

# Armstrong Design Envelope

Why a new Design Envelope  
pump is always better than  
adding a variable speed  
drive-on-the-wall to an  
existing pump

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White paper

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**This paper details a factory test rig simulation comparing an Armstrong Design Envelope (DE) pump with a traditional pump and a wall-mounted Variable Frequency Drive (VFD) to a traditional pump in an energy upgrade retrofit.**

The study found the following:

- Energy savings achieved with the Design Envelope pump were 20 to 25% greater than the savings achieved by adding a VFD to a pump.
- The built-in variable flow controls of a Design Envelope pump increased the energy savings to 78% or more.

Additional benefits of replacing the existing pumps with Design Envelope pumps not addressed in this paper include:

- Energy savings from maintaining as-commissioned operating performance (up to 25%) through Armstrong's Active Performance Management capabilities.
- Installed cost savings and on-going energy savings created through sizing for appropriate system redundancy and implementation of parallel pumping.
- The savings potential of variable flow
- Lower operating and maintenance costs of installing a new replacement pump versus those associated with continuing to operate an old pump.
- Potential improvement in energy efficiency (5 to 6%) of the entire chilled or heating water plant
- Real-time knowledge of system flow and pump operating conditions for an advanced level of system trouble-shooting and optimization.
- Treating the pump replacement as the first step in an entire Chilled or Hot Water Plant upgrade program, with the potential to reduce energy consumption by \$0.40 per square foot. (\$4.30 per square meter)

**PAPER**

In most HVAC mechanical rooms, constant flow systems are proportionally balanced, to ensure the appropriate design flow reaches all heat transfer components. The original balancing will, most likely, have produced a higher flow than specified. This is due to the system resistance head being lower than originally specified. When this happens, a balancing contractor would manually restrict flow at the main system throttling valve, to a point where the system curve has moved from the overflow balanced condition to the specified design flow and head, though now operating at a higher pressure than the system requires. The valve throttling wastes energy, although,

opening the valve will waste even more energy. This paper explores energy saving possibilities using test rig instruments and installing different pumping units, in an effort to find the optimum energy-saving solution.

Constant speed pumps, with wall-mounted Variable Frequency Drive [VFD], and Design Envelope units in this test, are selected for a random design flow and head of 150 Usgpm (34.5 m<sup>3</sup>/h) flow and 45 feet (13.73 meter) head, which would represent a throttled system condition. See **FIG 1 ROW [1]** in test data results, below

Connecting a VFD, typically mounted on a convenient wall, to a mechanical room constant speed pump, and then fully opening the system throttle valve, will allow the pump speed to be manually reduced from the VFD. Pump speed can be reduced until the unit matches the specified design flow, resulting in reduced operating costs.

Opening the system throttling valve reduces the pump head by 15%, about a 5% speed reduction, which is an average value for a system where the design head has been oversized. **FIG 1** below, shows that at a reduced speed an older constant speed pump would deliver 12% energy savings compared to a closed valve. A Design Envelope pump, with present-day integrated hydraulic, power and electronic design provides 31% energy savings, or 22% greater savings than the VFD reduced speed unit. See **FIG 1 ROW [2]** in test data results, below

As indicated above, specified HVAC design head values are often oversized. In many HVAC systems, the head adjustment can exceed the average by a large amount, as the original design head value may have contained multiple safety factors. In our test, the system throttling valve is opened further, maintaining design flow, but producing a head that is 30% below the original design specification of 45 feet, for tenant comfort and more responsible energy usage. From **FIG 1** below, reducing the speed of an older constant-speed pump delivered 23% energy savings from the closed valve energy usage. **Design Envelope pumps deliver 42% energy savings, or 25% greater savings than the VFD reduced speed unit.** See **FIG 1 ROW [3]** in test data results, below

