Tri-State G&T Irrigation Pumping Optimization for Energy and Water

Webcast A: Irrigation Scheduling Optimization @ 8:30-9:45am MST

Break @ 9:45-10:15am MST

Webcast B: Pump System Optimization @10:15-11:45am MST

February 20, 2019

Welcome, and thanks for joining us today!

Reminder: please mute your phone when not speaking to reduce background noise.

This webcast is being recorded, including Q&A. By being on this call, you are providing your consent to be recorded.

The webcast recording and PDF of the presentation will be provided to Tri-State for distribution.

Question and Answer:

- Questions are welcome at any time throughout the webcast.
- You may type your question in the chat room if you prefer

Agenda

THURSDAY, FEBRUARY 20, 2019 (ALL TIMES MST)		
TIME	**TOPIC**	**PRESENTER**
8:30 a.m.	**Welcome & Background**	*Myles Jensen, Tri-State G&T*
8:35 a.m.	**Introductions & Learning Objectives**	*Sara Beaini & Micah Sweeney, EPRI*
8:40 a.m.	**Part A - Irrigation Scheduling Optimization**	*Dr. Lameck O. Odhiambo, Steven Melvin, Jonathan Aguilar, Irrigation Innovation Consortium*
9:30 a.m.	**Questions & Discussion**	*All*
9:45 a.m.	**Break**	
10:15 a.m.	**Part B - Pump System Optimization**	*Alex Kramer & Michael Michaud, Hydraulic Institute*
11:05 a.m.	**Adjustable Speed Drives (ASDs) for Energy Efficiency**	*Mark Stephens, EPRI*
11:20 a.m.	**Emerging Technologies**	*Sara Beaini & Micah Sweeney, EPRI*
11:25 a.m.	**Questions & Discussion**	*All*
11:40 a.m.	**Wrap-Up**	*EPRI and Tri-State G&T*

Why are we here?

- Tri-State and Member Systems engaging with our customers
  - Recent challenges with irrigators

- Tri-State experience with EPRI on resources for Motors/Drives/Pumps

- EPRI partners with Hydraulic Institute and Irrigation Innovation Consortium to support experience and resources for irrigation applications

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Objective: Provide Resources on Irrigation Pumping

Today's Webcast:

- Effective Irrigation Scheduling Practices
- Pump System Optimization for Irrigation
- Operational Costs and Prices: Measuring and Quantifying
- Emerging Energy and Water Efficiency Technology Considerations

Follow-on activities:

- Regional workshop or in-depth webinars
- Irrigation Resources Audit
  - Result: Irrigation Cost Worksheet

Intro to EPRI

ELECTRIC POWER RESEARCH INSTITUTE

BORN IN A BLACKOUT

Founded in 1972 as an independent, nonprofit center for public interest energy and environmental research

New York City, The Great Northeast Blackout, 1965

EPRI'S VALUE

To provide value to the public, our members, and the electricity sector

THOUGHT LEADERSHIP

INDUSTRY EXPERTISE

COLLABORATIVE MODEL

OUR MEMBERS…

- 450+ participants in more than 30 countries
- EPRI members generate approximately 90% of the electricity in the United States
- International funding – nearly 25% of EPRI's research, development, and demonstrations

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Introduction to Pump System Optimization

Hydraulic Institute

Hydraulic Institute and Pump Systems Matter

HYDRAULIC INSTITUTE

PUMP SYSTEMS MATTER

Energy | Efficiency | Economics

Hydraulic Institute The mission of the Hydraulic Institute is to be a value-adding resource to member companies, engineering consulting firms, and pump users worldwide by developing and delivering comprehensive industry standards, expanding knowledge by providing education and tools for the effective application, testing, installation, operation, maintenance, and performance optimization of pumps and pumping systems, and by serving as a forum for the exchange of industry information. For more information on the Hydraulic Institute, its member companies and its Standards Partners, visit www.pumps.org

Pump Systems Matter (PSM) Pump Systems Matter is a non-profit educational organization established by the Hydraulic Institute and leading utilities and energy efficiency organizations, to educate the industry on the benefits to pump systems optimization and energy efficiency to improve bottom-line savings of end-user companies.

Instructor:

Alex Kramer

BSEE, MSSE

President of NECO Systems, Inc., which provides systems integration and consulting services for pumping packages and controls in commercial, industrial, and municipal water and waste water facilities. The company has over 3400 installations and has built its business over 25 years.

Mr. Kramer's experience includes design, engineering, fabrication and service of pumping systems packages including water pressure boosters, heat transfer, geothermal circulating, fuel oil transfer, and waste water. He also has extensive experience in design and implementation of real time industrial computer control systems for electric utilities, steel mills, power plants, chemical processes, hydro-electric plants, and gas distribution systems.

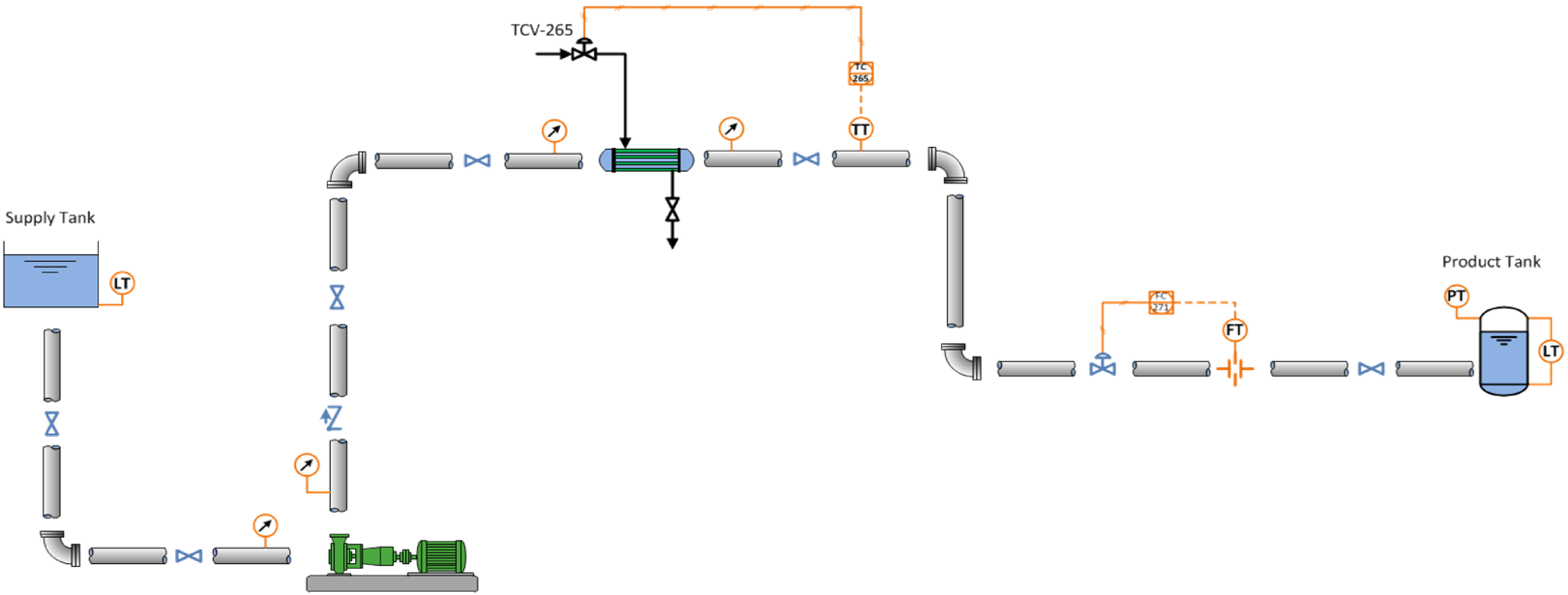
Mr. Kramer is certified by the Hydraulic Institute as a pump system optimization instructor. The Hydraulic Institute (HI) is the global authority on pumps and pumping systems and develops comprehensive pump standards, guidelines and guidebooks and serves as a forum for pump industry.

Mr. Kramer also held senior management positions in technology and operations at one of the top 5 U.S. technology distributors from 1982 to 2001, leaving as CEO upon acquisition of the company by others.

Outline: Pump System Optimization

- Importance of a *Pump System* Approach
- Look at entire system for efficiency & reliability
- Pump system basics: System & Pump Curves, Best Efficiency Point
- Affinity laws – impact on energy efficiency
- Pump efficiency & reliability
  - Independent of the driver (motor or engine)
- Variable Frequency Drive (VFD) to gain efficiency, improve reliability & provide control

What is a Pumping System?



Devices interconnected with pipelines that use the mass and energy of a fluid to perform work, carry out a process, or to make a product.

