Optimization in Water Pumping Systems

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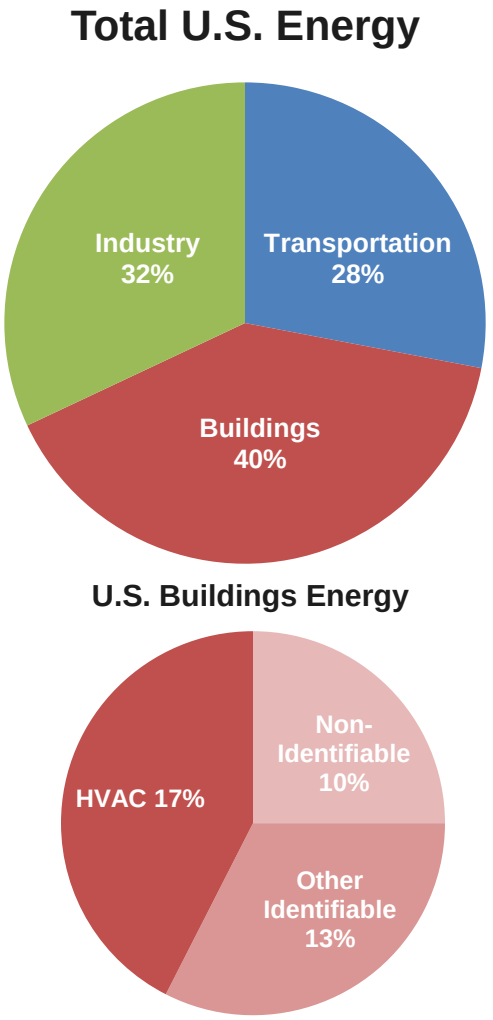
Learning Objectives

At the end of this program, participants will be able to:

- differentiate traditional pump selection versus modern pump selection to meet ASHRAE 90.1 requirements
- discuss added values that provide cost and energy savings in pumping units with integrated controls
- describe how sensorless pump control works and its advantages, and
- list the various ways that integrated pumping systems can contribute towards LEED® points earned for a building project.

U.S. Energy Consumption 2010

- Buildings consume 40% of total U.S. energy.
- Of this 40%, HVAC systems represent 17% of energy consumption.
- Pumps play a pivotal role in HVAC systems.



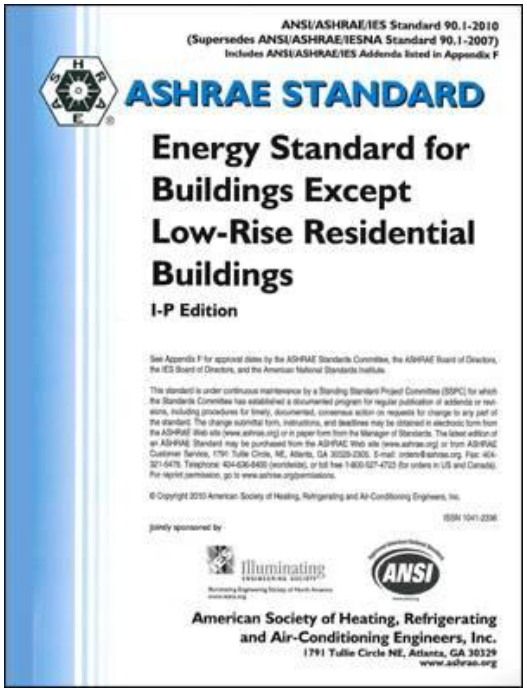
Building Loads

- Commercial buildings use chilled water systems for cooling, and hot water systems for heating.
- These systems operate at part-load the vast majority of the time.
- The emphasis on meeting heating and cooling loads tends to encourage the practice of oversizing pumps.
- A systems approach will typically yield a quieter, more efficient, and more reliable hydronic system.

ASHRAE Standard 90.1-2010 / 13

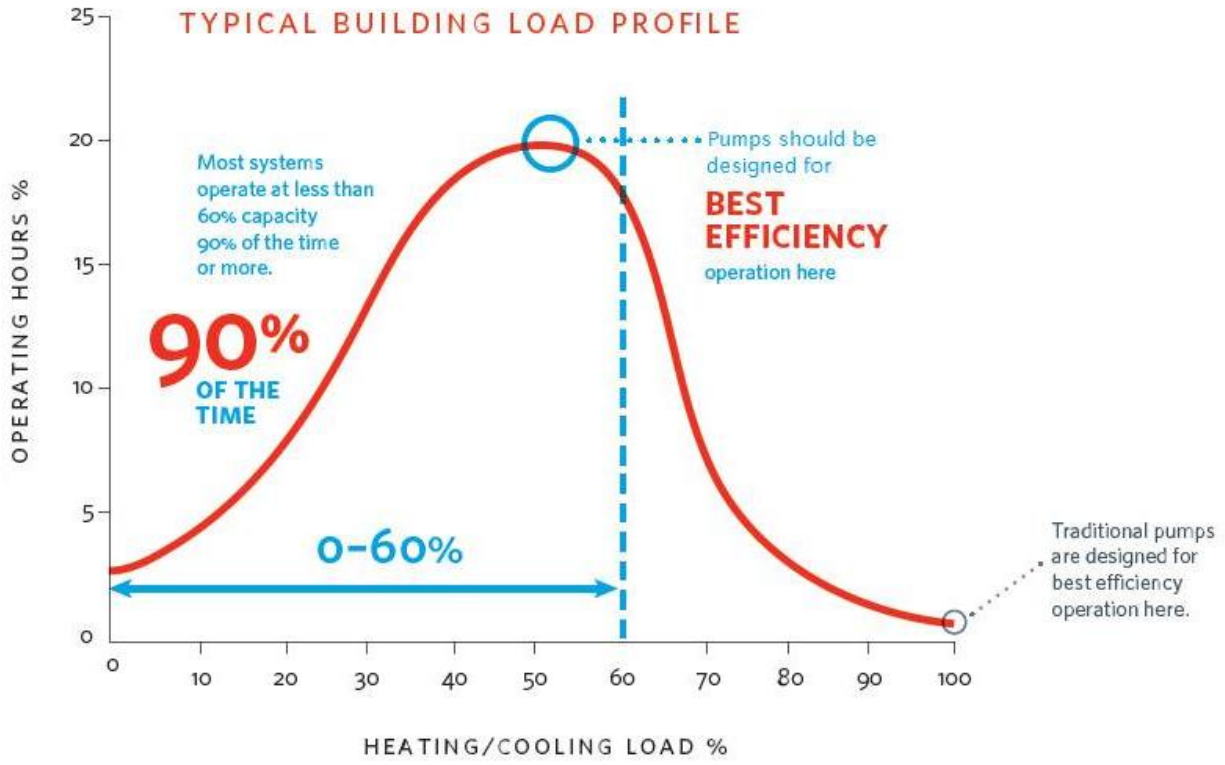
Section 6.5.4 of the ASHRAE 90.1 standard states:

"6.5.4.1/2 Hydronic Variable Flow Systems …Individual chilled water pumps serving variable flow systems having motors exceeding 5 hp (3.7 kW) shall have controls and/or devices (such as variable speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow…"



Building Load Profile

Most systems operate at less than 60% capacity, 90% of the time or more.



Variable Flow Pumping Systems

- Can adapt to changing capacity demands.
- Should be designed for best efficiency at part-load:
  - lower energy consumption
  - reduced operating costs, and
  - improved equipment reliability.