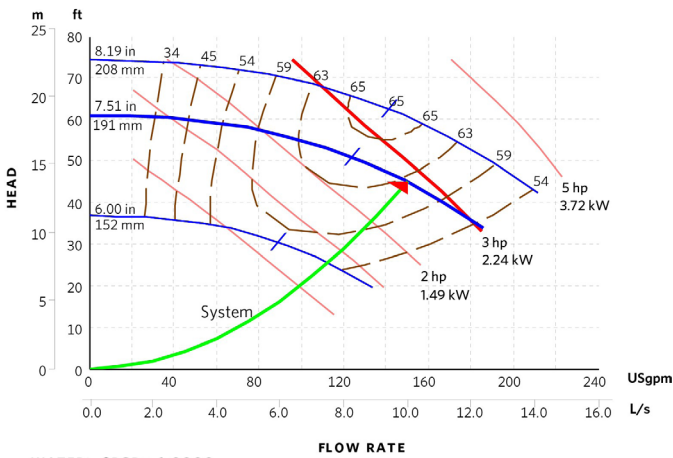
Design Envelope [DE] units with intelligent, variable speed, demand-based controls in **variable flow systems** can select optimum pumps from specified system flow and head, using inherent load profile data. The on-board controls will adjust the pump(s) speed from sensing and understanding system demand. In modern HVAC pumping all applications today should be variable flow and energy upgrades should always attempt to take advantage of available technology. In variable flow systems, this allows deeper reductions in energy use, usually

balancing to about ~50% average flow. It turns out that 50% flow is also a good general approximation of the average of an actual building load profile. **At this 50% operating level, the Design Envelope pump saves 78% savings compared to a closed valve and 71% compared to reduced speeds to 30% below design head.** See FIG 1A in test data results, below

**ENERGY SAVINGS COMPARISON – CONSTANT SPEED W/ VFD VS DESIGN ENVELOPE PUMP**

**CASE 1: DESIGN FLOW AND HEAD**

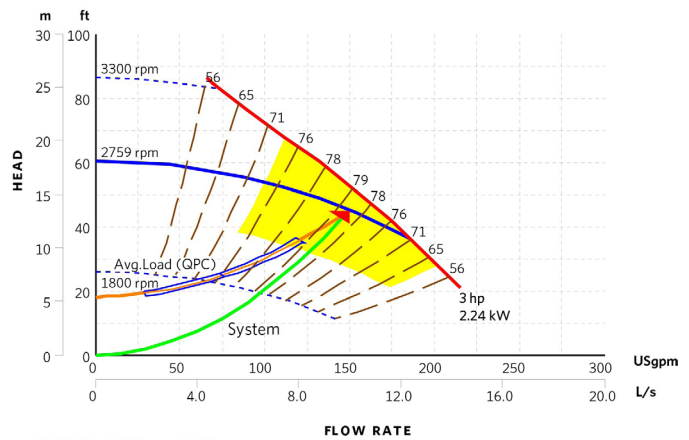
Series 4380  
2x2x8 @ 1765 rpm



WATER:, SPGR= 1.0000

Energy Consumed = 2.17 kW

Series 4380  
Design Envelope: O205-003.0  
Integrated Intelligent Variable Speed with Sensorless Control

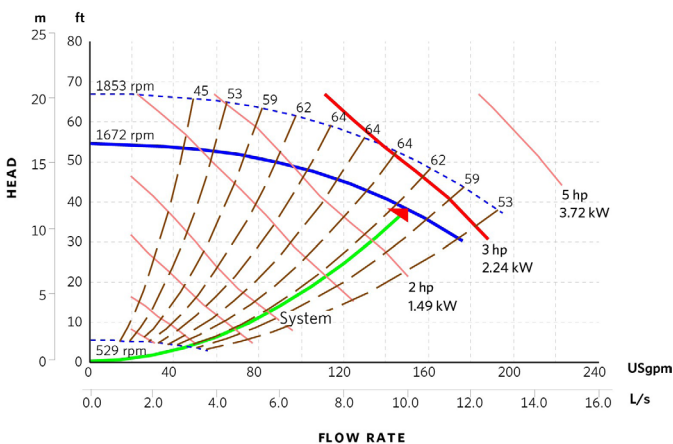


WATER:, SPGR= 1.0000

Energy Consumed = 1.71 kW

**CASE 2: 85% DESIGN HEAD**

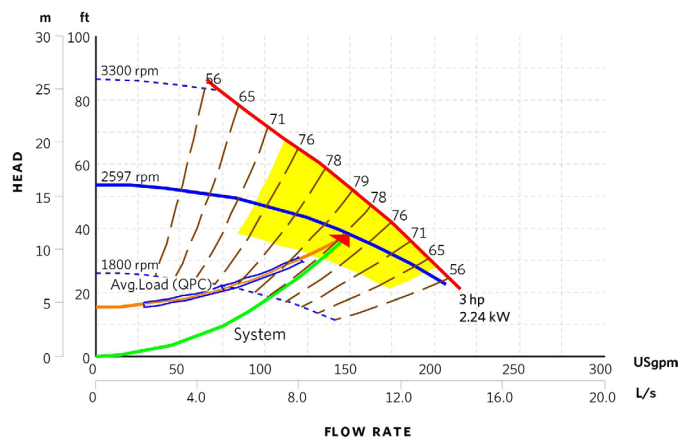
Series 4380  
2x2x8 @ 7.51in (191mm)



