old or wastewater piping
  - Use C = 120 for moderate, well kept water piping
  - Use C = 150 for new, DIP cement lined piping

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Pipes – Flow & Friction Measurement

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Pipes – Pumping Cost

Cost to pump through a given pipeline, PC, is a function of head loss, power cost, and efficiency

$$PC = 1.65\, H_L Q \frac{a}{E}$$

where: PC = Pumping cost ($/yr. based on 24 hr./day)
H_L = Head loss (ft./1000 ft.)
Q = Flow (gpm)
a = Unit cost of electricity ($ /KWH)
E = Total efficiency of pump system (% /100)

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Valves

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Valves – Throttled Conditions

- Valve Selection – Flow Control
  - Globe valves
  - Ball valves
  - Eccentric plug valves
  - Butterfly valves
  - Swing check valves
  - Tilted disk check valves
- Valve Selection – Pressure Reduction
  - Globe valves
  - Ball valves
  - Eccentric plug valves

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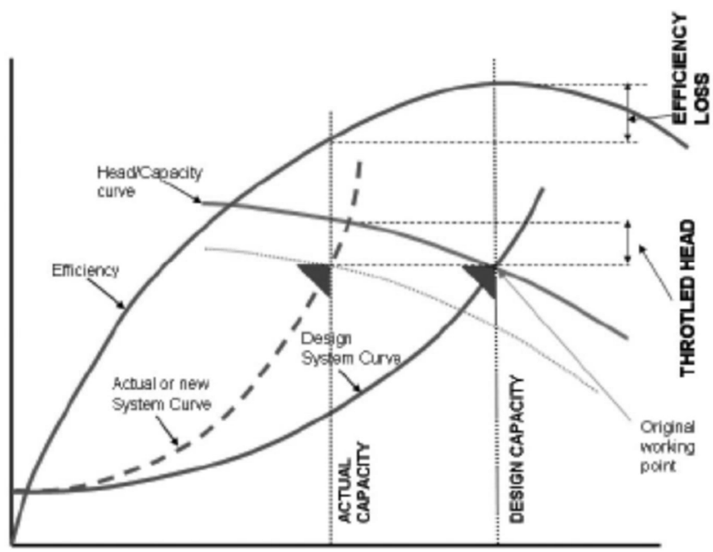
Valves – Throttled Conditions



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Valves – Friction Factors (aka Efficiency Bleeders)

- C_v: Flow coefficient (size specific rating)
  - High C_v good, low C_v bad
- K factor: Resistance coefficient
  - Low K good, high K bad

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Valves – Efficiencies

Type of Valve (12″)	Port Size	Cv	K
Control Valve	100%	1800	5.7
Silent Check Valve	100%	2500	2.95
Swing Check Valve	80%	3410	1.58
Dual Disc Check Valve	80%	4000	1.15
Nozzle Check Valve	100%	4700	.083
Ball Check Valve	100%	4700	.083
Eccentric Plug Valve	80%	4750	.081
Surgebuster Check Valve	100%	4800	.80
Tilted Disc Check Valve	140%	5400	.63
Butterfly Valve	90%	6550	.43
Cone Valve	100%	21,500	.04
Ball Valve	100%	22,800	.03

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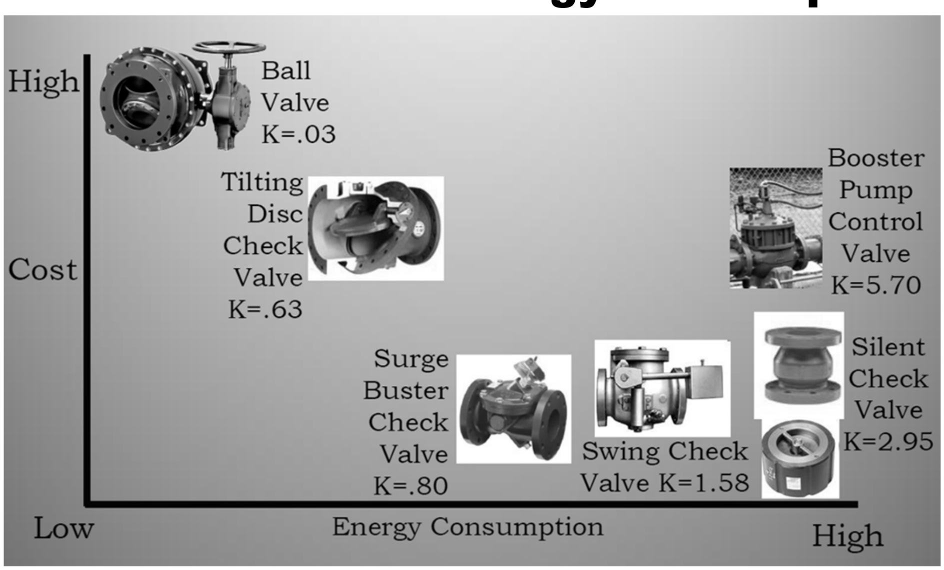
Valves – Cost vs. Energy Consumption