Traditional Flow Control

- Most of the buildings in the 1970s used two basic types of flow control:
  - flow bypasses, or
  - throttling discharge valves with trimmed pump impellers.

- Bypass arrangements is the least efficient and least used method of flow control.

- Throttling control does save energy compared to bypass methods; a variable speed operation can save much more energy.

Modern Control with Differential Pressure Sensor

- The building industry has transitioned to using variable speed pumps with two-way valves to achieve variable flow.

- Today, a system composed of the pump, VFD, and sensor is commonly used to control HVAC systems.

Integrated Control Pumping Systems

These pumping systems with integrated controls can achieve the lowest first cost AND lowest operating cost when the pump, motor, and variable speed controls are integrated.

Control Options:

- Pump manufacturer controls
- Building management system (BMS)
- Sensorless mode
- Remote sensors

Feature Options:

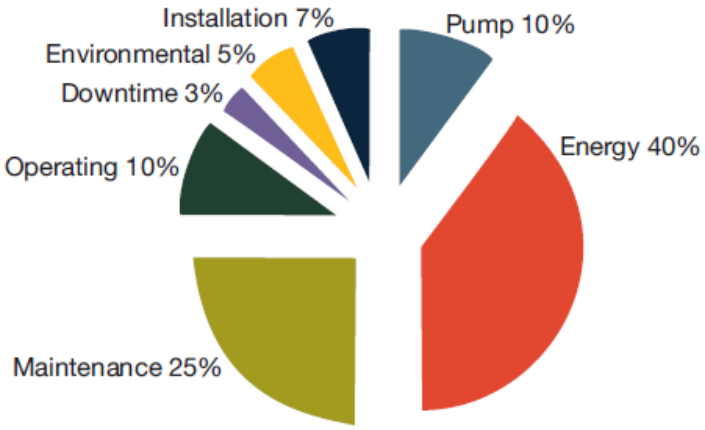
- Integrated controls from 20 W to 450 hp/315 kW
- Stand-alone controls to 1250 hp/900 kW
- Outdoor capable to 125 hp/90 kW

Life Cycle Cost of Pumping System

Greatest cost in the lifetime of a pumping unit is the operational energy costs.

Operation energy factors include:

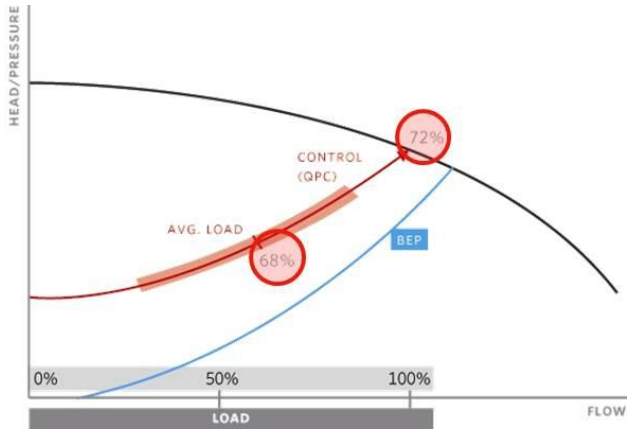
- Optimized Capacity and Motor Power
- Pump Motor Starting
- Quadratic Pressure Control
- All-Variable Plant Controls, and
- Sensorless Controls.



Selections Save Energy and Cost

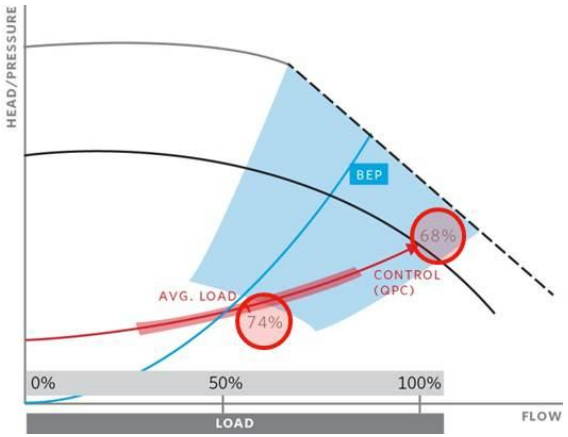
The average load efficiency is higher with an integrated control pump when compared to a pump with wall-mounted controls (non-integrated), and it is capable of saving 7% in pump costs and 14% in energy costs.

4" Pump with non-integrated controls



Design Point: 72% efficiency
Average Load: 68% efficiency

3" Pump with integrated controls



Design Point: 68% efficiency
Average Load: 74% efficiency

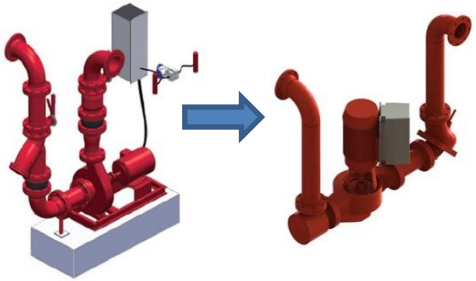
Optimized Capacity and Motor Power

Comparison of a 1000 USgpm @ 90 ft pump, 40 hp motor vs. a 30 hp traditional motor:

- Savings in smaller motor and controls
- Motor/integrated controls = $1,070 or 18%
- Power wiring = $50
- Total harmonic distortion = 25% reduction
- 50% flow is 30% or 12hp
  - 30 hp motor delivers 12hp - 1.5 percentage points more efficient than 40 hp

Traditional Pump with Wall-Mounted Controls

Integrated Control Pump

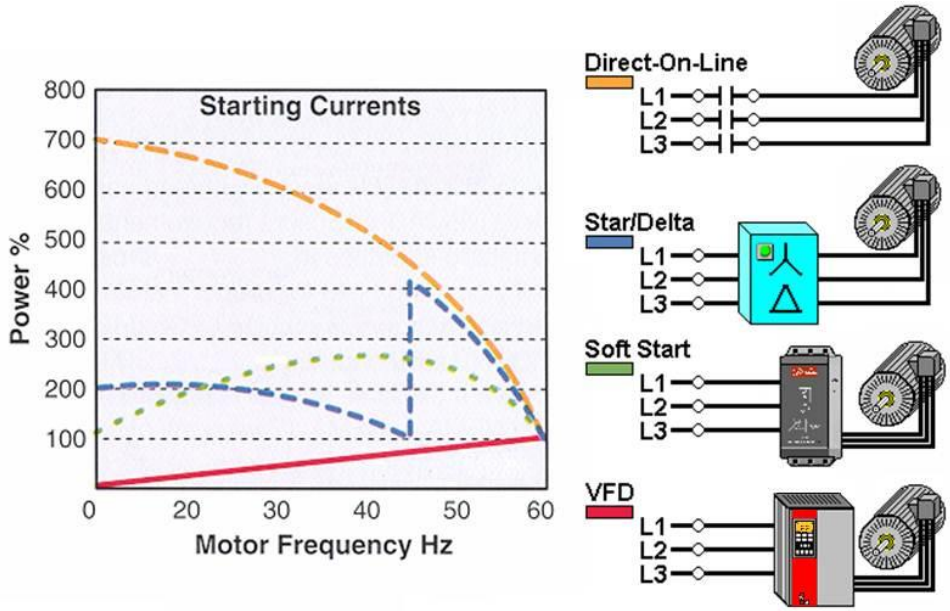


40 hp

30 hp

Pump Motor Starting

- Pump motor starting must provide a gentle ramp up or down in speed.
- Direct-on-line is the oldest way to start a pump.
- The current required to start can go as high as 700%.