WATER:, SPGR= 1.0000

Energy Consumed = 1.92 kW

Series 4380  
Design Envelope: O205-003.0  
Integrated Intelligent Variable Speed with Sensorless Control



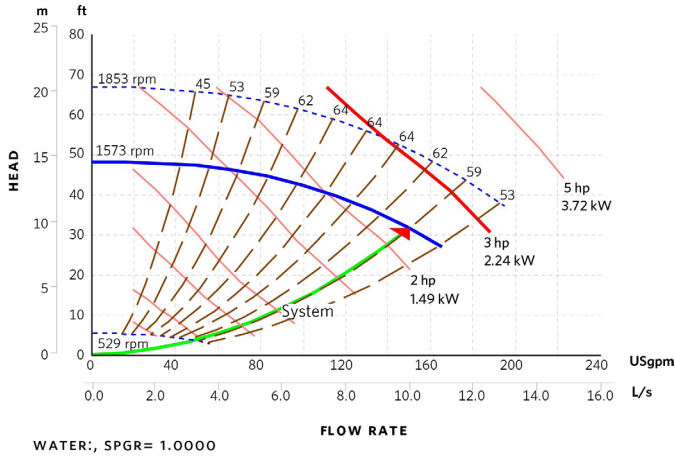
WATER:, SPGR= 1.0000

Energy Consumed = 1.49 kW

**CASE 3: 70% DESIGN HEAD**

**Series 4380**

2x2x8 @ 7.51in (191mm)

