ARMSTRONG

Condensing boiler plant (CP/VS)

Design Envelope application guide

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DESIGN ENVELOPE APPLICATION GUIDES

Performance improvements are among the top priorities of many building professionals today. Whether you are a developer, design consultant, engineer, contractor, facility manager or owner, chances are that you face increasing demands to not only reduce costs, but also deliver performance improvements. Public awareness on multiple levels – from the individual all the way through to government bodies – has grown to the point that energy conservation, carbon reduction, tenant comfort, and other health and environment-driven practices are key objectives for any prominent, sizeable building project.

To support and sustain this paradigm shift, Armstrong has developed a suite of advanced fluid flow and HVAC offerings that we call 'Design Envelope solutions'. Design Envelope solutions integrating intelligent demand-based control to deliver optimal performance and the lowest possible cost, both at commissioning and throughout their full operating life.

This document is one of our Design Envelope Application Guides, a set of booklets that discuss a broad range of real-world HVAC scenarios. In each scenario the use of Design Envelope technology can result in tremendous improvements in performance of your HVAC installation (compared to standard industry practice) and ultimately your building - technically, financially, and environmentally.

The intent of this Application Guide is to present HVAC System designers with an alternative to standard practices for design layout, configuration, and design calculations and help you leverage the full potential of Armstrong Design Envelope solutions. Each Application Guide addresses a specific system configuration for HVAC or data center applications. The system configurations cover heating and cooling scenarios, including circuit configurations ranging from all constant flow, to full variable flow and variable speed plant configurations. The Application Guides will present piping arrangements, valving requirements, de-coupler configurations, instrumentation locations, control system options, and the associated impact on first cost and life-cycle costs. The full series of application guides is available for download from Armstrong's website at www.armstrongfluidtechnology.com

APPLICATION DIRECTORY

HVAC

COOLING

9.561 – All-variable water cooled chiller plant

9.562 – Water cooled chiller plant (CP/VS)

9.563 – Water cooled chiller plant with economizer

9.564 – Ground source heat pump system (VP)

HEATING

9.565 – Condensing boiler plant (VP)

This guide covers: 9.566 – Condensing boiler plant (CP/VS)

9.567 – Closed circuit heat pump system (VP)

DISTRICT COOLING

9.568 – Water cooled central plant (all-variable)

9.569 – Water cooled central plant (CP/VS)

9.570 – Water cooled central plant (VP/VS)

DATA CENTRES

COOLING

9.571 – Water cooled chiller plant with economizer (VP)

9.572 – Water cooled chiller plant (all-variable)

9.573 – Water cooled chiller plant (CP/VS)

VP = Variable primary flow

CP/VS = Constant primary flow / variable secondary flow

VP/VS = Variable primary flow / variable secondary flow

All-variable = All variable chiller plant, variable primary flow, variable secondary flow, variable condenser flow

The application discussed in this technical paper is for condensing boilers with a constant primary and variable secondary design.This would be typical in apartment, schools, offices and other single zone facilities.

The plant design that best utilizes the Design Envelope options includes the Design Envelope 4300 Vertical Inline pumps with a Parallel Sensorless Pump Controller.

APPLICATION DETAILS

Equipment	Condensing boilers	▪
Use	HVAC	▪
Configuration	Const. primary flow	▪
	Var. secondary flow	▪

DESIGN ENVELOPE BENEFITS SUMMARY

Design Envelope benefit	Design Envelope savings over conventional plant
Lowest installed cost	31%
Lowest operating cost	40%
Lowest environmental cost/ impact	3,745 lbs
Lowest project and operating risk	(See table on page 8)
Total Design Envelope 1st year savings	**$15,917 (31%)**