Pump Motor Starting

Star/Delta:

- a relay switches the configuration from Star to Delta when the motor reaches close to maximum speed

Soft Start:

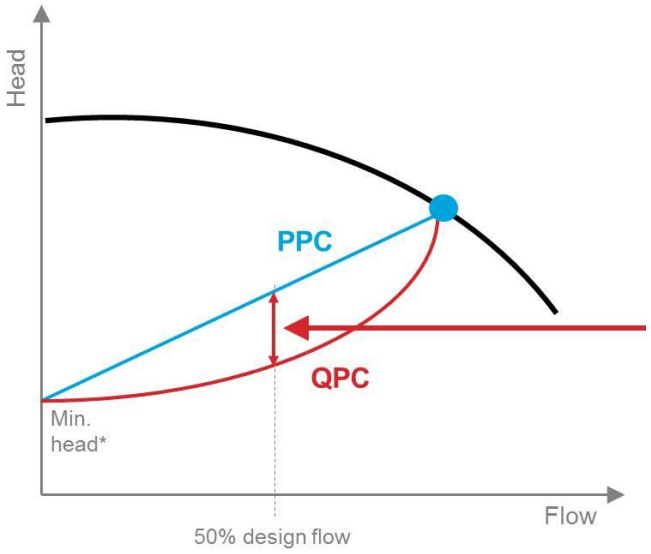
- electric timers monitor/limit either the voltage or the current
- many of these devices cannot be used for long periods of time

VFDs/Integrated Controls:

- controls both the frequency and the voltage simultaneously
- provides full control over the acceleration/deceleration ramps
- the best method of starting or stopping a pump

Energy Savings: Control Curve Strategies

Using a quadratic pressure control (QPC) control curve can yield more than 25% energy savings at part-load over a proportional pressure control (PPC) control curve at part-load.



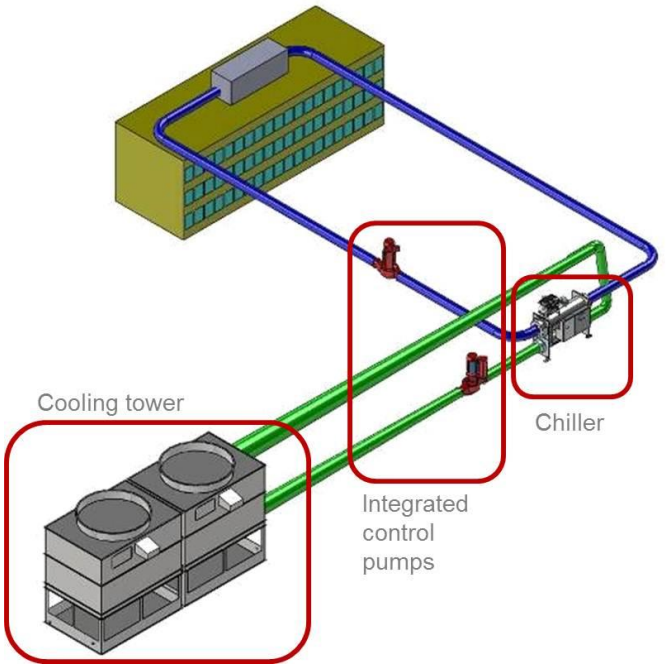
25%+
Energy Savings
at 50% Design Flow

Energy Savings: Chiller and Cooling Tower

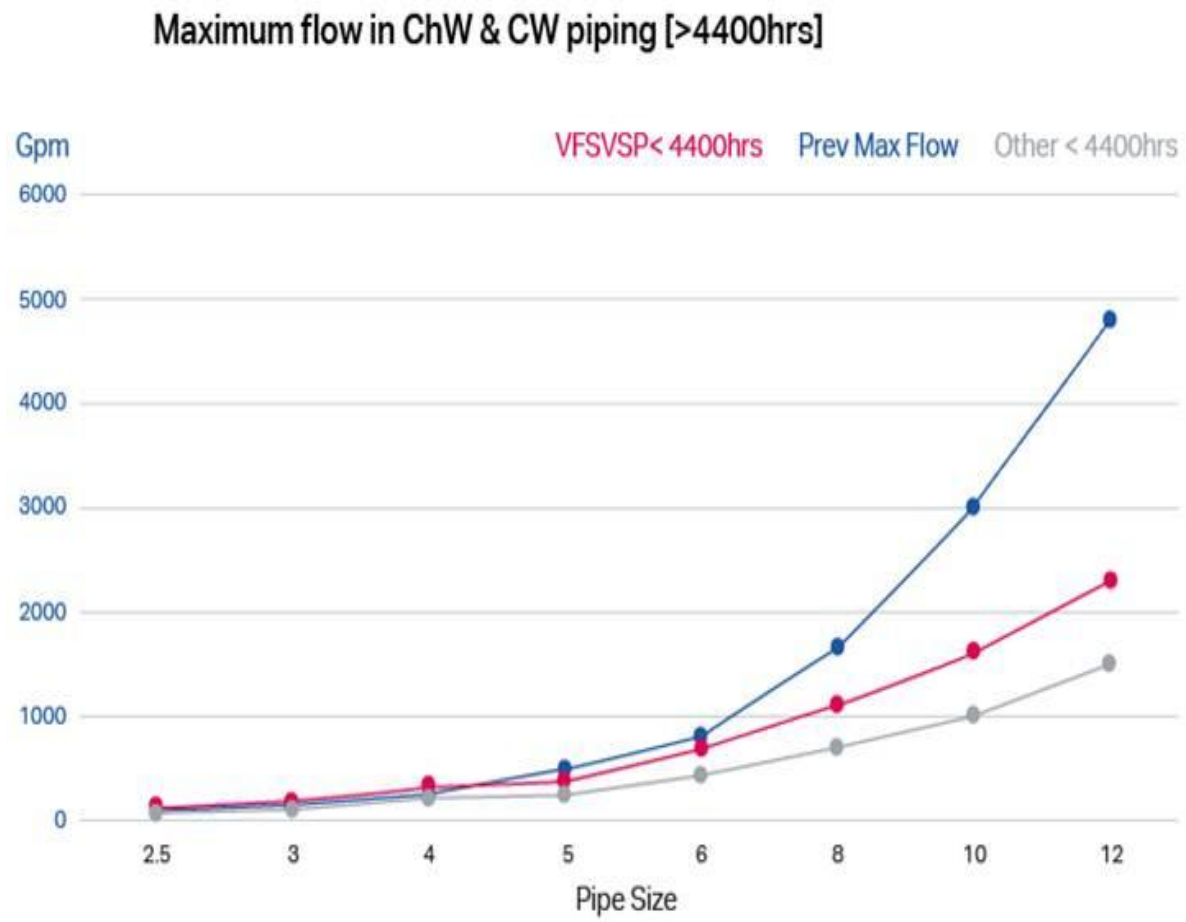
Using an all-variable plant:

- lowers the chiller's condenser pressure requirement
- lowers the chiller's energy consumption
- enables higher tower performance
- enables better system efficiency through improved balancing of air and water flow ratios

Integrated control pumps can be used with ultra-high-efficiency plant controllers to provide energy savings.