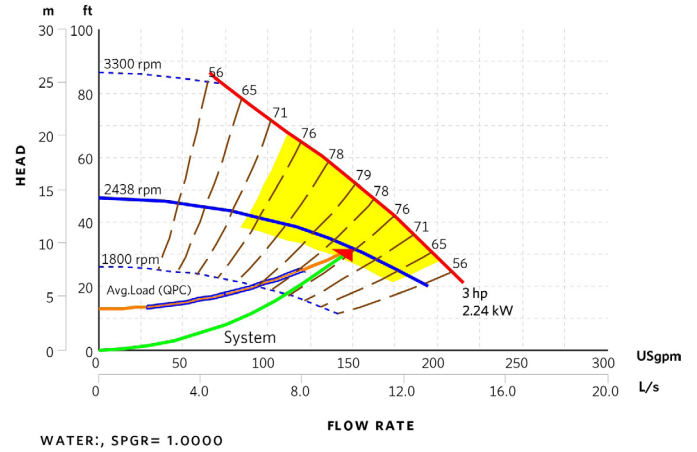


**Energy Consumed = 1.67 kW**

**Series 4380**

Design Envelope: O205-003.0

Integrated Intelligent Variable Speed with Sensorless Control



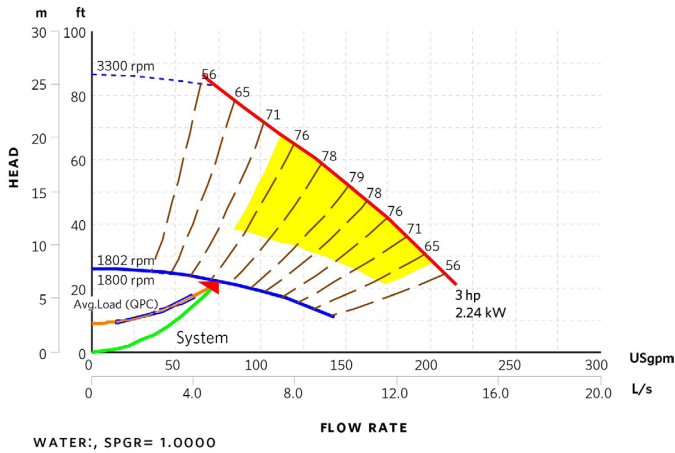
**Energy Consumed = 1.26 kW**

**50% OF DESIGN FLOW**

**Series 4380**

Design Envelope: O205-003.0

Integrated Intelligent Variable Speed with Sensorless Control



**Energy Consumed = 0.48 kW**

**ENERGY SAVINGS COMPARISONS: SUMMARY**

CASE	DESIGN CONDITIONS	CONSTANT SPEED PUMP/ VFD				DESIGN ENVELOPE PUMP		DE VS VFD
		Flow GPM (L/s)	Head Ft (m)	Electrical Power Drawn (kW)	Savings	Energy (kW)	Savings	
[1]	Design Flow/Head	150(9.46)	45.0(13.7)	2.17		1.71	21%	
[2]	85% Design Head	150(9.46)	38.3(11.7)	1.92	12%	1.49	31%	22%
[3]	70% Design Head	150(9.46)	31.5(9.6)	1.67	23%	1.26	42%	25%

FIG 1. Test data for Constant Speed pump (CS), CS with VFD and Design Envelope (DE) unit

ENERGY SAVINGS @ 50% OF DESIGN FLOW					
Details	Flow GPM (L/s)	Head Ft (m)	Energy (kW)	Savings	Comments
Design Envelope @ 50% Flow	75 (4.73)	22 (6.70)	0.48		
Constant Speed @ Design	150 (9.46)	45(13.73)	2.17	78%	Design Envelope @ 50% Flow vs Constant Speed @ 100% Flow
Design Envelope @ Design	150 (9.46)	45(13.73)	1.71	1.67	Design Envelope @ 50% Flow vs Design Envelope @ 100% Flow

FIG 1A. Savings @ 50% flow with Design Envelope unit vs 100% flow with Design Envelope and Constant Speed

**TEST RIG INTEGRITY**

The test details indicated above are accurate, as the constant speed unit with VFD and Design Envelope unit were tested one at a time. Each unit was replaced in the piping after the previous unit was removed. This was to ensure that each unit experienced identical conditions. The test rig used is simplified for such a comparison, taking all complications, and all possible errors, out of the system. See FIG 3 and text below.

Armstrong maintains Pump Test Lab Approval per the Hydraulic Institute [HI] 40.6 Test Standards which include the test rig used for this test. Each pumping unit used was 3hp, close coupled Vertical In-Line design. HI designation for these units is OH5.

All Design Envelope units provide the flow and head that they are producing and the power they are consuming as outputs directly from the pumps. They are mapped for flow, head, efficiency values, to ANSI/HI 14.6 testing requirement, accuracy is recorded for +/-5% controls read-out. During this test, the readings used were from the test rig instrumentation to ensure they were consistent between the pump with wall mounted VFD vs the Design Envelope pump readings.

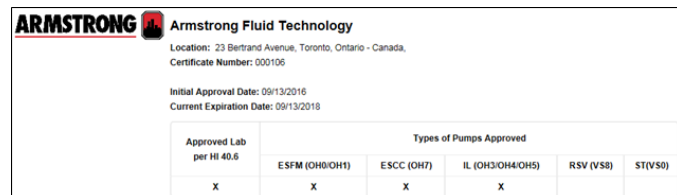


FIG 2. Armstrong HI test lab approval

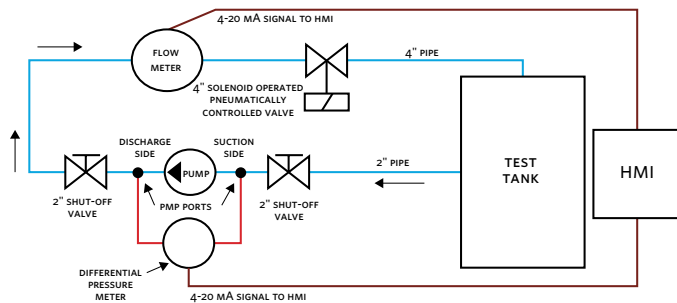


FIG 3. Simplified test rig arrangement used for this test

This test rig is simple, small and accurate. [TR-16]. The HMI registers and displays very accurate values from the unit's differential pressure and flow meters; the HMI can be used to return signals to minutely adjust the opening of the [2] meters. Flow and/or head readings can also be adjusted manually at the shut-off valves and pneumatic control valves. Testing for this project was repeated to prove consistency and accuracy, which was ensured by using the same test rig and conditions for each unit. This is a safe, reliable rig, with proven capabilities for accurate testing.