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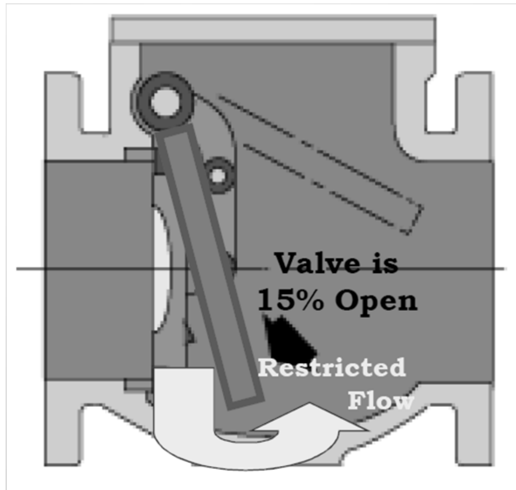
Valves – Partially Open/Restricted



Conventional Swing Check Valve
(Lever & Weight or Spring Controlled)

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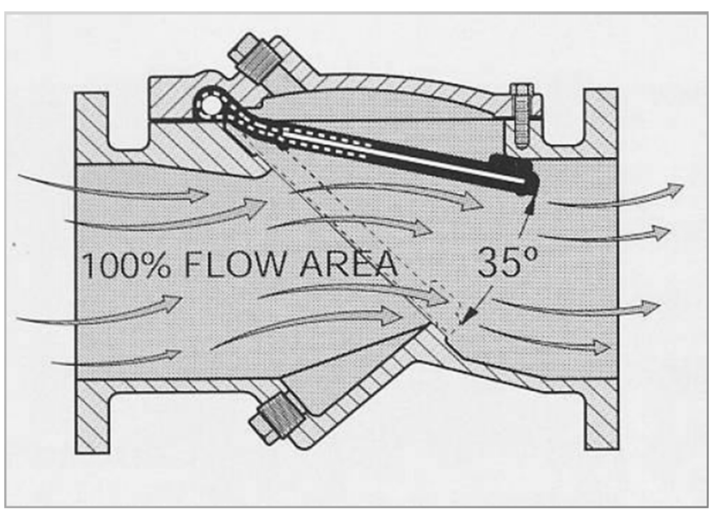
Valves – Fully Open/Unrestricted



"Surgebuster" or "SwingFlex" Swing-type Check Valve

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Valves – Pressure Management

- Pressure Reduction – via SCADA (remote)
  - Concept: Remotely actuate water system PRV valves to decrease system pressures during off-peak times, and increase pressure during peak flow periods
  - Reduces Non-Revenue Water loss
  - Reduces pump run times
  - "Smart" PRV valves:
    - Low pressure during low demand
    - Higher pressure during high demand

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Energy Efficiency/Reclamation

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Energy Efficiency/Reclamation

- Off-Peak Pumping
  - Off-peak hours for the purposes of electrical billing are Saturday, Sunday, and 8 PM to 8 AM Mon through Fri
  - Lower kW/hr rates
- Pumping Optimization
  - Applies to larger HP motors
  - Necessarily involves VFDs
  - Consists of running more pumps at lower RPMs/speeds instead of running one pump at full speed