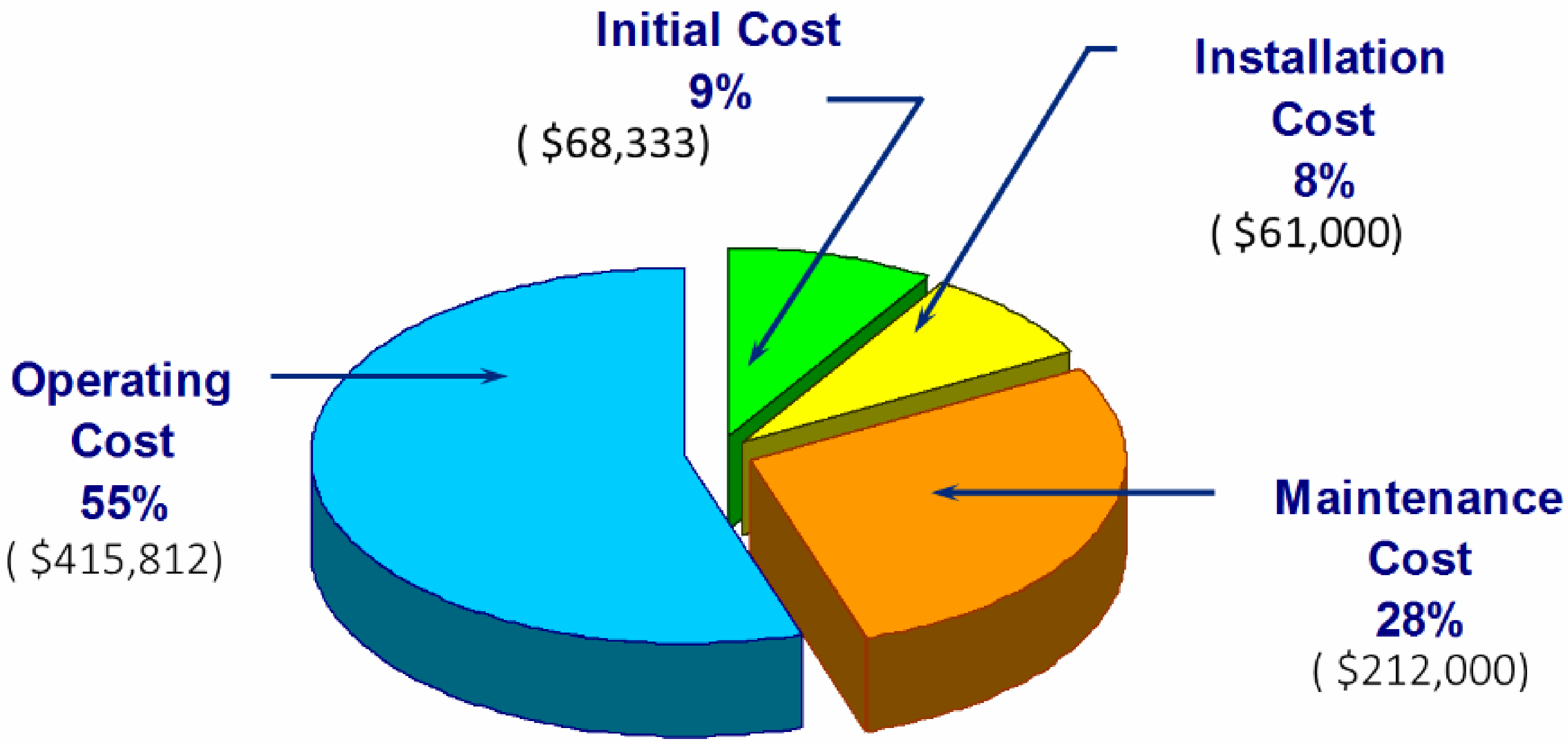
Fundamental concepts, principles, and mathematics apply across industries and disciplines.

Inefficient Pumping Systems

- Evaluation of 1690 pumps at 20 process plants:
  - Average pumping **efficiency is below 40%**
  - Over **10% of pumps** run **below 10% efficiency**
  - Major factors affecting pump efficiency:
    - Throttled valves
    - Improper pump selection
  - Seal leakage causes highest downtime and cost

- "Expert Systems for Diagnosis of the Condition and Performance of Centrifugal Pumps“
- *Finnish Technical Research Center Report

20 Year Life Cycle Cost of Typical 75 HP Pumping System



Total 20 Year Life Cycle Cost = $757,145

Reference : CostWare Analysis

Pump Input & Output Power

$$whp = \frac{QH(SG)}{(3960)}$$

$$bhp = \frac{whp}{\eta_P} = \frac{QH(SG)}{(3960)\eta_P}$$

where:

whp = pump output power (hp)

bhp = pump input power (hp)

- Q = volumetric flow rate (US gpm)
- H = total head (ft)
- SG = fluid specific gravity (dimensionless)
- η_p = pump efficiency
- 3960 = conversion factors to hp

Look Beyond Energy Savings

- Energy cost is a top consideration, but there are also values for non-energy benefits:
  - Higher Reliability
  - Increase Productivity
  - Less Equipment Wear and Tear
  - Reduce Maintenance Cost
  - Reduce Production Losses
  - Increase Capacity Utilization
  - Reduce Environmental Impact
  - Increase plant safety

Key Points

- Market research indicate that pump efficiency is less than 50%

  - Identify and effectively eliminate unnecessary losses

- Pump systems are big energy users in many plants – know how much these systems are costing you - *Reduce energy consumption*

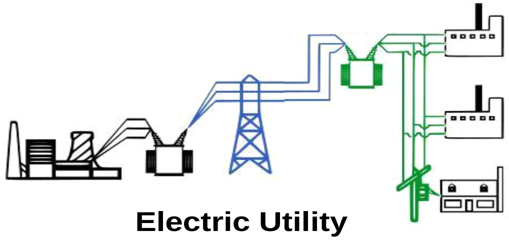
- Lifetime energy costs can be significantly greater than the installed cost of a pumping system

- Look beyond energy savings - *Improve reliability; Minimize the cost of ownership*

How Pumping Systems Become Inefficient

- Lack of standards for designing pumping systems
- Engineers tend to over-size pumps, control valves, and other equipment to ensure individual components will work
- Systems designed to meet future requirements, but operated to meet current market needs
- Systems age, equipment wear takes its toll and reduces overall system efficiency
- Process changes and modifications affect the system operation
- Lack of a “system approach” can hide problems that reduce overall system efficiency

The System Optimization Solution



Electric Utility

Transformer

Switchgear

Component Optimization involves segregating components and analyzing in isolation.

System Optimization involves looking at how the whole group functions together and how changing one can help improve the value of the entire application solution.

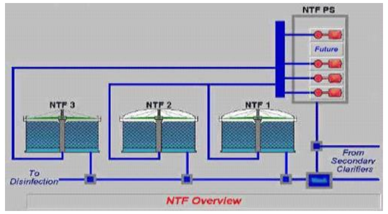
At each interface, there are inefficiencies. The primary objective should be to maximize the overall cost effectiveness of the entire system, or simply stated…"how much output energy is delivered per unit of input energy."

Variable Frequency Drive

Motor

Gearbox

Coupling



System

Energy Efficiency Improvements

Identify Options for Optimization

- Variety of solutions available to reduce energy consumption
- No single option is the solution to all optimization efforts
- Solution may consist of a combination of the options available

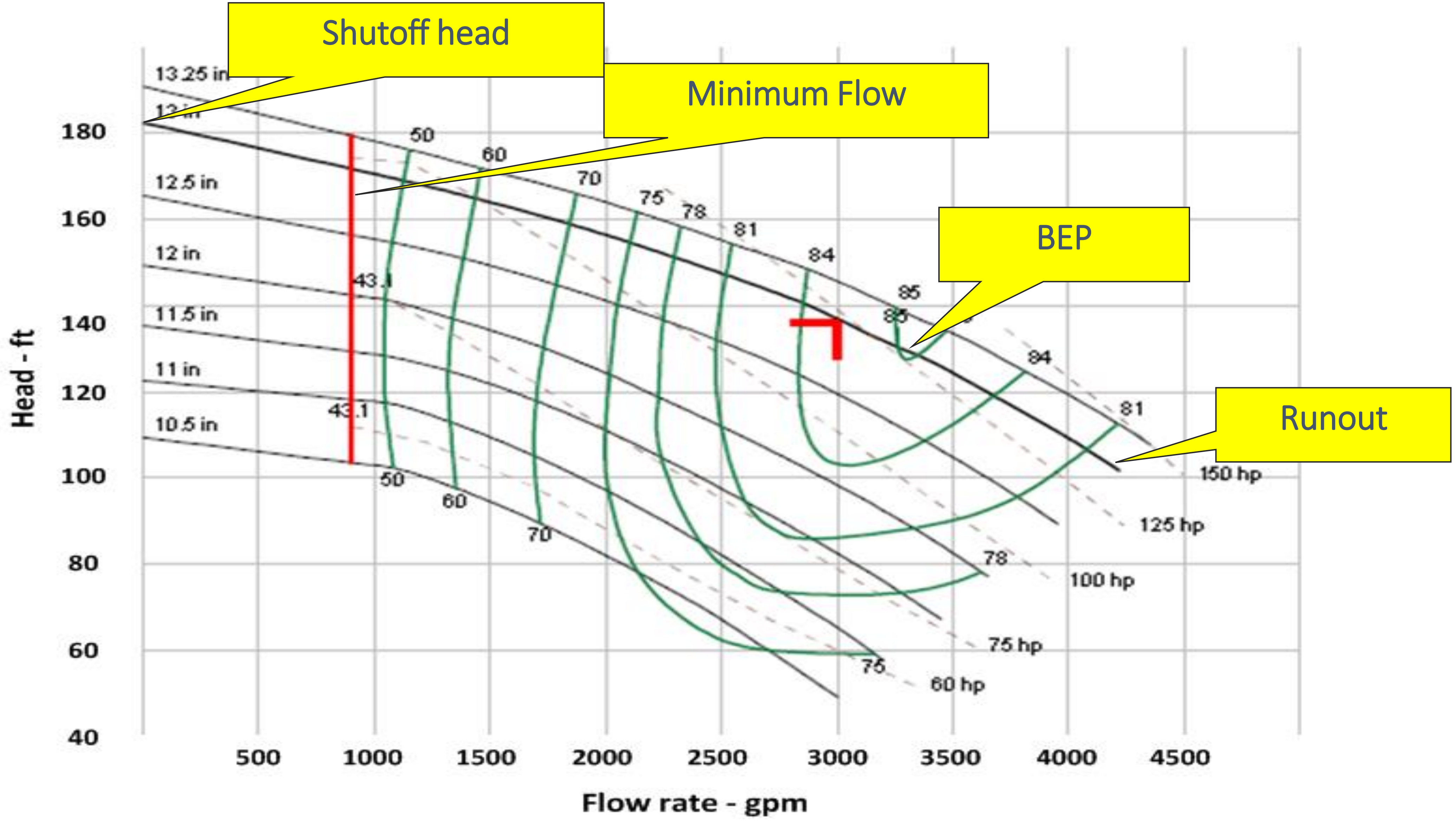
- Solutions fall into 3 broad categories:
  1. Reduce system head (static and dynamic)
  2. Reduce system flow rate or operating time
  3. Modify or replace equipment