ASHRAE 90.1-2010: Table 6.5.4.5



Pumping Implications

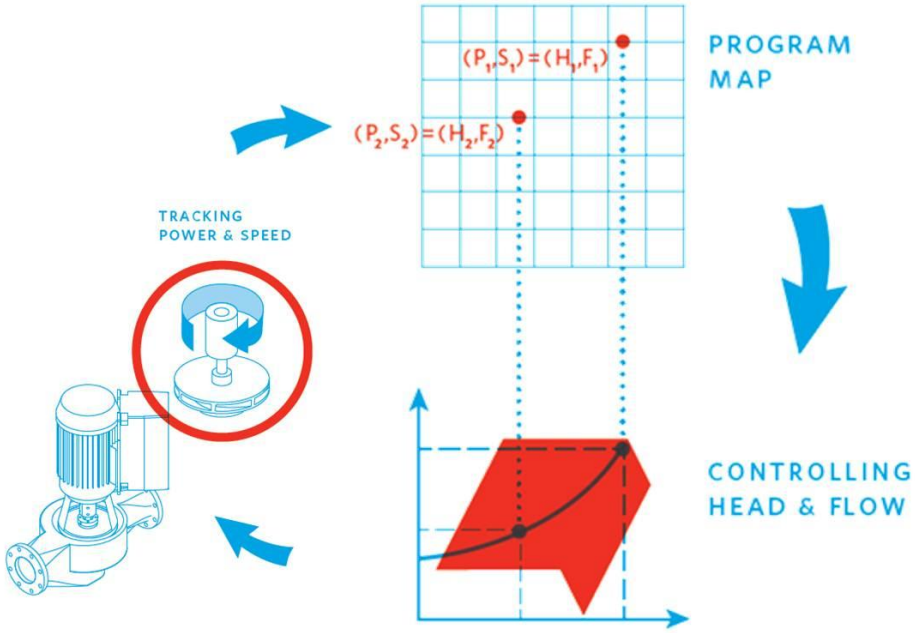
- For example, at 1400 USgpm, the ASHRAE 90.1-2007 requirement was 8" pipe.
- Under 90.1-2010, the requirement is 10" for variable speed systems, and 12" for constant speed systems.
- This provides another example of cost savings from variable speed, integrated control pumps:
  - 10" pipe x 100 ft. long = $4,640 pipe cost
  - 12" pipe x 100 ft. long = $5,260 pipe cost

Sensorless Control

Pre-programs the pump curve parameters into the integrated controls.

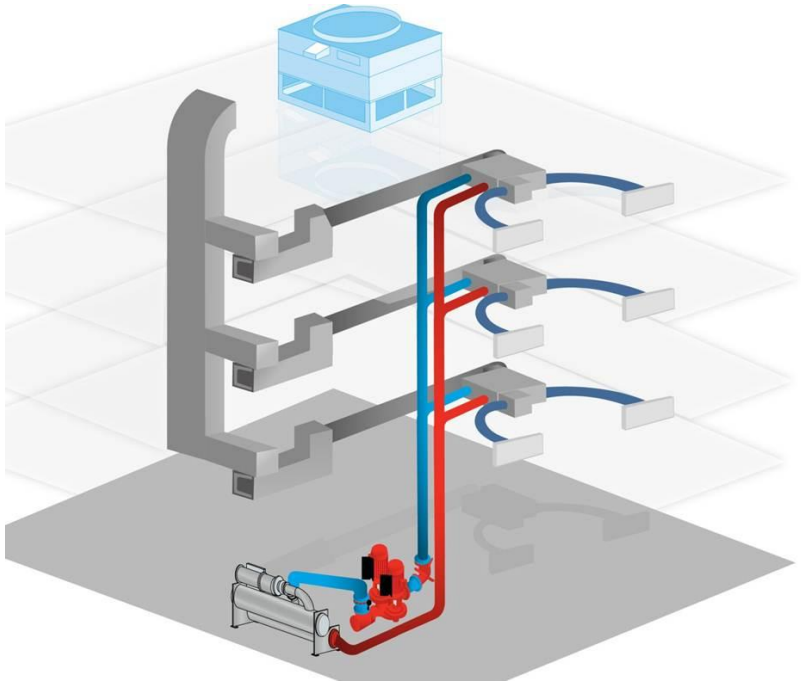
Key Parameters

- Flow
- Head
- Power
- Speed



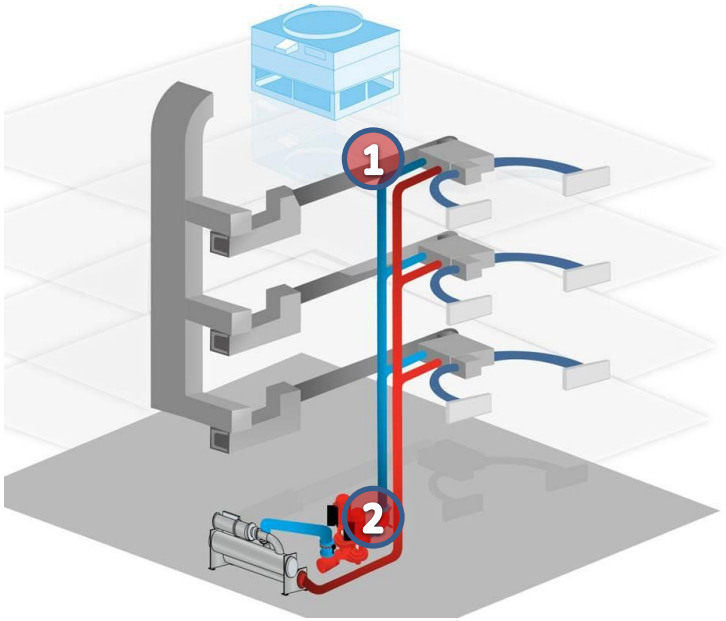
Sensorless Control: Traditional Control with Differential Pressure Sensor

In this simplified example, the chiller and pump are found in the basement mechanical room, and the pump distributes chilled water to the cooling coils.



Sensor Location

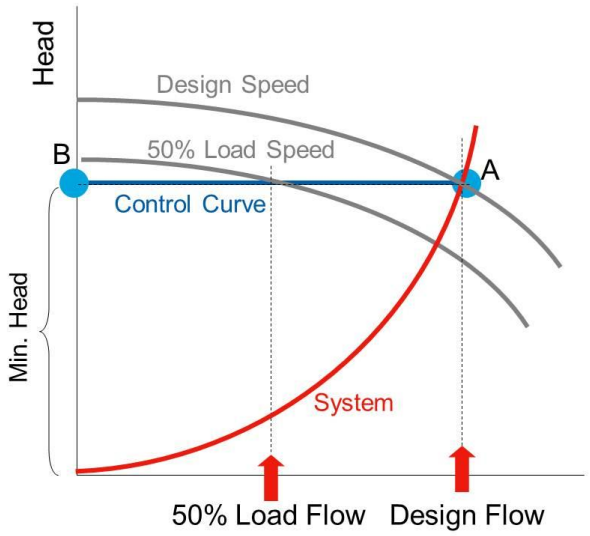
- One method is to install the sensor at the most remote load (1).
- Another option is to install it in the mechanical room (2).