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Energy Efficiency – Off-Peak Pumping

Electrical Demand Analysis

	From Interval Data:			From JCP&L Bills:			Potential Demand Savings Calculation:		
Month	Estimated Minimum Demand, kW	**Estimated Max Demand without Reservoir Pumping, kW**	Max Demand with Reservoir Pumping, kW	**On Peak Demand, kW**	Off Peak Demand, kW	Existing Demand Charge	**Potential Demand Savings without On-Peak Reservoir Pumping, kW**	Potential Demand Charge without On-Peak Reservoir Pumping	Estimated Demand Charge Savings
May 2013	300	**1,000**	1,369	**1,238**	1,231	$7,884	**238**	$6,370	$1,514
Jun. 2013	400	**1,000**	1,430	**1,430**	1,402	$9,838	**430**	$6,880	$2,958
Jul. 2013	400	**1,000**	1,782	**1,687**	1,782	$11,607	**687**	$6,880	$4,727
Aug. 2013	500	**900**	1,525	**1,620**	1,642	$11,146	**720**	$6,192	$4,954
Sept.2013	400	**1,100**	1,337	**1,313**	1,337	$9,036	**213**	$7,568	$1,468
Oct. 2013	400	**900**	1,227	**849**	1,227	$5,407	-	$5,407	$0
Nov. 2013	500	**800**	1,402	**793**	849	$5,049	-	$5,049	$0
Dec. 2013	600	**850**	1,393	**1,382**	1,402	$8,806	**532**	$5,415	$3,391
Jan. 2014	500	**1,000**	1,367	**1,367**	1,354	$8,710	**367**	$6,370	$2,340
Feb. 2014	400	**800**	1,268	**1,236**	1,268	$7,870	**436**	$5,096	$2,774
Mar. 2014	350	**700**	717	**655**	912	$4,169	-	$4,169	$0
Apr. 2014	400	**650**	1,277	**1,277**	1,227	$8,132	**627**	$4,152	$3,980

KW Charge: (Demand Charge)

Potential Annual Savings: **$28,105**

$6.88 per max KW for June-Sept
$6.37 per max KW for Oct-May
$2.33 per KW Minimum Charge
1,782 kW = highest on-peak or off-peak demand created in the current and preceding eleven months

MINIMUM DEMAND CHARGE PER MONTH: The monthly KW Demand Charge under Distribution Charge shall be the **greater** of (1) the product of the **KW Charge per maximum KW** and **the current month's maximum demand created during on-peak hours**; or (2) the product of the **KW Minimum Charge** and the **highest on-peak or off-peak demand created in the current and preceding eleven months** (but not less than the Contract Demand).

$ 4,152 = $2.33 x 1782, Minimum Demand charge for this 12 month period

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Energy Efficiency/Reclamation

- Hydro Microturbines
  - For use in potable water transmission or distribution mains
  - In lieu of conventional PRVs
  - Minimum 1.0 MGD flow, Δ=40 to 50 psi min, ideal
  - Pressure drop that would normally be lost via heat in a PRV now spins a turbine that generates electricity back to the grid
  - Existing PRV stays in place downstream

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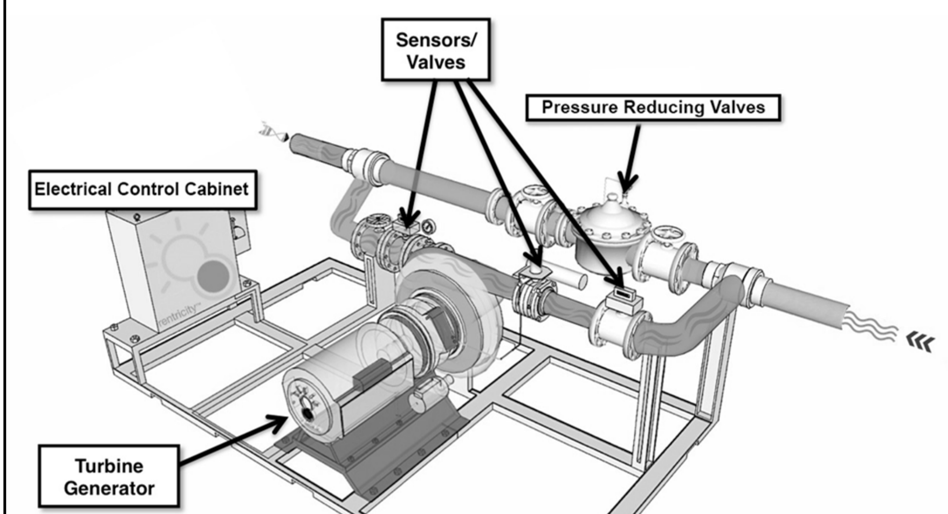
Energy Efficiency/Reclamation