Pump Performance Curve

- Shows the tested hydraulic performance of a pump for a single impeller diameter or a range of impeller sizes for a given pump casing
- Total head, power, efficiency and NPSHr*curves plotted against rate of flow
- If operating as designed & tested, pump will run on its curve based on the hydraulic resistance of the system it is installed in
- Supplied by the pump manufacturer and is used for:
  - Pump selection
  - Troubleshooting
  - Performing system assessments

* **NPSHr**: Net Positive Suction Head Required)

Pump Curve Landmarks

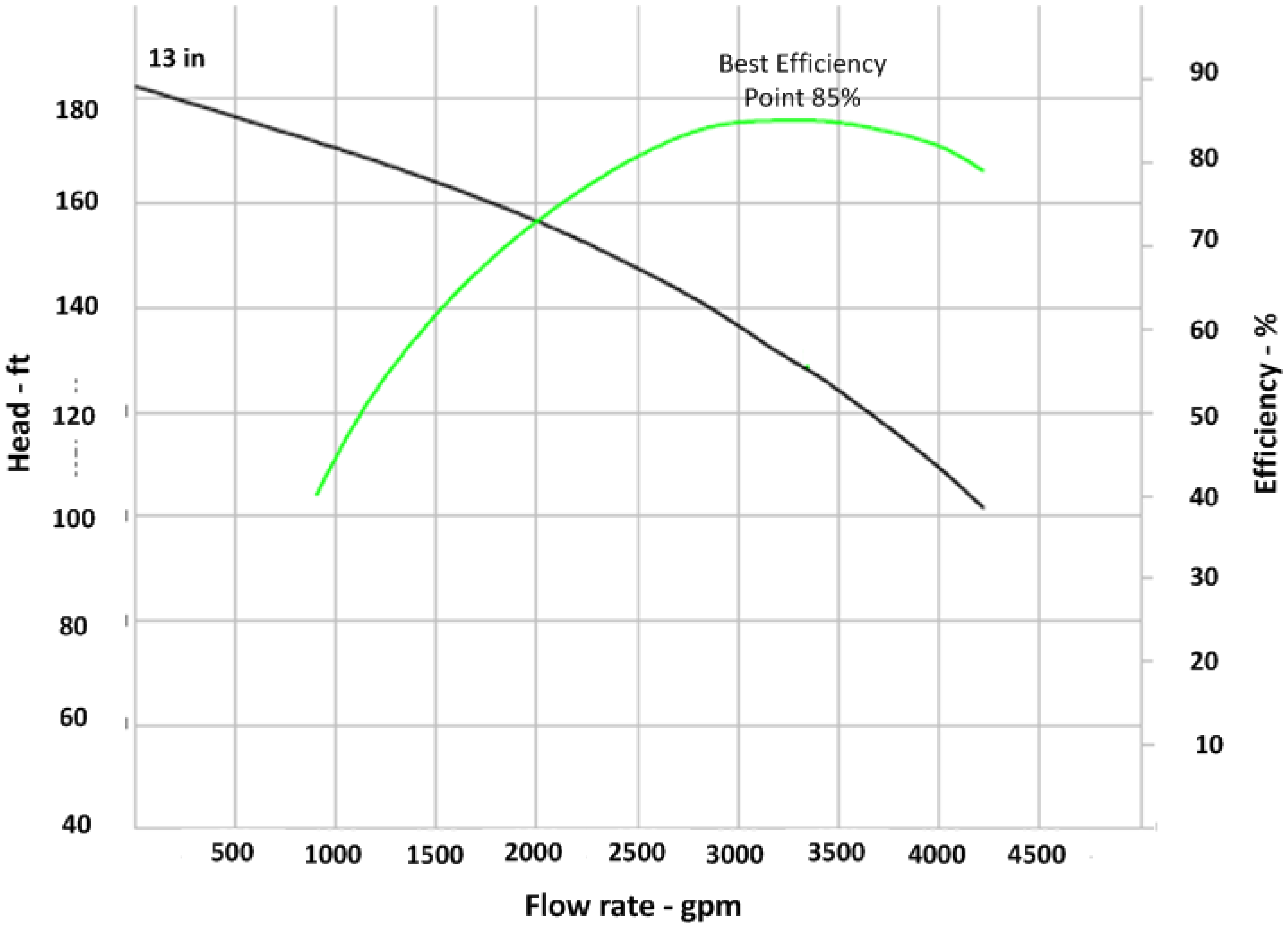


Best Efficiency Point

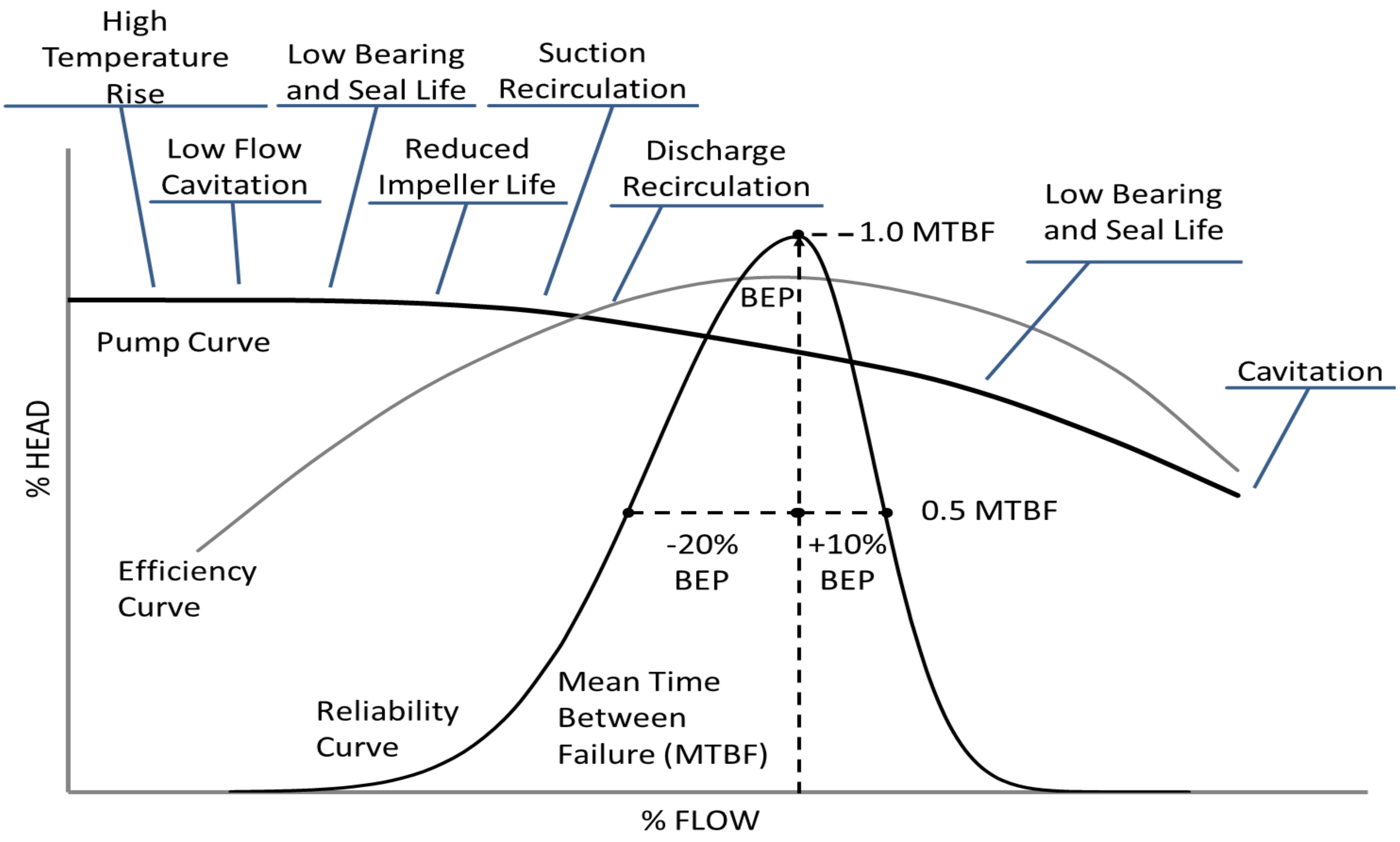
- The flow rate and total head at which the pump efficiency is maximum

<u>Operation *Off BEP*:</u>

- Increased vibration
- Reduced Seal and Bearing Life
- Increased potential for cavitation
- Suction & discharge recirculation



Efficiency and Reliability are Related



Pump Affinity Rules

- Pump performance can be changed by changing the pump speed or impeller diameter
  - Changing pump speed