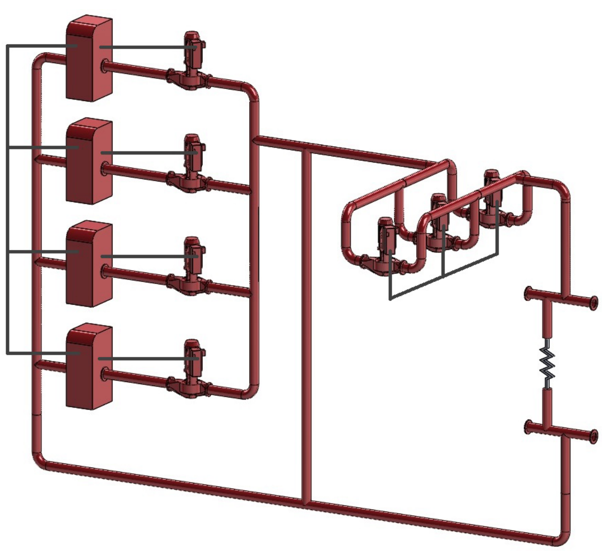


FIG. 1
DESIGN ENVELOPE PLANT LAYOUT.

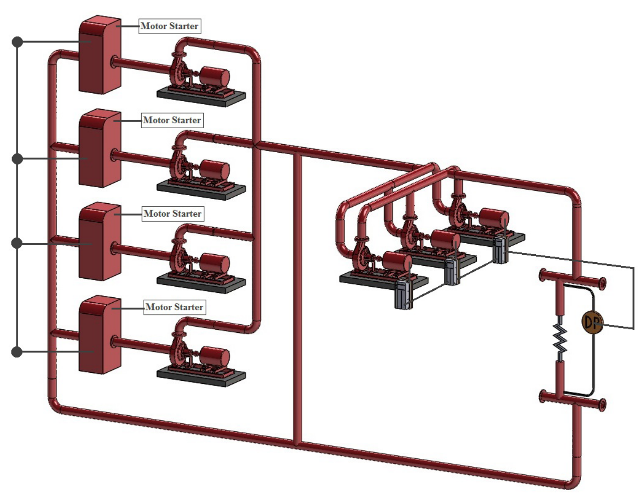


FIG. 2
CONVENTIONAL PLANT LAYOUT.

PLANT LAYOUT
DESIGN ENVELOPE VS. CONVENTIONAL

	Design Envelope plant	Conventional plant
Heating	Condensing boilers (3 plus 1 redundant) Single zone	Condensing boilers (3 plus 1 redundant) Single zone
Pumps	Design Envelope 4300 Vertical in-line pumps	4200 Horizontal End Suction Pumps Concrete slab & inertia pads Flex connector
Secondary Circuit	Design Envelope 4300 Vertical in-line pumps	4200 Horizontal End Suction pumps Wall mounted drives Concrete slab & inertia pads Flex connector

A comparison of the Design Envelope system and the conventional approach using horizontal pumps is shown in figures 1 and 2. The plant design that best utilizes the Design Envelope options includes the Design Envelope 4300 Vertical Inline pumps with integrated controls. Both systems have pumps directly connected to the boiler and pumping into a header that supplies a single zone. To avoid mismatched flows between the primary and secondary circuits a de-coupling pipe has been added. If both circuits are on full flow then water would flow directly from the primary circuit into the secondary. As the secondary flowrate reduces a portion of the primary flow is fed through the de-coupler to maintain a constant primary flowrate.

BACKGROUND ON CONDENSING BOILERS

In North America and the UK, low temperature hot water heating systems were traditionally designed with a supply temperature of 80°C (180°F) and a return of 70°C (160°F). Continental Europe took a slightly different approach and utilized a larger temperature difference with 80°C (180°F) supply and 60°C (140°F) return temperatures. Doubling the system Δt (delta temperature) halves the flow required to supply the heating energy resulting in reduced pump sizes and pipework diameters, friction losses, and ultimately electrical power consumption.