**OPERATING COST SAVING POSSIBILITIES**

**SUMMARY**

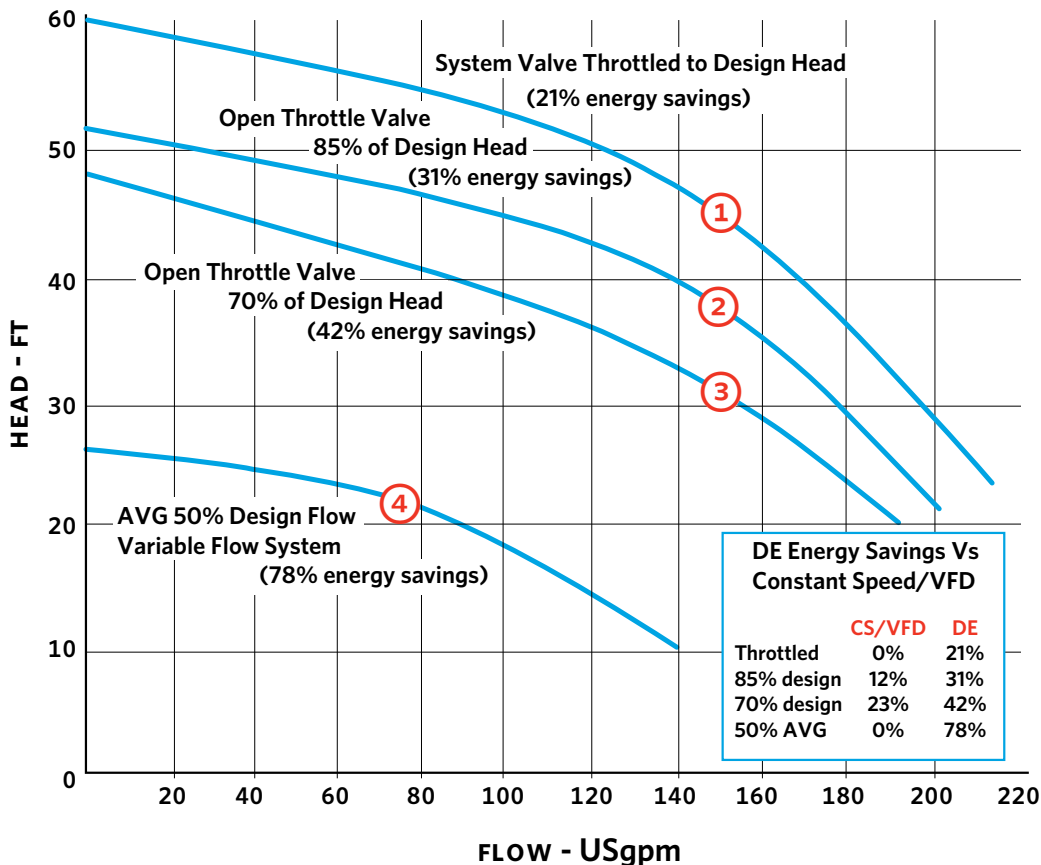
**This test shows that, when adding VFDs to installed constant speed pumps, the process can save 12% to 23% from throttling valves being opened 15% to 30% from the fully throttled design head system valve; which were great savings in the 1990's when VFD's first started common use.**

Meanwhile, the Design Envelope units, with integrated controls, current-day casing flow design and intelligent variable speed control save 31% to 42% operating costs or an **additional 22% to 25%**, on top of the constant speed pump with 1990's technology wall mounted VFD speed reduction.

Other savings are readily available from intelligent demand-based controls included in Design Envelope pumps. All buildings experience constant variation in heating and cooling needs. Demand-based controls vary the system flow to meet the system needs. This typically averages about 50% of system design flow, over the course of a year. Demand-based controls saved 78% energy compared to closed valve operation or **another 71%** operating costs, beyond operating constant speed at 70% of the design head in our test.

Details from this testing session only confirms the results from many previous installations, showing significant savings in operating costs (plus lowest installation costs) through installing Design Envelope units.

**PUMP CURVE PROCESS FOR IMPROVED ENERGY SAVINGS WITH DESIGN ENVELOPE UNITS**



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