    Capacity $Q_1 / Q_2 = N_1 / N_2$

    Head $H_1 / H_2 = (N_1/N_2)^2$

    Power $P_1 / P_2 = (N_1/N_2)^3$

  - Changing pump impeller diameter*

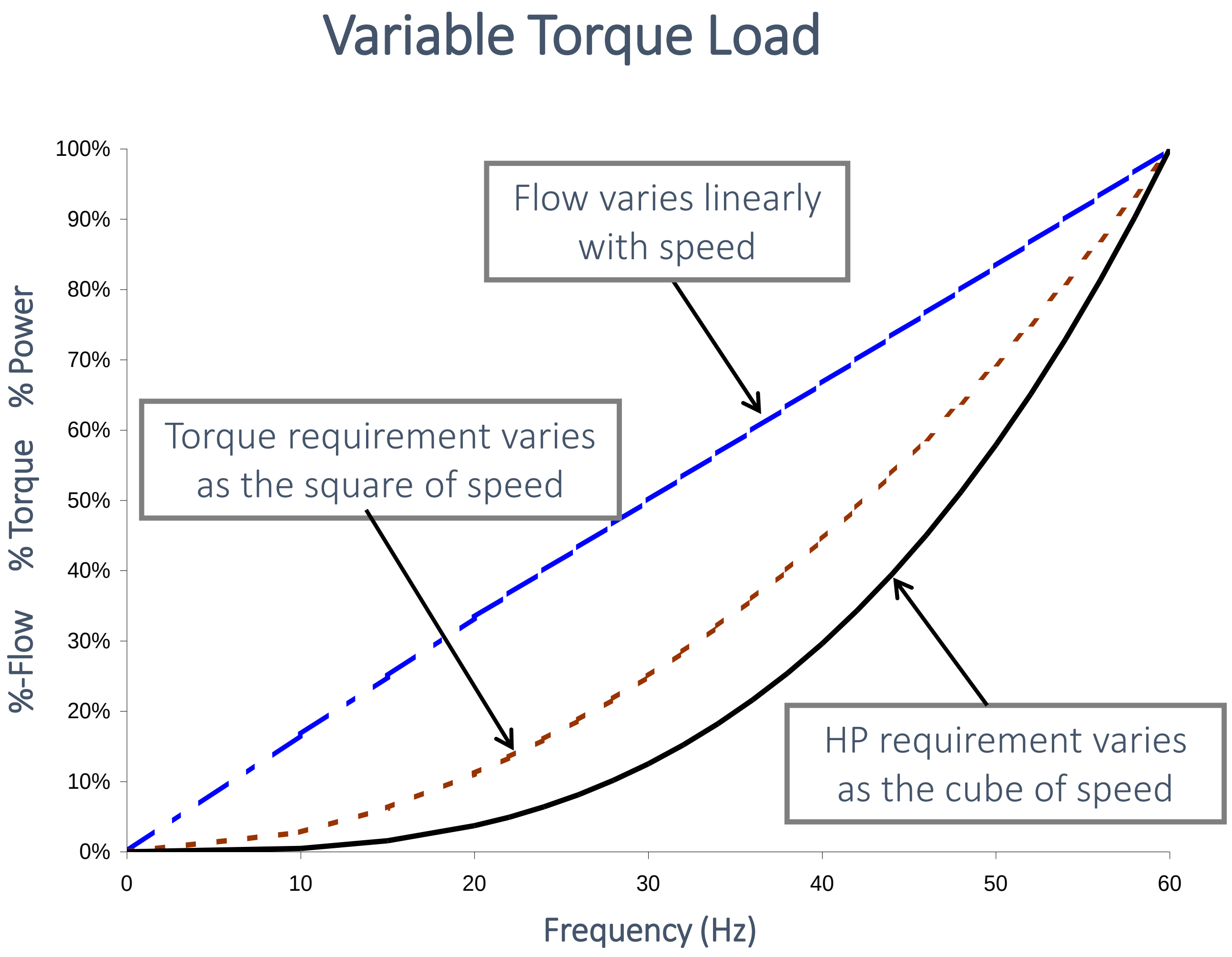
    Capacity $Q_1 / Q_2 = D_1 / D_2$

    Head $H_1 / H_2 = (D_1/D_2)^2$

    Power $P_1 / P_2 = (D_1/D_2)^3$

* Use for small changes

Application Types: Variable Torque Loads



Examples of how the Affinity Laws apply to variable torque loads:

25% reduction in speed =

58% reduction in kW

44% reduction in P&T

50% reduction in speed =

87.5% reduction in kW

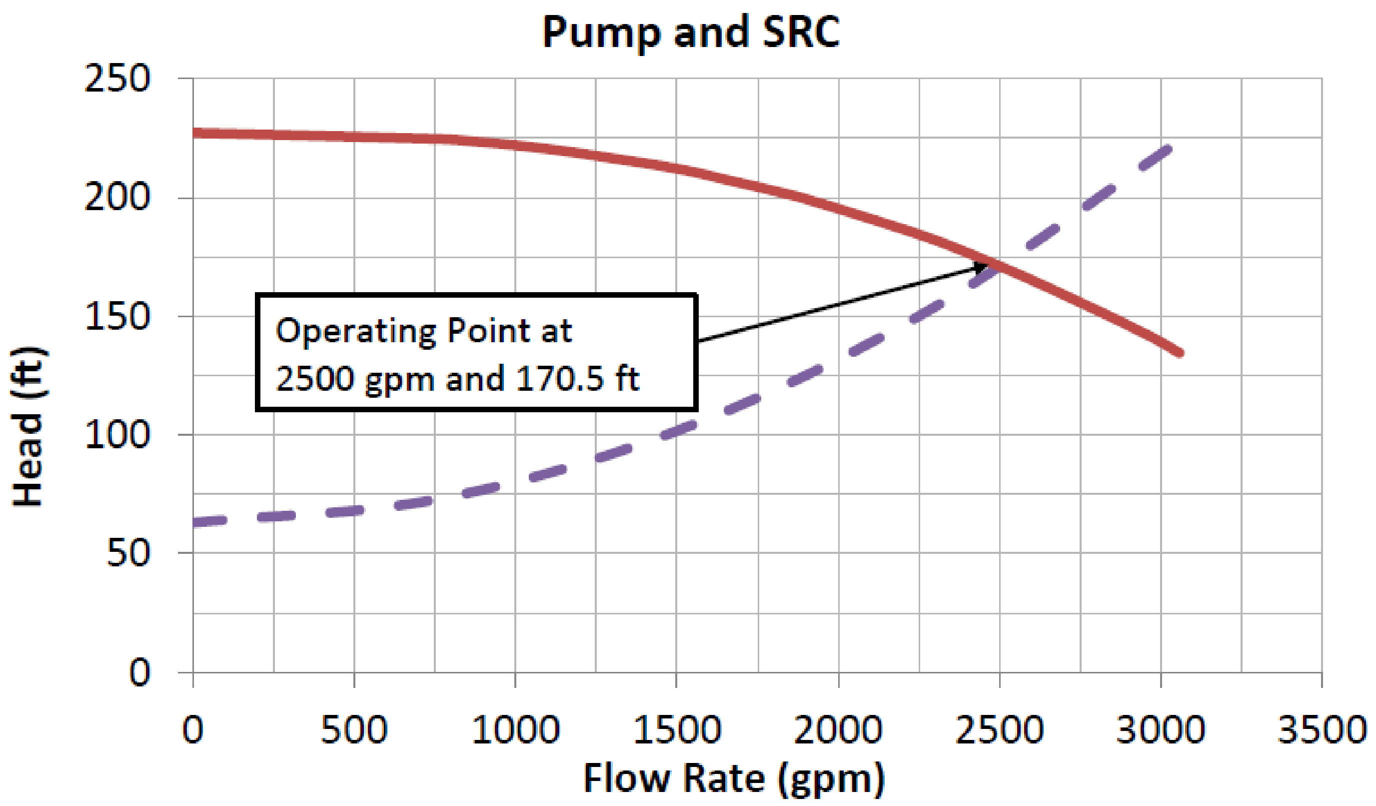
75% reduction in P&T

System Resistance Curve

- Combines resistance of all devices into a single hydraulic performance
- System resistance curve plots static and dynamic head as a function of flow rate
- Displays interaction between the pump, process, and control for a range of flows.
- Helps view the energy picture of the system
- Cannot be drawn for all types of systems