Possible sensor locations:
1. Most remote load
2. Mechanical room

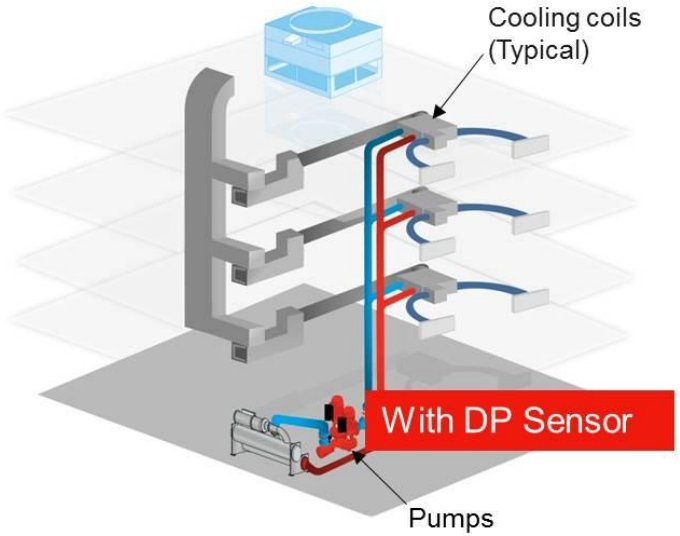
Sensor Location in Mechanical Room

- Minimum head is the same as the design head
- Doesn't result in much energy savings at 50% load flow
- Configuration won't meet the ASHRAE 90.1 energy standard
- Very simple to install



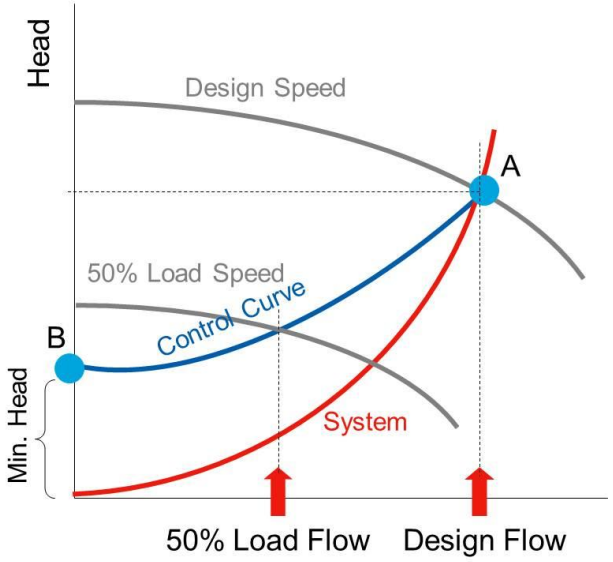
A Design Point

B Minimum Head



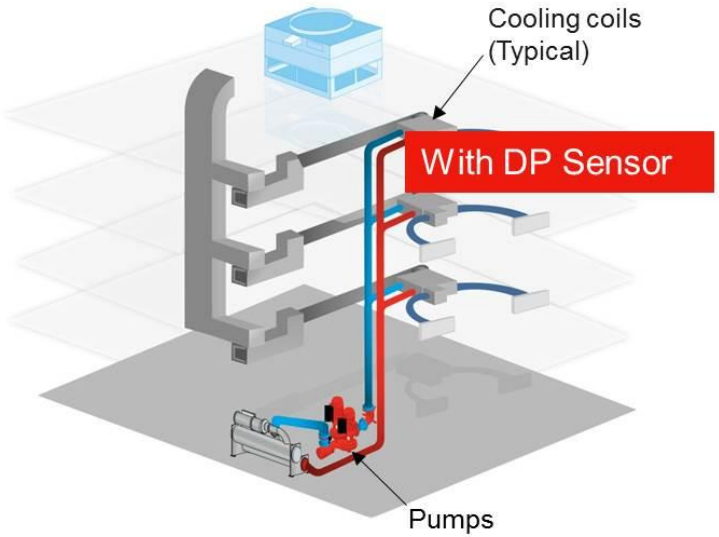
Sensor Location Remote Load

- Configuration provides tremendous energy savings, meeting ASHRAE 90.1 standard for energy efficient operation
- Difficult to install



A Design Point

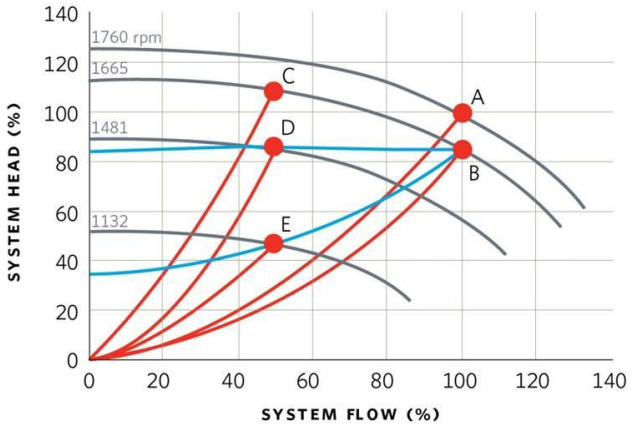
B Minimum Head



Sensor Location Operating Cost Comparison

Sensorless control can provide the same performance as a remote load sensor (Row E).

	Pump	Power	Incremental Energy Savings	Cumulative Energy Savings
A	• Constant Speed Throttled • Described in slide 15 • Traditional method	32.03		
B	• Reduced Speed Unthrottled • Constant Flow	27.11	15%	15%
C	• Reduced Constant Speed • Variable Flow	19.36	29%	40%
D	• Variable Speed • Variable Flow • Mechanical Room Sensor	14.35	26%	55%
E	• Integrated Control Pump • Remote Load Sensor • Sensorless	7.32	49%	77%

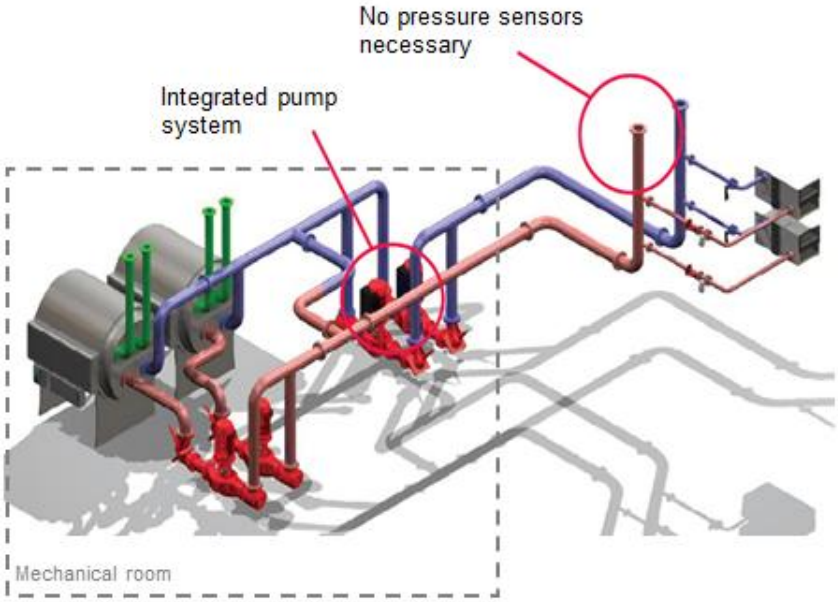


Points A and B are at the design flow. Points C, D, and E are 50% of design flow. Note that only E is able to meet the ASHRAE 90.1 standard for 70% energy savings at 50% of design flow.

Installation Savings for Lowest First Cost: Sensorless Controls

Sensorless controls provide savings in multiple areas:

- 49% more energy saved than with a sensor in the mechanical room.
- $2000 saved in installation, wiring, and sensor costs.
- An estimated $600 per pump comes from simplified commissioning alone.



Sensorless Control On-Site

Installing an integrated pump system negates the 3-4 month wait for commissioning of the sensors.

A 6x6x11.5 30 hp integrated pump system:

- Cost of pump = $9,702 USD
- Assume $0.10/kWh
- Variable flow-constant speed operation = $10,312/yr
- Variable flow-variable speed operation = $6,145/yr
- Savings = $4,167/yr
- Four-month savings = $1,389 or 14% of the pump cost

Flow Meter and Control

- Sensorless control can eliminate the need for a flow meter.
- Sensorless mode provides the ability for digital flow readout with an accuracy of +/- 5% and communication to the BMS.
- Capabilities include minimum/maximum for pump flow output.