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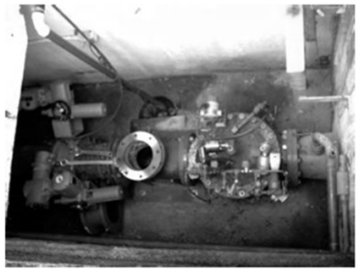
Energy Efficiency/Reclamation



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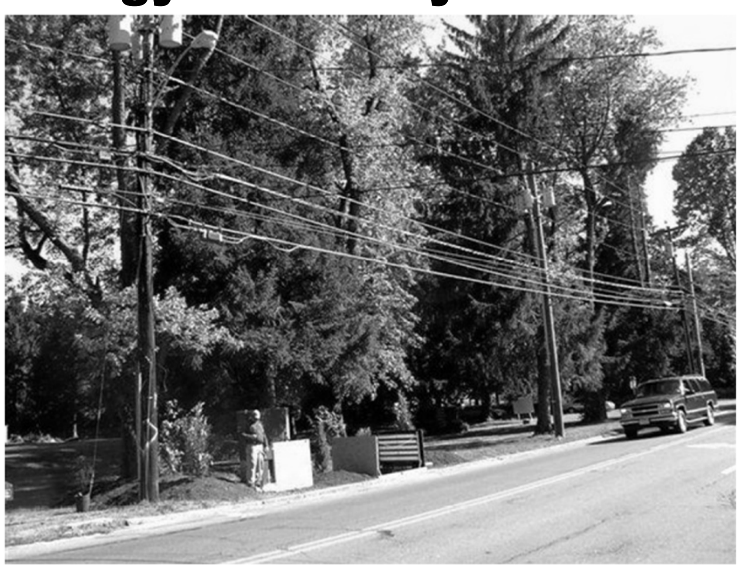
Energy Efficiency/Reclamation



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Energy Efficiency/Reclamation

- Wastewater Gas Microturbines
  - Similar to turbocharger equipment used in jet engines
  - Utilizes methane gases off of digesters for power source
- Wastewater Open Channel Microturbines
  - A concept
  - Would utilize head of water from a WWTP discharge

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Energy Efficiency/Reclamation

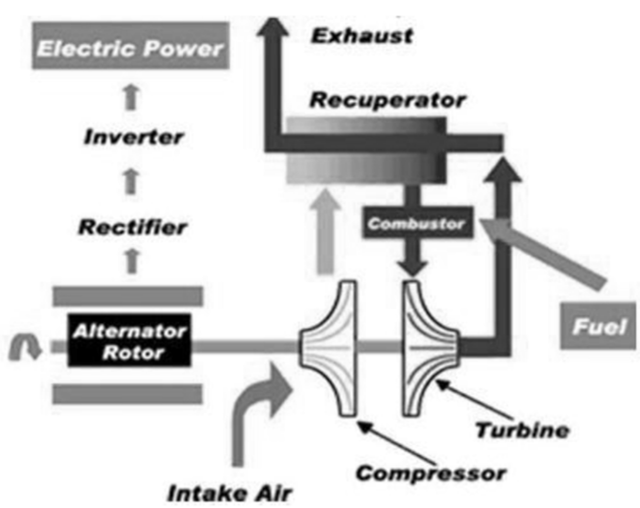

Figure 1: Microturbine Flow Diagram
(Source:www.wastegaspower.com/images/microturbine.jpg)

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Questions

Thank You!

Contact Information:

dapplegate@kielybuilds.com

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