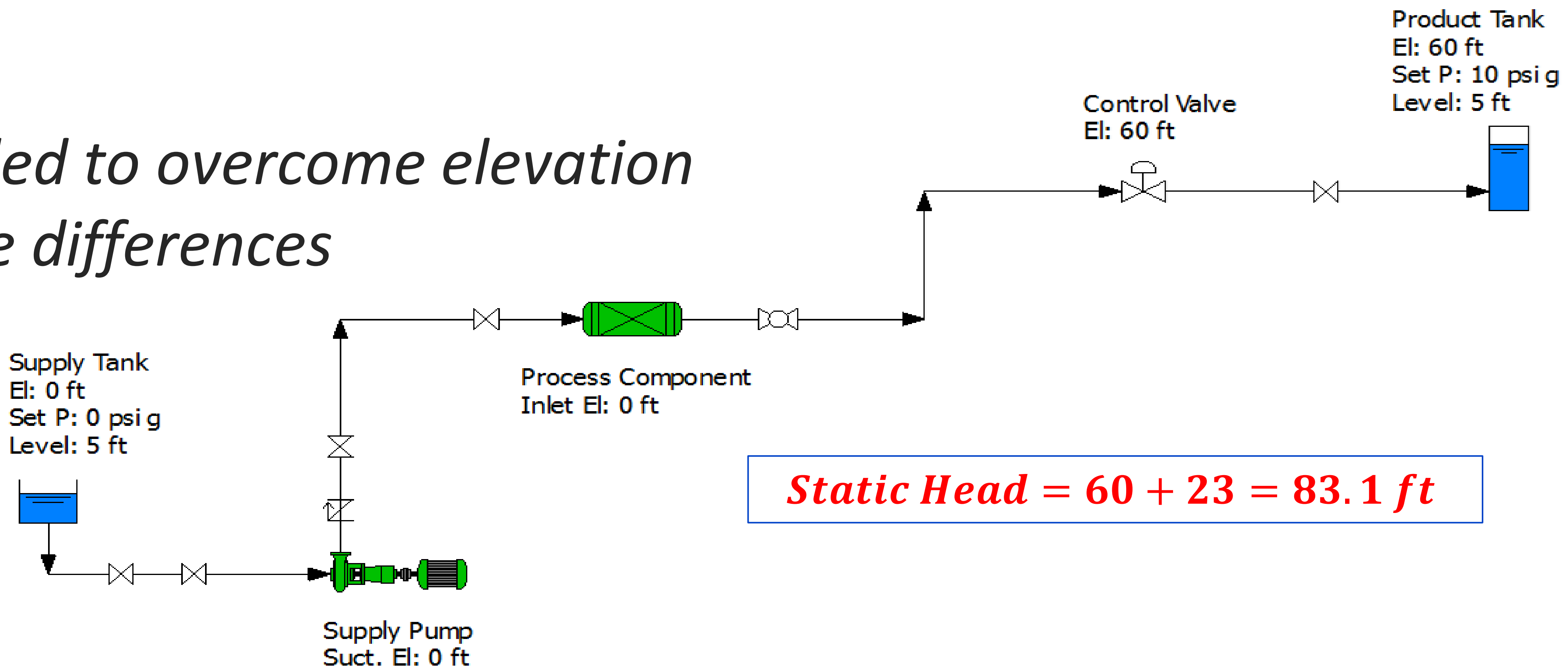
Pump and System Interaction

- Pump must operate on its curve
- Pump operates at intersection of Pump Curve and System Resistance Curve



Static Head

- *Energy needed to overcome elevation and pressure differences*



$$\boxed{\textbf{Static Head} = \mathbf{60 + 23 = 83.1}\ \boldsymbol{ft}}$$

$$Static\ Head = \Delta\ Elevation\ Head + \Delta\ Pressure\ Head$$

$$\Delta\ EH = \left(\begin{matrix}Elevation\ Destination\\ Tank's\ Liquid\ Surface\end{matrix}\right) - \left(\begin{matrix}Elevation\ Supply\\ Tank's\ Liquid\ Surface\end{matrix}\right) = 65\ - 5 = 60\ ft$$

$$\Delta\ PH = \left(\begin{matrix}Destination\ Tank's\\ Surface\ Pressure\end{matrix} - \begin{matrix}Supply\ Tank's\\ Surface\ Pressure\end{matrix}\right)\frac{144}{\rho} = 10 \times \frac{144}{62.4} = 23.1\ ft$$

Dynamic Head

- *Hydraulic energy dissipated as heat, noise, and vibration due to fluid flowing through a device*
- Head loss caused by friction and changes in fluid momentum

- Occurs in :
  - Pipe lines
  - Isolation valves
  - Fittings (e.g., elbows, tees)
  - Equipment (e.g., heat exchangers, filters, strainers)
  - Flow meters (e.g., orifices, nozzles, venturis)

Varying Flow Rate in a System

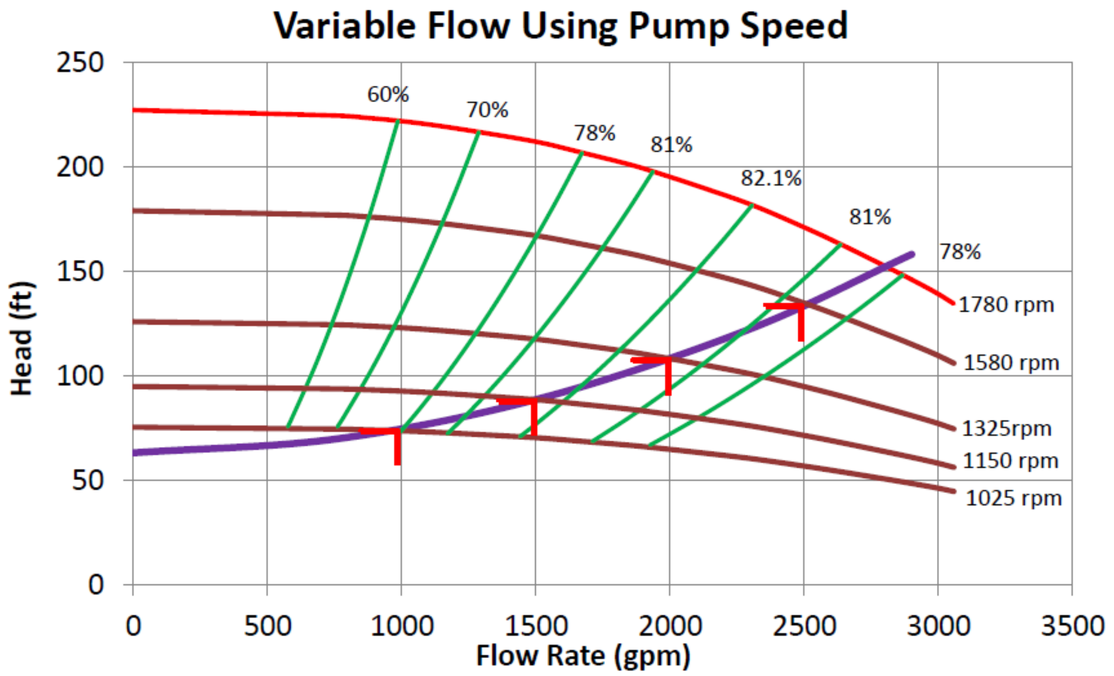
- Pumping systems typically do not operate at a single flow rate

- Flow through system can be adjusted by:
  - *Changing the position of a control valve*
  - *Changing the pump speed with a Adjustable Speed Drive*

- Effects of varying flow rate can be viewed on the system curve

Pump Speed Regulates Flow Rate

- System operating at 2500, 2000, 1500, and 1000 gpm for 2,000 hours/year each
  - Total power used: 388,600 kWh
  - Total Energy Costs: **$38,860**
  - Savings: $30,900 (44%)



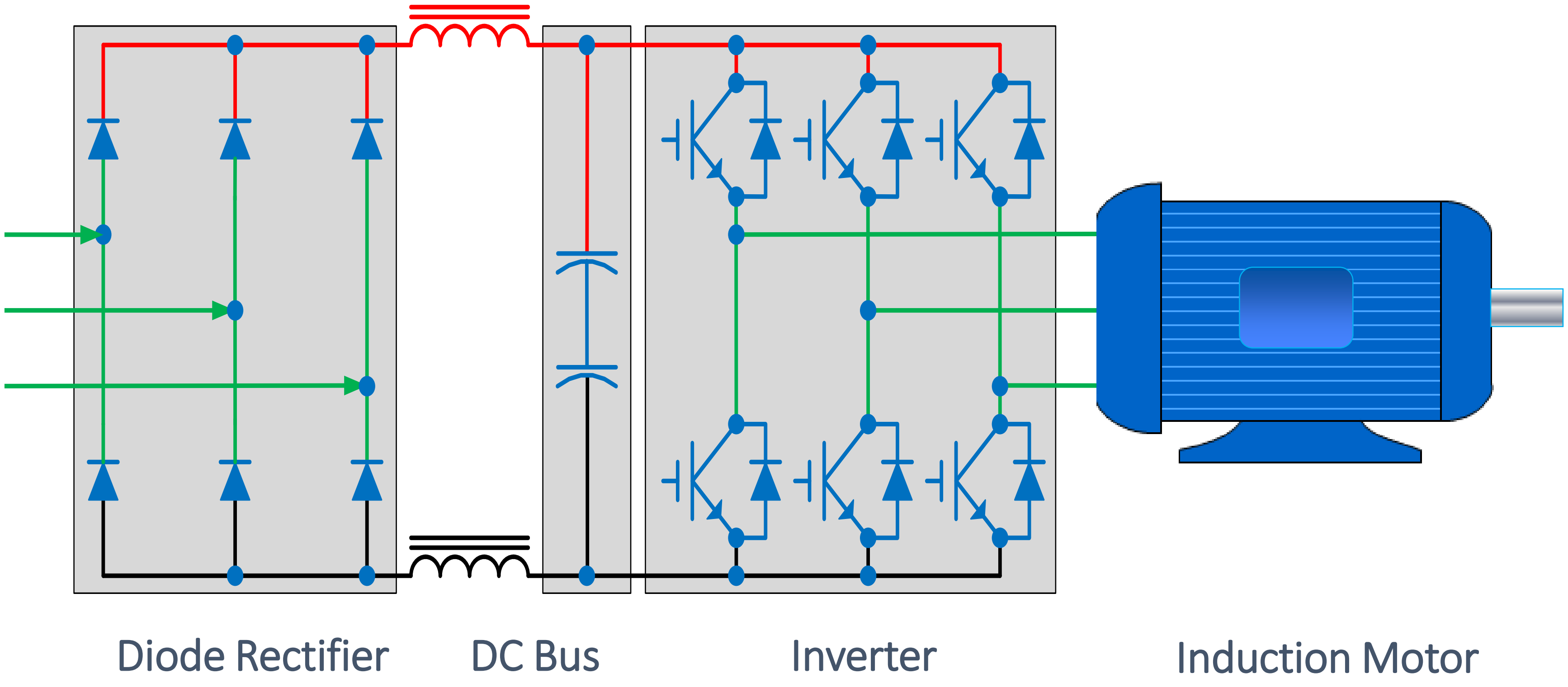
Q (gpm)	H (feet)	Density (lb/ft^3)	Pump Output Power (whp)	Pump Efficiency	Pump Input Power (bhp)	Motor Efficiency	Motor Input Power (hp)	Motor Input Power (kW)	VFD Efficiency	VFD Input Power (kW)	Operating Time (hrs)	Power Consumed (kWh)	Utility Rate ($/kWhr)	Operating Cost
2500	135	62.4	85.3	0.800	106.6	0.93	114.6	85.5	0.98	87.2	2000	174,404	$ 0.10	$ 17,440
2000	107	62.4	54.1	0.815	66.3	0.93	71.3	53.2	0.98	54.3	2000	108,550	$ 0.10	$ 10,855
1500	88	62.4	33.3	0.815	40.9	0.93	44.0	32.8	0.98	33.5	2000	66,956	$ 0.10	$ 6,696
1000	73	62.4	18.4	0.780	23.6	0.93	25.4	19.0	0.98	19.3	2000	38,690	$ 0.10	$ 3,869
											Total	388,600	Total	$ 38,860