=

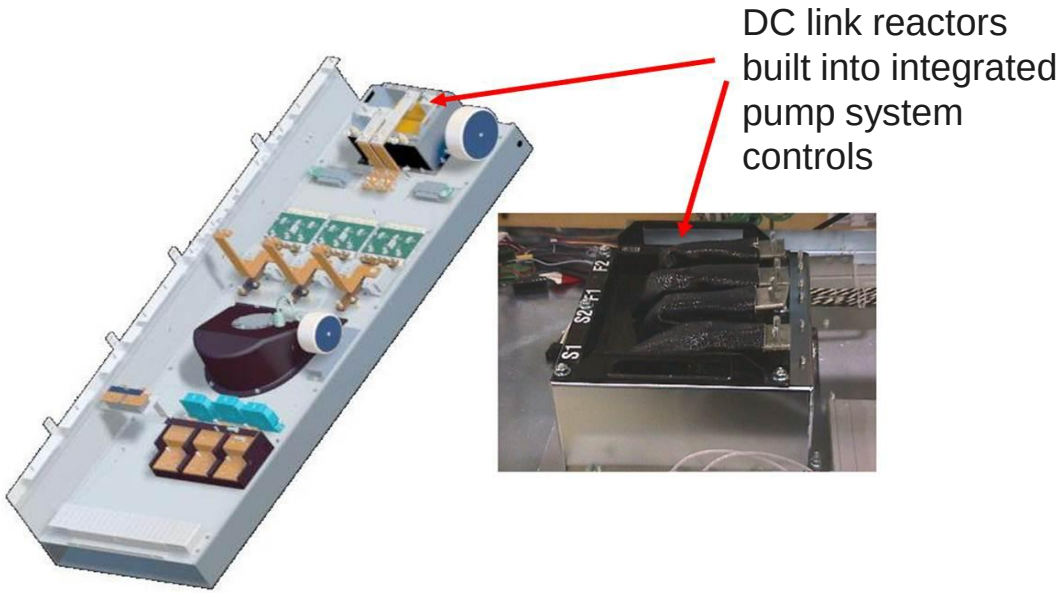
Wiring VFD Mounting Bracket

- With a sensorless control system, the wiring and conduit running out to the furthest pump can be eliminated.
- The only set of wiring comes down from the ceiling.
- The potential wiring variable frequency drive (VFD) mounting bracket savings—is estimated to be $340 per pump.

Harmonic Distortion

- The integrated pump system controls have DC link reactors built into the controls, equivalent to 5% AC line reactors.

- DC link reactors help reduce power line transients and mitigate harmonic distortion.



Emission and Immunity

- Integrated pumping systems include radio frequency interference (RFI) filters to ensure compliance to low emission and immunity requirements.

- Wall-mounted drives often do not include these and must provide them as an extra.

Reflected Wave Voltage

- If the distance between the motor and the control is long, a standing wave can form between the motor and control.

- Locating the controls next to the motor will mitigate this problem and eliminate the requirement for shaft grounding (bearing protection rings).

Bearing Protection Ring Kit

Motor Accessories

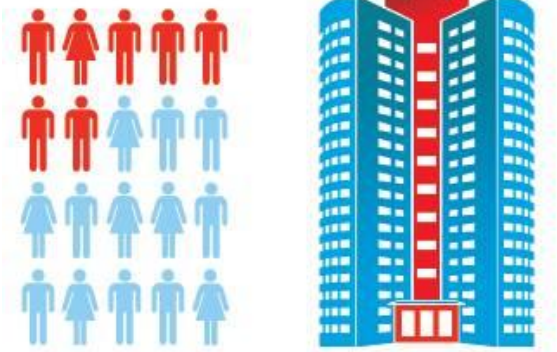
- Electric motors frequently feature space heaters and thermistors.
- Integrated pump controls eliminate the need for space heaters and thermistors.

Space Heaters
30 hp 286T = $420

Thermistors
30 hp 286T = $420
Tripping relay = $550

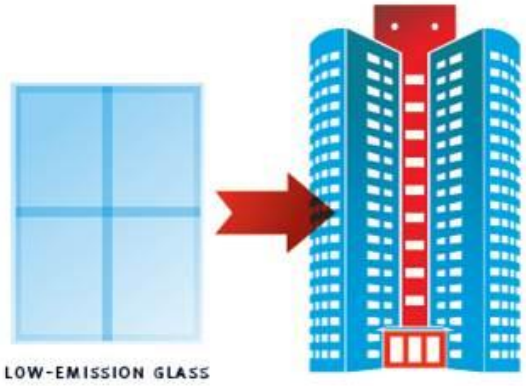
Re-Selection Risk and Cost

A pump with integrated controls will operate at high efficiency levels and will provide the exact pumping performance that supports the HVAC system and keeps costs at a minimum.



Occupant Load Changes

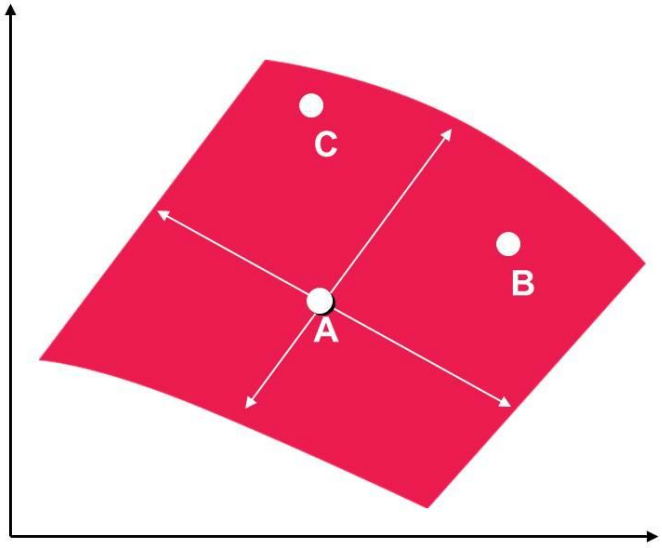
Surrounding Shade Changes



Building Design Changes

Re-Selection Risk and Cost

- Adaptability of an integrated control pumping unit reduces risk and cost.
- Changes in design can cost $100 per hour for re-engineering.
- Edmonton International Airport estimated a savings of $25,000 in re-selections during the construction phase alone.