The system Δt has a significant effect on the initial capital cost of a system but also, probably more importantly, on the life cost. The larger Δt reduces the mean temperature from 75 to 70°C. In today's buildings with vastly improved air tightness and thermal insulation, this has little impact on emitter size. These temperatures were selected for three reasons:

1. They were safely below the boiling point of water so there was little danger of over pressurising the system.
2. They were safely above the dew point of the flue gases so costly corrosion of the internal surfaces of the boiler was avoided.
3. They provided a fairly good LMTD (log mean temperature difference) for economic emitter sizing.

In traditional cast iron boilers where flue gas condensation was a real problem but a high surface temperature was not and energy was relatively cheap 80/70°C (180/160°F), return temperatures were fine.

Ultra efficient gas fired condensing boilers extract latent heat from the flue gases by dropping the temperature of the flue gases below the dew point, around 54°C (129°F). When flue gases drop below the dew point, acidic condensation forms and quickly corrodes ferrous boiler and flue materials. Condensing boilers built from aluminium or stainless steel using a 'plate' type heat exchanger, as opposed to the shell and tube type seen in conventional boilers, prevent this.

The system return temperature must be below the dew point, ideally 50/30°C (122/86°F), to ensure condensation or the efficiency can be as much as 10% below rated, depending upon boiler type and load. In any condensing boiler control strategy the temperatures (flow and return) and flowrates are as important, if not more so, than ever.

Sample - Constant Primary, Variable Secondary

Peak load	1,758 kW (6 MBTU/hour)
Boilers	4 Condensing boilers (3 duty, 1 standby)
Supply and return temperatures	71°C (160°F) and 49°C (120°F)
System head	328 kPa (110 ft)
Primary Flow/boiler+ Primary system head Secondary flow Secondary system head	6.38 l/sec or 100 US gpm 120 kPa (40 ft) 9.57 l/s (150 USgpm) 210 kPa (70 ft)

The system has a peak load of 1,758 kW (6 MBTU/h) divided between 3 boilers. Boiler flow and return temperatures are 71 – 49°C (160 – 120°F) with a total system head loss of 328 kPa (110 ft.).

The system has a variable flow secondary circuit served by three pumps in a Duty/Duty/Duty/Standby configuration giving an N+1 installation (redundancy at full load = 50%). Each pump is fitted with wall mounted inverters and controlled via a parallel pumping controller based on a differential pressure sensor across the zone. The secondary zone is controlled by two port control valves. As these valves close, the increase in pressure is measured by the sensor and causes the pumps to reduce speed proportionally based on the signal. Once the flow falls below the capacity of two pumps running at minimum speed one pump will switch off leaving the remaining pump to cover the load.

The primary system is constant volume meaning that 3 of the fixed speed pumps run at all times.

In the Design Envelope solution, fixed speed horizontal pumps are replaced by in-line mounted vertical pumps with integrated controls set to maintain a constant flow through the boiler, independent of system pressure changes. The performance of the modulating boiler remains at its design peak.

Replacing horizontal pumps and wall mounted VFDs with a Design Envelope sensorless or parallel sensorless equivalent improves system control via the quadratic control curve. Both the pump speed and the total number of pumps operating is modulated to match both the required flow and the optimal efficiency of the pumps.

Alternate Control Strategy using Unison Control

A typical example that includes variable volume primary flow with 'unison' boiler control variable boiler sequencing is indicated in Figure 3.

In this example multiple boilers are still installed in an N+1 capability giving 33% redundancy on both heat and flow. This type of system, although referred to as variable volume flow, is typically controlled via a boiler management system, which generally utilizes a 'unison' control. Unison control steps each boiler on in sequence at its lowest fire rate (typically 20%) and then modulates all boilers simultaneously to match the system load (controlled on either delta T or set point). This method of sequencing can offer higher boiler operating efficiencies by taking account of the higher part load efficiencies at low firing rates. As the controller sequences a boiler on it will send an enable signal to the associated pump to start. This sequencing of the boilers and pumps, gives the system its variable volume flow whilst maintaining relatively constant flow through the boilers.

BOILER 1 is enabled at 20% capacity.

Once demand has reaches 40% **BOILER 2** is enabled.