Reduce System Flow Rates

- *Higher flow rates than needed require more energy to be added at the pump*
  - Recirculation or bypass flow control
  - Unregulated flow through heat exchangers
  - Number of operating pumps not adjusted for seasonal changes in temperature
  - In batch operations, if fill and drain times be extended, flow rates can be reduced
  - Turn off pumps when flow is not needed
  - Isolate unnecessary flow paths

Variable Frequency Drive (VFD) System Architecture

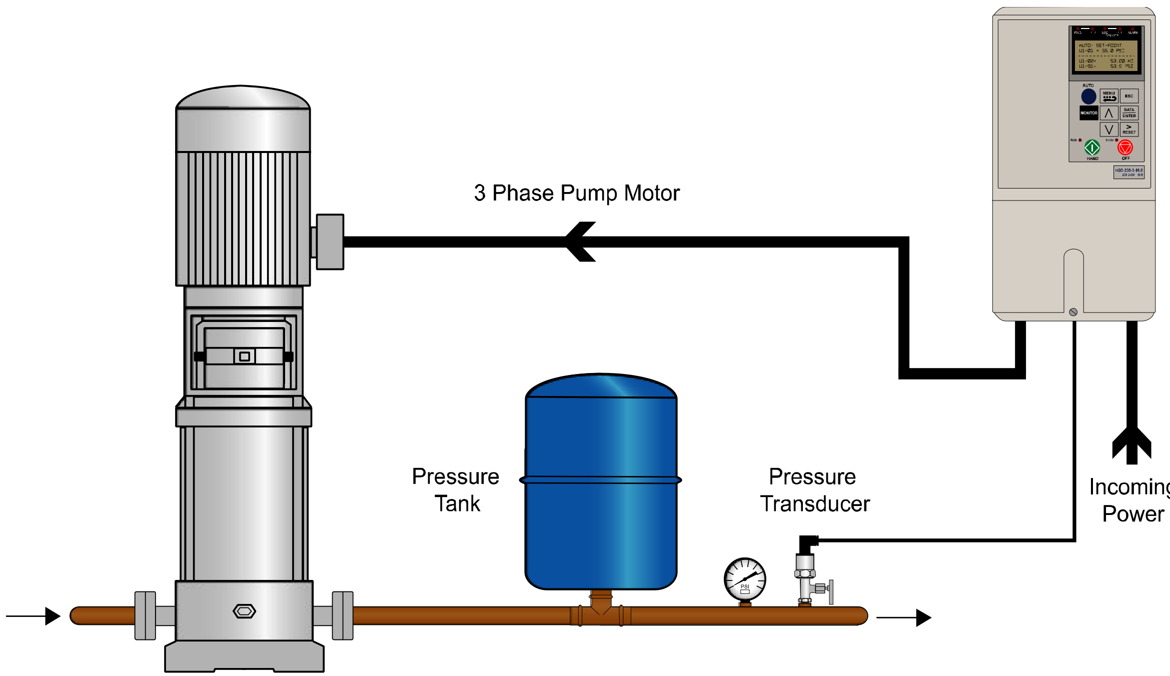
Elements of a Typical Variable Frequency Drive (VFD) System



*VFDs are subsets of Adjustable Speed Drives

Benefits with Variable Frequency Drive

- Reduced Energy Consumption - Affinity Laws
- Improved Process Control
- Increased Product Quality
- Increased Reliability
  - Less Mechanical Stress
  - Less Electrical Stress



Typical VFD Features

Protection Features

- Adjustable electronic motor overload
- Instantaneous over-current / short circuit
- Ground fault (motor circuit)
- Under / over voltage
- Under current (no flow / dry run)
- Surge arrestors

Operating Features

- Forward / Reverse operation without the use of contactors
- Multiple Acceleration and Deceleration ramp rates
- Critical frequency avoidance (skip frequencies)
- Multiple stopping modes: Coast, Ramp or Dynamic Brake
- Process variable control
- Power Filters (DC-Chokes, EMI filter, Harmonic filters)
- Programmable Logic Controller

Achievable Benefits of Pump System Optimization

- *Bottom Line: increased profitability*
- Energy savings and efficiency improvements
- Reliability (minimize unscheduled interruptions)
- Productivity
- Match system equipment to current process market needs
- Consistent quality of end product
- Compliance with rebate and energy initiatives, Corporate Good Neighbor marketing (LEED, Green Buildings, Etc)

Adjustable Speed Drives (ASDs) for Energy Efficiency

EPRI Presenter Bio: Mark Stephens

Mark W. Stephens, PE, CEM, CP EnMS
Principal Project Manager
Manager of EPRI's Industrial Energy Efficiency and Power Quality Services
Professional Engineer; Certified Energy Manager; Certified Practitioner in Energy Manage Systems for ISO 50001

- Mark Stephens manages research and services work related to Industrial Power Quality, Energy Efficiency at EPRI. He is a Senior Member of the Association of Energy Engineers, and several power quality standards working groups in IEEE and CIGRE. With over 30 years of professional experience, he has a solid background in all aspects of industrial plant systems including control systems, power quality, energy efficiency and energy management systems.
- Stephens joined EPRI in 1997 as an employee of the former Power Electronics Application Center (PEAC). His most visible projects include extensive research and management of the seminal EPRI System Compatibility Task 24 research program which led to the development of the SEMI F47 power quality standard. He was the secretary of the CIGRE C4.110 working group (Voltage dip immunity of equipment in installations), and was involved in the development of IEEE 1668-2017 (Recommended Practice for Voltage Sag and Short Interruption Ride-Through Testing for End-Use Electrical Equipment Rated Less than 1000 V). Stephens has worked to characterize and improve power quality, energy efficiency, and lower energy intensity in all manufacturing sectors by leading testing and site audits at customer locations in the worldwide. Working extensively to resolve industrial power quality and energy efficiency issues at the equipment level and process level, he has taught over 70 industrial related courses and is commonly asked to lecture on the subject at conferences worldwide. He has written over 20 conference papers on the subject matter as well.
- Stephens received a Bachelor Science degree in electrical engineering from the University of Tennessee in 1988 and has been a registered professional engineer in the state of Tennessee since 1995, a certified energy manager since 2010 and an ISO 50001 certified practitioner of energy management systems since 2012.

Line-connected Motor vs. ASD-connected Motor

- Line-connected motor operates at full speed at full power
  - Flow may be controlled using valve (less efficient)
  - Full power operation may translate to higher demand charge

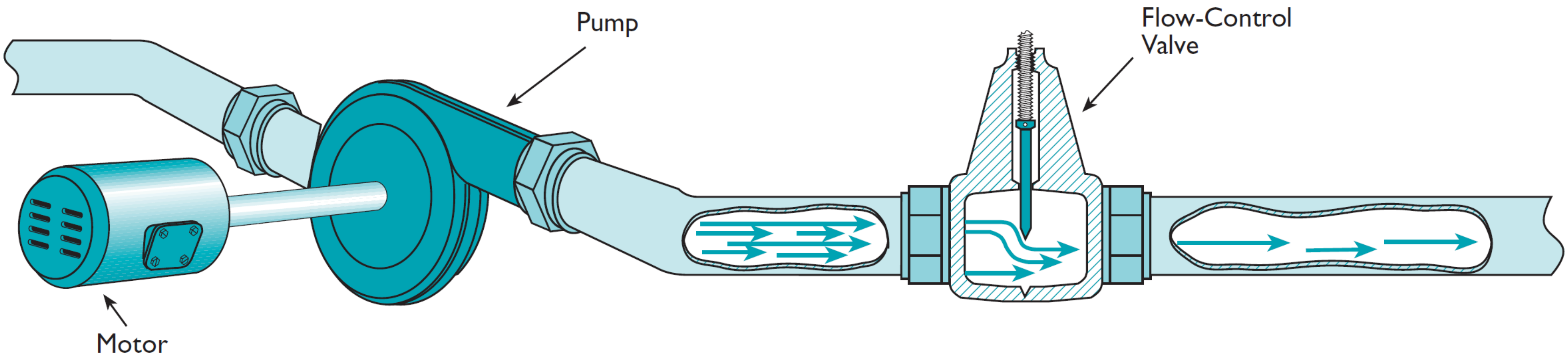


Figure A. Motor-driven process using a flow-control valve to control the rate of flow of a liquid coolant

ASD Allows Reduced Motor Speed

- Significant Power (kW) reduction by reducing motor speed
  - Less kW used
- Less power demand may result in reduced demand charge
- However, pump characteristics change with rpm
  - May require a different pump
- ASDs produce *harmonics*
  - Line Reactors (chokes) or filters may be necessary
    - Added costs