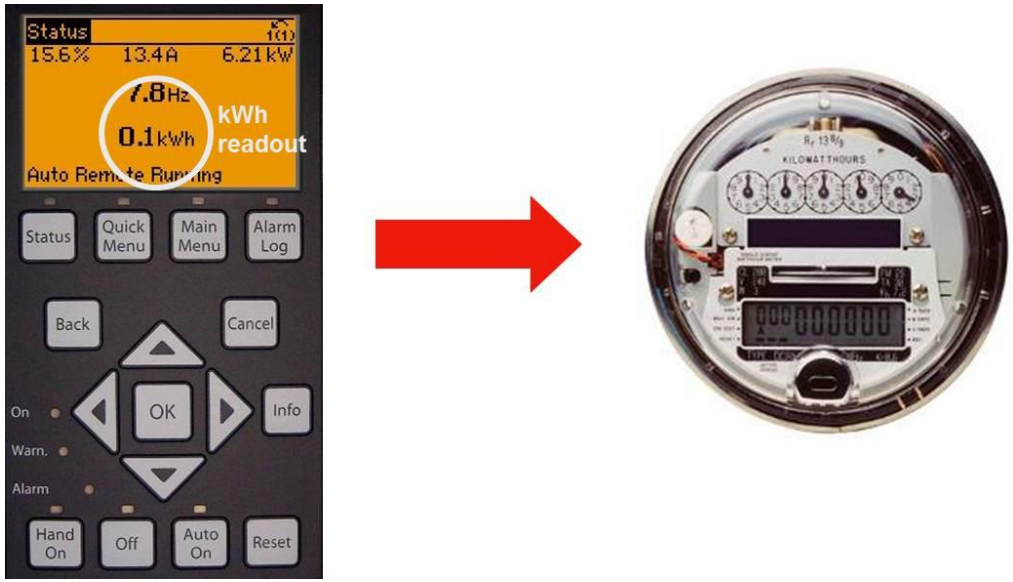


Edmonton International Airport
A: Original design
B: Second design
C: Final design

Energy Metering Capability

The integrated controls can be used:

- as an energy meter for energy measurement verification, and
- for trending analysis towards demand response.



Wall Space

There is no room on this wall for multiple VFDs.

First Cost

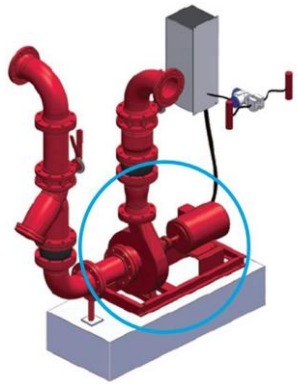
- The cost to the contractor for an integrated pump system: $9,900
- Percentage of pump cost found in savings: up to 75%

Example: 1000 USgpm at 90 ft Selection: 6x6x11.5 30 hp Integrated pump system	
Selections (energy and cost)	$1,140
Impeller Trim (energy and cost)	---
Sensorless Control (eliminate DP sensor)	$2,600
Smaller Size Motor and Control	$1,070
Wiring VFD Mounting Bracket	$340
Harmonic Distortion Emission and Immunity Requirements	$440
Reflected Wave Voltage	$270
Motor Accessories	$1,390
Envelope Re-selection Adaptability	$300
Energy Metering Capability	$100
Wall Space	---
TOTAL	**$7,650**

Vertical Inline over End Suction Configurations

The pump configuration can provide tremendous savings and improve the life cycle cost of the pump.

- First cost savings
- Pipe savings
- Floor space savings
- Maintenance savings

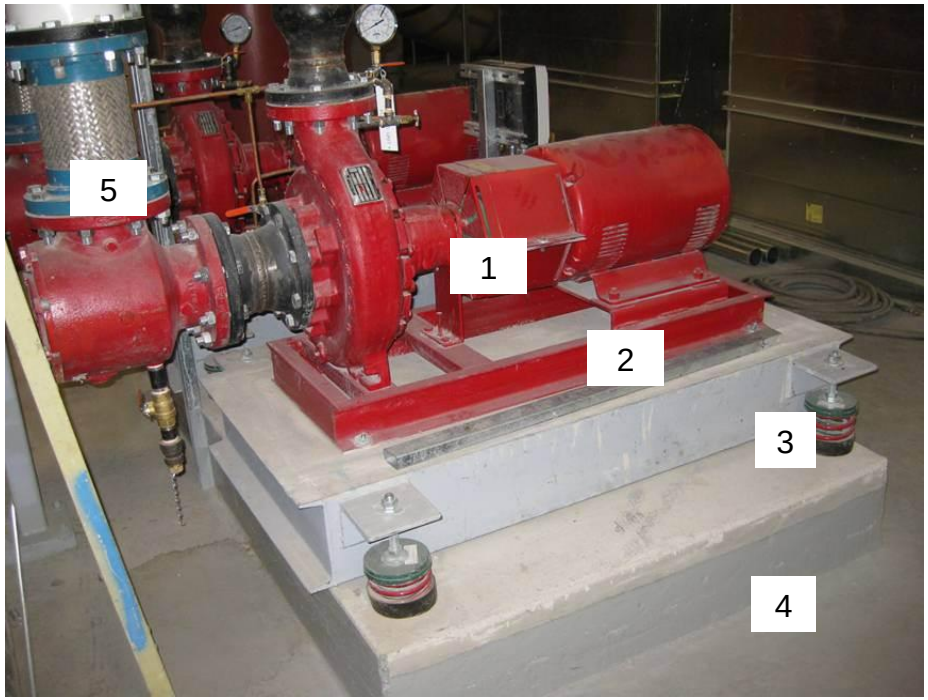


VS.

End Suction Pump Installation

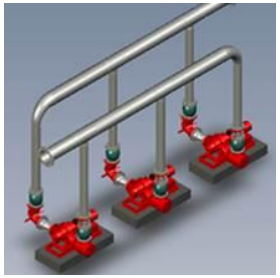
Additional costs come from end suction pump installation.

1. Coupling re-alignment costs
2. Grouting costs
3. Inertia base costs
4. Concrete base costs
5. Flex connectors costs



Integrated Pump over Horizontal Split Case

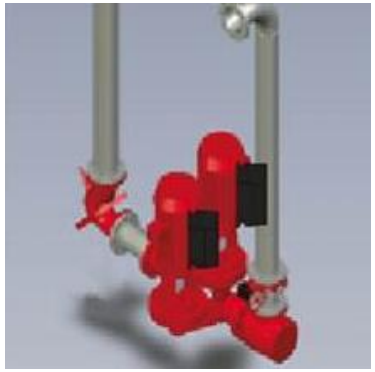
An integrated pump system eliminates the flex connectors, the concrete bases, and inertia bases, and there is no realignment of the flex coupling during commissioning.



Costs	3-Pump Horizontal Split Case System 6x5x12	3-Pump Integrated System 6x6x11.5 30 hp	Savings
Installation	$19,572	$8,327	$11,245 = 57%
Floor Space	105.7 sq ft	44.2 sq ft	$9,225 ($150/sq ft)

Integrated Pump over End Suction

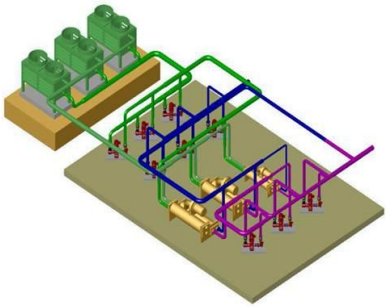
A vertical inline dual pump is mounted directly into the piping, inherently giving the smallest installed footprint.

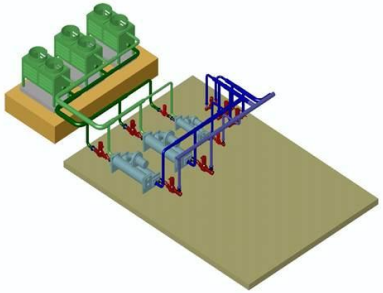


Costs	2-Pump End Suction System 6x5x10	2-Pump Integrated System 8x8x10 20 hp	Savings
Installation	$9,214	$3,444	$5,770 = 62%
Floor Space	36.1 sq ft	20.1 sq ft	$2,400 ($150/sq ft)

Pipe

The vertical inline pumps (VILs) present a huge opportunity for pipe savings (40–50%). Here's an example of a plant room optimization for Glendale Arena, home of the Phoenix Coyotes.