BOILER 1 and **BOILER 2** both run at 20% capacity to acheive 40% demand.

Once demand reaches 60% **BOILER 3** is enabled.

BOILER 1, BOILER 2, and **BOILER 3** all run at 20% capacity to acheive 60% demand.

Once demand reaches 80% **BOILER 4** is enabled.

BOILER 1, BOILER 2, BOILER 3, and **BOILER 4** all run at 20% capacity to acheive 80% demand.

To reach full load (300%) each boiler would only have to run at 75% capacity.

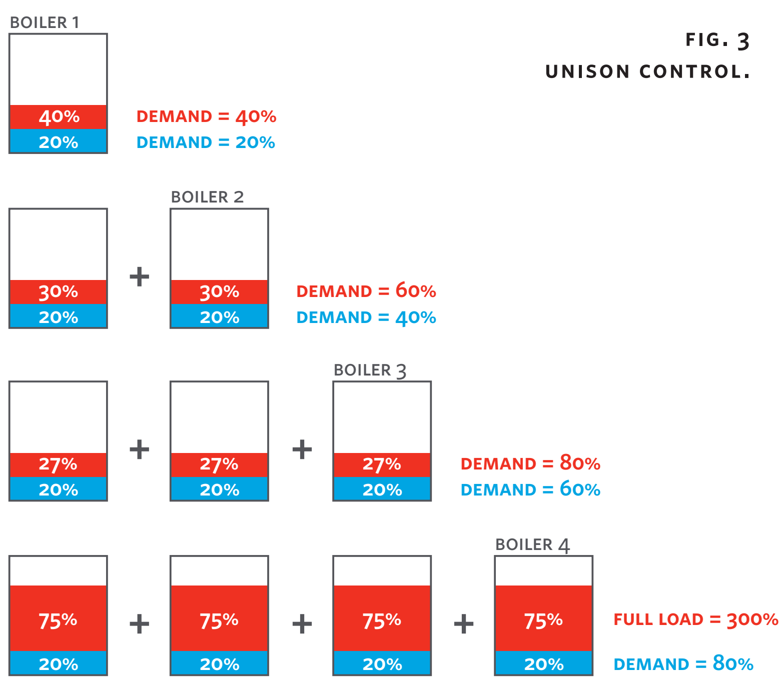


FIG. 3
UNISON CONTROL.

DESIGN ENVELOPE BENEFITS SUMMARY

Design Envelope benefit	Design Envelope savings over conventional plant	
Lowest installed cost		$14,517
Lowest operating cost		$1,400
Lowest environmental cost/impact	(Volume (lbs of material))	3,745
Lowest project and operating risk		—
Total Design Envelope 1st year savings		**$15,917 (31%)**

LOWEST INSTALLED COST

Savings area	Design Envelope plant installed savings	
Material & installation		($3,421)
Time (labour)	($75/hour)	6,988
Power infrastructure	(kW connected reduction)	—
Space	(Sq ft ($150/sqft))	9,450
Civil structure		—
Utility rebates		—
Commissioning & call backs	USD ($75/hour)	1,500
Total installed savings		**$14,517 (31%)**

Installation and commissioning savings resulting from use of Design Envelope pumps reduce the installed cost by 30% over the conventional approach.

Installing Armstrong pipeline mounted, vertical inline Design Envelope pumps gives several benefits to the installation, commissioning and control of the system. The Design Envelope pumps have integrated controls, with an in-rush less than the rated current when initially powered. This compares favourably to the 600%+ in-rush associated with fixed speed motors. In addition the Design Envelope pumps automatically limit pump output, eliminated the need to use large non-overloading motors associated with fixed speed pumps. The pumps eliminate the necessity for concrete plinths and inertia base's used with the majority of horizontal pumps, eliminating over 3700 lbs of material from the environmental footprint of the installation.