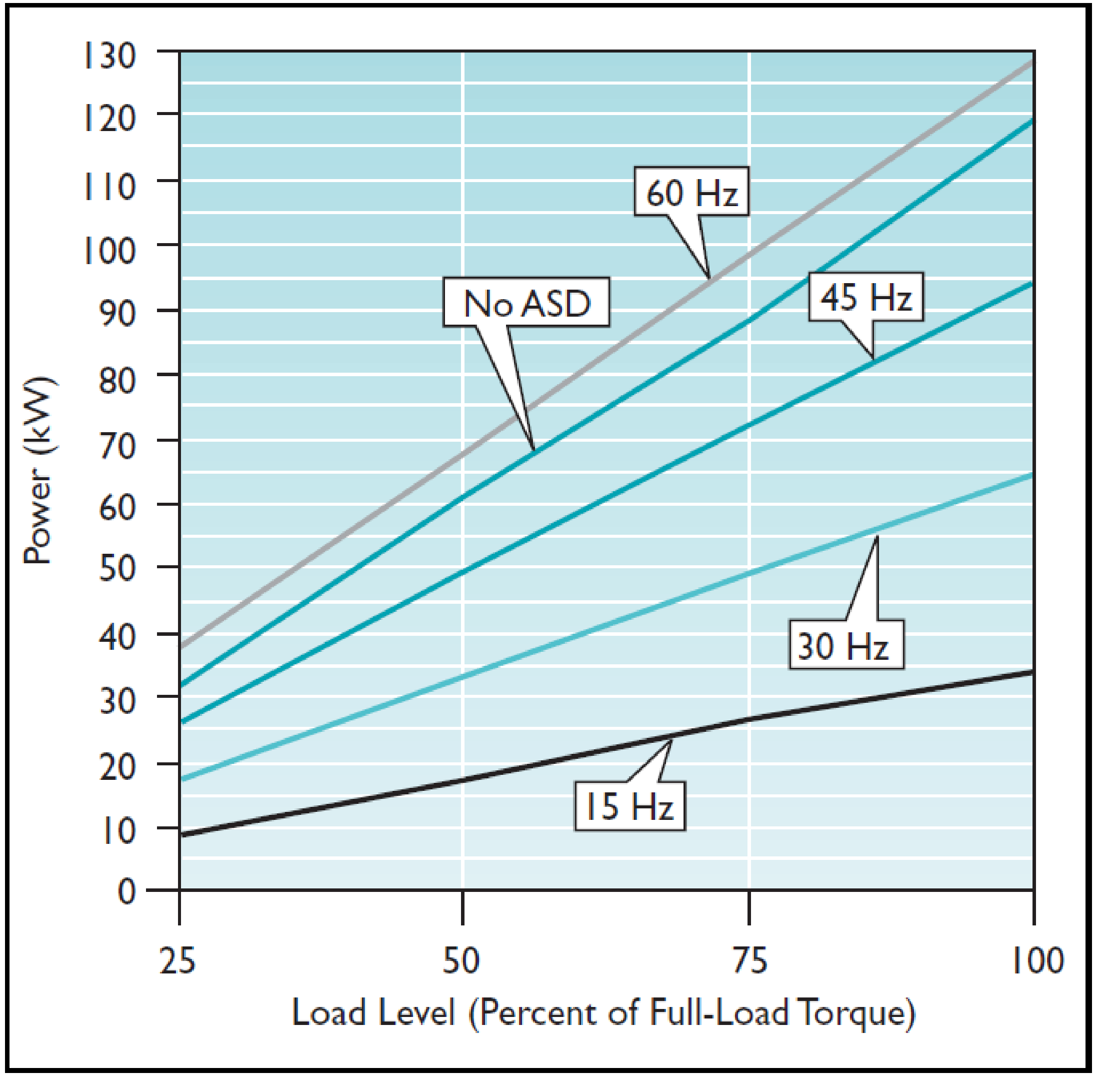


Figure 4. Power consumption of the motor alone (no ASD) and the ASD/ motor system based on load level and ASD frequency

ASD May Produce Savings at Lower Speeds

- Reduced pump and mechanical losses
  - Reduced motor losses
  - Reduced ASD losses
  - Reduced losses = greater efficiency
- Affinity Laws:
  - $Flow_2/Flow_1 = RPM_2/RPM_1$
  - $Pressure_2 / Pressure_1 = (RPM_2)^2 /(RPM_1)^2$
  - $HP_2/HP_1 = (RPM_2)^3 /(RPM_1)^3$
- Pumps:
  - HP = GPM * Head (feet) * Specific Gravity / 1713 * Pump efficiency⁺
  - HP = GPM * PSI * Specific Gravity / 1713 * Pump efficiency⁺

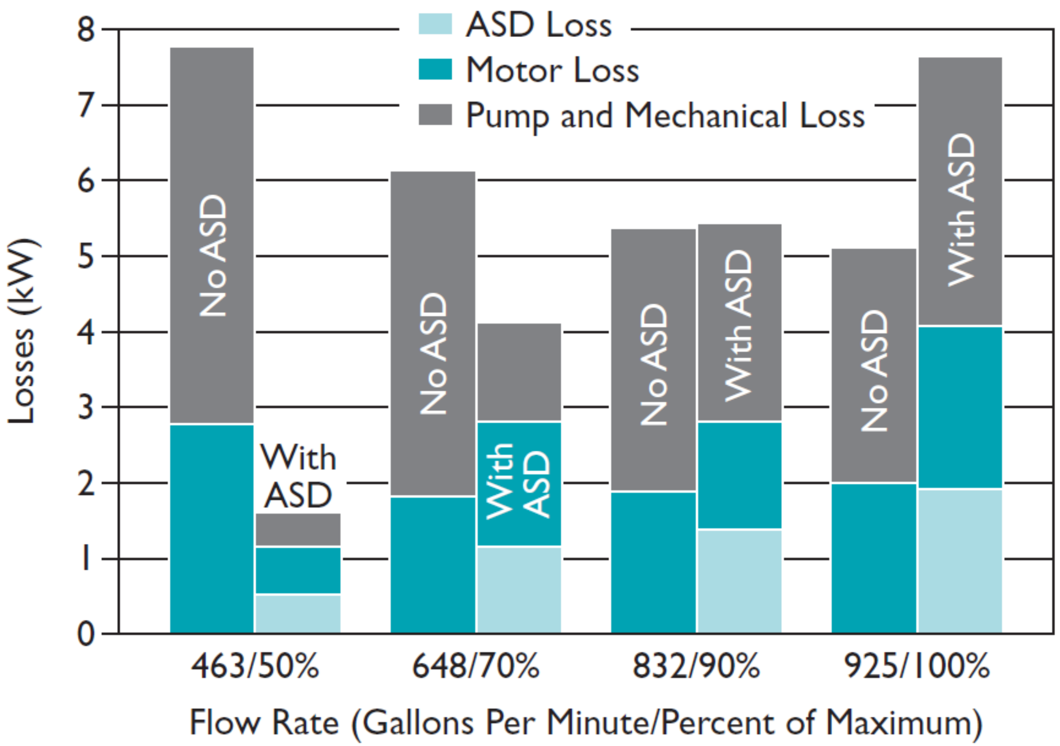


Figure B. Losses in system elements with mechanical control versus ASD control at four different flow rates

⁺ **Can vary greatly**

Pump Configuration Considerations

- Cost may depend on existing pump configuration, available voltage, or necessary modifications
  - Submersible
  - In-line
  - Other

https://dealerselectric.com/Package-GT1245-and-FRN100G11S-2UX.asp

- Pump motor-ASD packages may be available
  - Example: 100 HP, 3600 RPM, 405TSC Frame Marathon Motor with 100 HP, 230 V, 3 Phase, Fuji FRN VFD
    - On-line price: $5,658

- Therefore, many factors may influence the cost of implementation including necessary protective cabinets

Slowing Motor Speed to Save Costs ($0.1532/kWh, $12/kW)

- Case 1: Direct Connect Motor
  - HP1 = 100, or 74.57 kW (rpm1 = 1800 , full rpm)
  - 74.57 kW * 3960 hr = 295,297 kWh
    - 295,297 kWh * $0.1532/kwh = $45,239.50 energy cost
  - $12/kW/month * 74.5 kW * 6 months = $5,364 demand cost

Total energy cost: $50,603.50

- Case 2: Drive Connected Motor (up to ½ load)
  - If HP2 = 48 HP, or 35.79 kW (rpm2 = 1406 , using affinity laws…)
  - 35.79 kW* 3960 hr = 141,728 kWh
    - 141,728 kWh * $0.1532 /kwh = $21,713 energy cost
  - $12/kW/month * 48 kW * 6 months = $3,456

Total energy cost: $25,169

[Savings of $25,434 over the growing season]

Drives for Motors

- **Single-phase** customers (can adapt for three-phase motors)
  - Some drive models accept either 1-phase or 3-phase input
    - Single phase conductor and drive front-end may not handle required current for full load operation, therefore, derating of drive is required
    - Implementation costs may depend upon pump configurations (immersible, in-line, etc.) which are not known
      - *Payback within one growing season may be possible*