Costs	Horizontal Split Case	Vertical Inline	Savings
Piping	$225,975	$128,960	$97,015 = 43%
Length of Pipe	2751 ft (2751/100=27.51x3'tdh =82.53'tdh)	1723 ft (1723/100=17.23x3'tdh =51.69'tdh)	1028 ft

Floor Space

Bayfront Towers Tampa, FL
Shown here is a compact mechanical room with no space for two individual pumps and no space to mount drives on the wall. The solution is a simple, single, large air handling unit (AHU) system.

Shorewood Packaging, Danville, VA
This photo provides an example of how mounting pumps off the ground can be a solution to a lack of floor space.

Maintenance

- Seal change-out is much faster on VILs compared to base-mount: 30 minutes versus two hours.
- Some VILs don’t use bearings, which dramatically reduces failures and maintenance costs.

Benefits of Integrated Design vs. Traditional

This example illustrates the value that integrated control solutions deliver.

Traditional Solution
Space: 100%
Installed Cost: 100%

Integrated Control Solution
Space: 44%
Installed Cost: 67%

Integrated Control Solution
Space: 26%
Installed Cost: 39%

Benefits of Integrated Design vs. Traditional

- A traditional solution in the pumping world is to add variable speed drives together with a sensor to a bank of end suction pumps mounted on huge inertia bases.

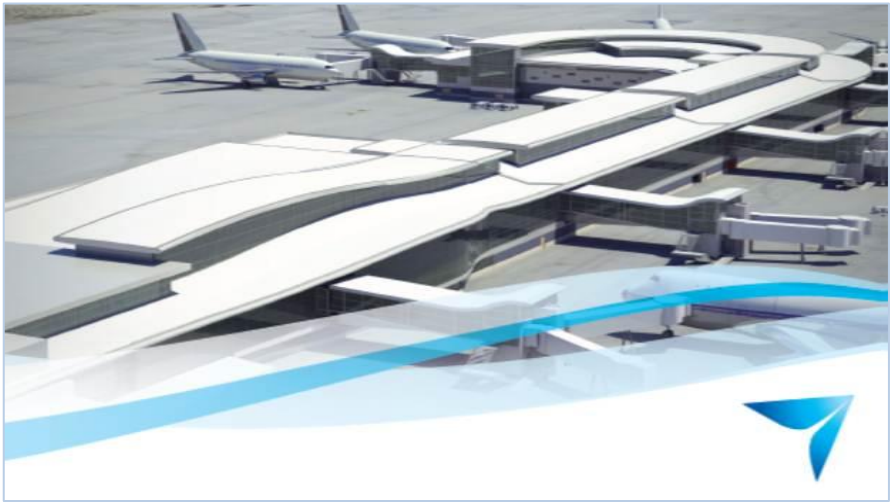
- If we compare an integrated control solution to a traditional end suction solution requiring 100% in space and installed cost, we see that an integrated control solution provides superior value.

- With far less space requirements and fewer components, space savings up to 26% is an obvious benefit. Space savings translate to reduced installed cost up to 39%.

Case Study: Expansion of Edmonton International Airport Expansion

- The design initially specified standard vertical inline pumps, but the nature of the expansion provided an opportunity to switch to 56 integrated control pumps.

- The contractor found value in the elimination of wiring from VFD to the motor, sensors and sensor wiring.



Comparison: Savings from Integrated Control over VFD

Vertical Inline with Integrated Control vs. Vertical Inline with VFD		
SAVINGS	• No Wiring Required between VFD & Motor • No Mounting Bracket for VFD	$30,000
	• No Sensors Required	$50,000
	• Design Savings	$25,000
TOTAL FIRST COST (INSTALLED) SAVINGS:		**$105,000**

- PAYBACK: 0 months
- Not included: Smaller electrics commissioning savings

Comparison: Savings from Integrated Control over VFD

Vertical Inline with Integrated Control vs. Horizontal End Suction with VFD		
SAVINGS	• No Wiring Required between VFD & Motor • No Mounting Bracket for VFD or Installation	$30,000
	• No Sensors or Installation Required	$50,000
	• No Pump Inertia Base and Grouting • No Alignment or Installation • No Flex Connectors	$200,000
	• Design Savings	$25,000
TOTAL FIRST COST (INSTALLED) SAVINGS:		**$305,000**
LIFE COST (20 years)		**$444,000**
ANNUAL COST SAVINGS (energy, maintenance, risk)		**$8,200**

- PAYBACK: 0 months
- Not included: Smaller electrics commissioning savings

Overview: LEED® Certification

- The U.S. Green Building Council (USGBC) is a 501(c)(3) non profit organization composed of leaders from every sector of the building industry working to promote buildings and communities that are environmentally responsible, profitable and healthy places to live and work. USGBC developed the LEED (Leadership in Energy and Environmental Design) green building certification program, the nationally accepted benchmark for the design, construction, and operation of high performance green buildings.

- LEED credit requirements cover the performance of materials in aggregate, not the performance of individual products or brands. Therefore, products that meet the LEED performance criteria can only contribute toward earning points needed for LEED certification; they cannot earn points individually toward LEED certification.

- For detailed information about the council, their principles and programs, please visit www.usgbc.org.

Integrated Pumping Systems: LEED Contribution

An integrated pumping system can make a valuable contribution towards LEED accreditation.

- Two prerequisites and three credits, representing 24 points in the LEED® for New Construction™ 2009 rating system

- One prerequisite and up to 27 points, available through three credits in LEED® for Existing Buildings: Operations & Maintenance™.

Oversized pumps provide the opportunity for significant energy efficiency improvement and a reduction in energy consumption.

ASHRAE 90.1-2007

Pump Performance Specified for Appendix G Baseline Building

Pump Type	Pump Power	Drive Type
Hot Water	19 W/gpm (i.e. 60-ft head with 60% combined impeller/motor efficiency)	Continuous variable flow; variable speed drives (VSD) for buildings ≥ 120,000 ft^2
Chilled Water	22 W/gpm (i.e. 75-ft head with 60% combined impeller/motor efficiency)	VSD on secondary pumping loop for systems with cooling capacity of ≥ 300 ton
Condenser	19 W/gpm	n/a

LEED® for New Construction & Major Renovations™

LEED NC and LEED Canada-NC 2009

- EAp1: Fundamental Commissioning of Building Energy Systems, Points Available: Required
- EAp2: Minimum Energy Performance, Points Available: Required
- EAc1: Optimize Energy Performance, Points Available: 19
- EAc3: Enhanced Commissioning, Points Available: 2
- EAc5: Measurement and Verification, Points Available: 3

LEED® for Existing Buildings: Operations & Maintenance™

LEED EBOM 2009

- EAp2: Minimum Energy Performance
  - Points Available: Required
- EAc1: Optimize Energy Efficiency Performance
  - Points Available: 18
- EAc2: Existing Building Commissioning
  - Points Available: 6
- EAc3: Enhanced Commissioning
  - Points Available: 3

ASHRAE 9.3.1 Construction Waste Management

Section 9.3.1 Construction Waste Management (mandatory)

9.3.1.2 Total Waste

9.3.4 Storage and Collection of Recyclables & Discarded Goods

Description:

- A minimum of 50% of non-hazardous construction/demolition waste material shall be diverted.
- Total waste shall not exceed 42 yd3 or 12,000 lbs per 10,000 ft2 of new building area.

Relevant Benefits of an Integrated Pumping System:

- Only one set of packaging on-site - on larger projects with 50 pumps, the impact can be significant.

Thank you for your time

Questions?

This concludes the GBCI
Continuing Education Systems Course

www.armstrongfluidtechnology.com