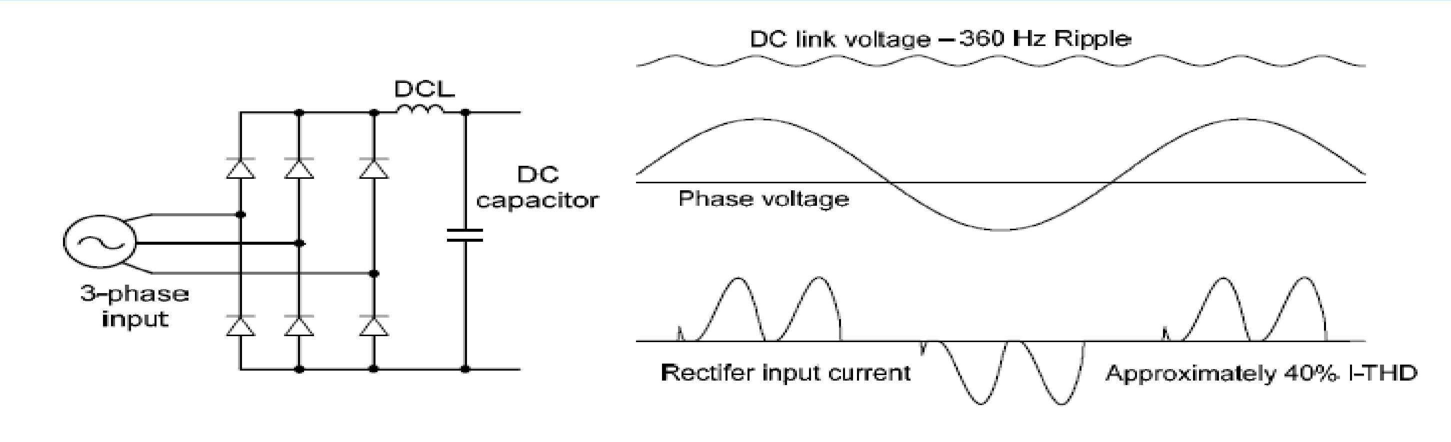
  - Bonitron offers a device connecting to the ASD DC bus allowing single-phase-to-three-phase *full-power* charging of the bus to power the 3-phase motor
    - Advantages – operate up to 125 HP 3-phase drive and motor at full and reduced speed
    - Disadvantage – added cost of Bonitron device to ASD and motor cost, *higher current draw*
      - *Available hp: 15, 30, 50, 75, 125 plus line reactors*
      - *Total Material Cost ranges from ~$1300 (15hp) to ~$6,100 (125hp)*
      - *Drive and motor costs vary but payback within one growing season may be possible*

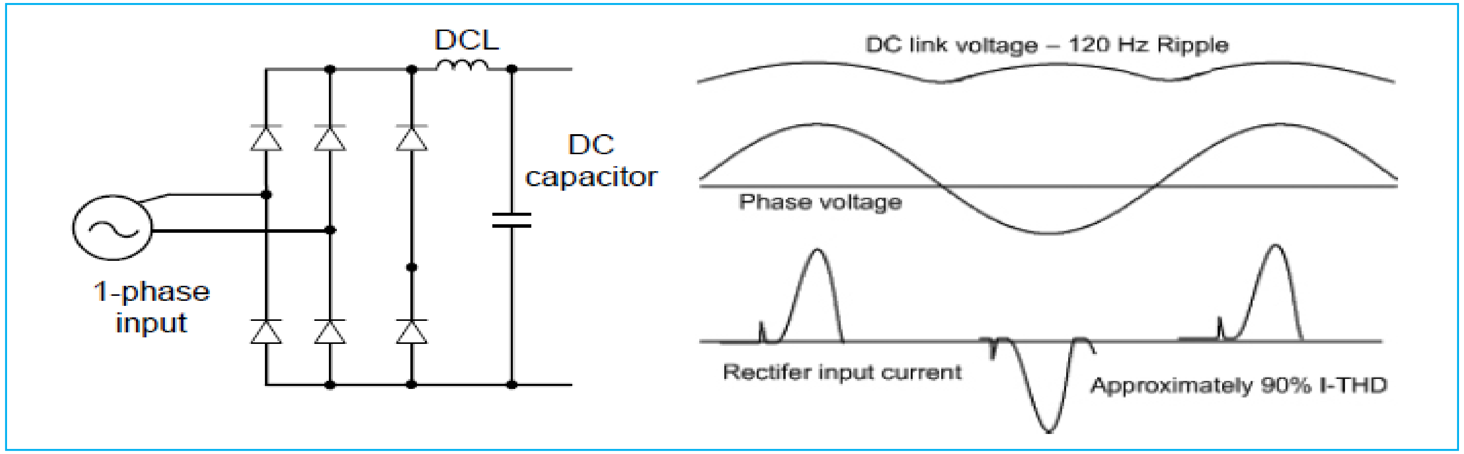
Drives for Motors

- **Three-phase** customers
  - Implementation costs may depend upon pump configurations (immersible, in-line, etc.) which are not known
    - *Payback within one growing season may be possible*

Three Phase Adjustable Speed Drives used in Single-Phase Applications

- Note the increased total harmonic distortion when powering a three phase input ASD with single phase voltage.





Ref: Yaskawa Application note AN.AFD.15, Applying Drives to Single-Phase Input Applications

Ref: ab.rockwellautomation.com

Sampling of Emerging Motor Technologies

Single-phase Solution: Written-pole Motor

- Another option for single-phase applications is the written-pole motor
  - Advantages:
    - Smooth starting and less starting current
      - About 2x full-load current vs. 6 to 12 times for normal induction motor
      - Less flicker and voltage drop at startup
    - 93% efficiency
    - Up to 100 hp
  - Disadvantages: no change in speed possible or resulting energy savings

SPPS – Single-Phase Power Solutions

- BELLE single-phase, written-pole motor (30-100 hp)
- Synchronous operation at 1800 rpm
  - Increases flow (2-3%), pressure (4-6%), and horsepower (8-10%)

Case study 1

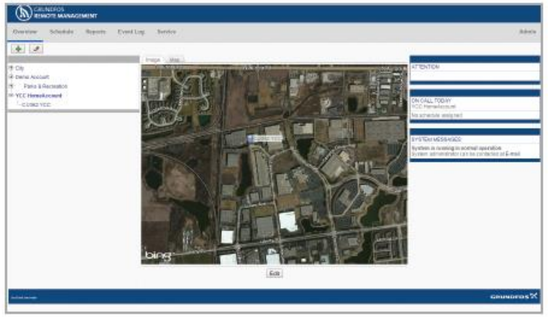
- Two 75 hp motors for two 50 hp booster pumps providing 1,600 gpm
- **$1.6M energy savings since 2002**

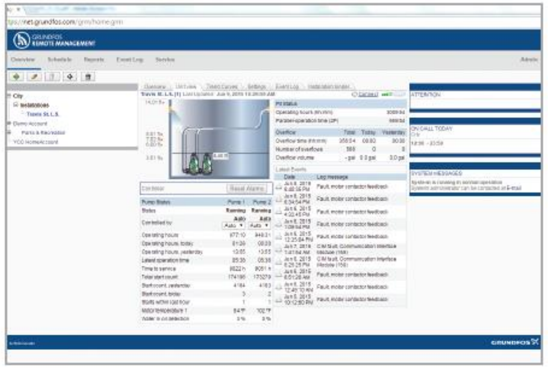
Case study 2

- 100 hp motor for ½-mile center pivot in TX panhandle
- Estimated savings: $650/mo over prior nat. gas engine, not including maintenance and EPA requirements

Grundfos Remote Management (GRM)

- Web-based remote monitoring, management and reporting system
- Allows controls from PC or smartphone
- Pump alarms
- Pump controllers
- Auxiliary sensors and meters





ALARMS AND WARNINGS	
Overflow	Motor temperature
High level	Overvoltage
Alarm level	Undervoltage
Dry running	Overload
Bearing temp. high	Underload
.... and many more	

OPERATIONAL DATA	
Pumped volume	Operation time
Energy consumption	Number of starts
Specific Energy	Parallel running time
.... and more	

REMOTE CONTROL
Manual operation (forced start)
Alarm reset
Adjust start, stop and alarm levels

Features and benefits:

- Status overview of entire system in map / aerial image
- Live monitoring, analysis and adjustments
- Trends and reports to identify improvement opportunities
- Manage on-call personnel to receive system alerts
- Plan service and maintenance based on actual operating data

Software Motor Corporation

SMC
SOFTWARE MOTOR CORPORATION

Smart Motor System: Switched Reluctance Motor

Available up to 10 hp (20 hp in development)

Software-based controller improves motor efficiency by 75% compared to single-speed induction motor

- Controller for switched reluctance motor (with or without position sensor)
- Improved coil winding techniques
- Motor operates with SMC inverters, connected & controlled through cloud

Vulcan Ultra-Efficient High Rotor Pole Switched Reluctance Motor

Vulcan Programmable Variable Speed Drive

Vulcan Advanced Motor Controller

Advanced Software

Cutting-edge Cloud Integration

- Bringing energy efficiency through IoT motor system for
- UL certified
- Many agricultural fan users
- Currently 2 pump trials → interest in participating?

Advantages of Switched-Reluctance Motor

- Higher torque and efficiency at low speed than induction motor
- Simple oval coils with no magnets improve reliability
- Lower operating temp allows installation in an enclosure
- Variable-speed, high-torque motor offers energy savings and improved reliability in irrigation applications

Pump System Discussion Questions

- Who uses single-phase vs. three-phase power systems?
- Range of pump sizes?
- Extent of use of adjustable speed drives?

- Number of water sources per pivot?
- Length of pipe runs to pivots?

- Current challenges?
- Technology interest?

Irrigation Resources Audit

- **Objective:** quantify real costs of irrigation using gas vs. electric
- EPRI offering energy audit to 5 irrigators <u>at no cost</u>
- **Example info:**
  - Acreage, crops:
  - Number of pumps, wells, pivots:
  - Horsepower of pumps used
  - Average head pressure:
  - Irrigation schedule (daily, seasonal):
  - Electrical service available? 3-phase? What voltage?

Please reach out if you would like to participate!

Thanks for your attention!

Together…Shaping the Future of Electricity