LOWEST ENVIRONMENTAL COST

Savings area	Design Envelope plant environmental savings	
Carbon footprint (energy)	(ton GHG [90% NG, 10% hydro])	—
Construction waste	(Volume (lbs of material))	3,745

Design Envelope pumps can be supplied complete with suction guides and a triple duty (Flo-Trex) valve that further enhances the offering and reduces installation time and the physical space requirements. Estimated installation time savings for a project of this size would be in excess of 1 day and require 5.5-6 m^2 (63 ft^2) less space in the mechanical room than conventional horizontal end suction units, that can be used for other purposes and provide easier access for pumps and other mechanical equipment maintenance.

The integrated intelligent drive provided with the Design Envelope approach provides further enhanced features that can be leveraged during the commissioning and operation of the system. The controls are programmed with the required flow. Changes can be made at site and accommodate variances in head (against design) and flow rate changes (due to design change or boiler selection). Proportional balancing of the boiler circuit is no longer required since the flow is controlled by the sensorless control in the Design Envelope pump. The minimum boiler flow is set on each individual pump which will speed up the pump when the minimum flow is reached, until sufficient pressure is reached to open the bypass valve. This would normally only ever operate when one boiler is running at very low load, unless the boiler management system shuts off the boiler. This strategy will maintain a constant flow independent of any pressure fluctuations due to boilers sequencing or variation in the 3 zones whilst minimizing the operation (opening) of the differential by-pass control valve, thus saving energy, stabilizing the operation of the system (in particular the flow through the boilers) and maintaining the return LTHW temperature (essential for condensing).

In addition to operating and installation advantages, there are considerable savings in the commissioning process.

Design Envelope pumps can be set for the maximum flow through the boiler. This eliminates the need to balance the flow to the boiler and balance the flow between the various boilers in the system. The Design Envelope pump can be set to maintain a minimum flow rate through the boiler until the pump reaches maximum speed.

Also, for a variable primary system the use of a DE pump with a maximum operating point (flow and head) will prevent the pump pressure from exceeding the operating point as zone valves are closed. This simplifies setting the pressure setting on the reverse acting DP valve, and under most situations will allow a significant reduction in the flow capacity of the valve as it will only be required to operate when the load is reduced to below that required when one boiler is operating below the minimum flow rate.

Combined the above factors should conservatively save in excess of a full day of on-site commissioning for each of the drives and the flow balancing.

LOWEST OPERATING COST

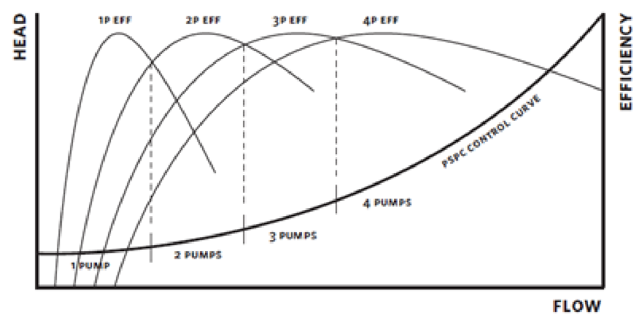
Savings area	Design Envelope plant operating savings (annually)	
Energy	(kWh (hrs))	$700
Maintenance	($75/hour)	$700
Reliability	(increased availability)	-
Total operating savings		**$1,400 (40%)**

Following the installation and commissioning, the Design Envelope solution also provides the lowest annual operating cost. The vertical inline pumps are easier to maintain, and in this instance should be expected to save an annual average of $700 or just over an hour of labor per pump per year in maintenance. On the energy side, the parallel sensorless control keeps the pumps as close to their best efficiency point as possible saving an additional 30% of the energy relative to other pumps with variable speed drive.

By staging the pumps based on their efficiency curve rather than by through traditional capacity based sequencing, significant savings are achieved.

With the elimination of remote differential pressure sensors, the system operates closer to its intended design as sensors inevitably drift over time and pressure sensors are often located in areas with limited or difficult access.

Refer to the white paper on Design Envelop Parallel Sensorless Pump Controller for further details on the sequencing strategies.



LOWEST PROJECT AND OPERATING RISK

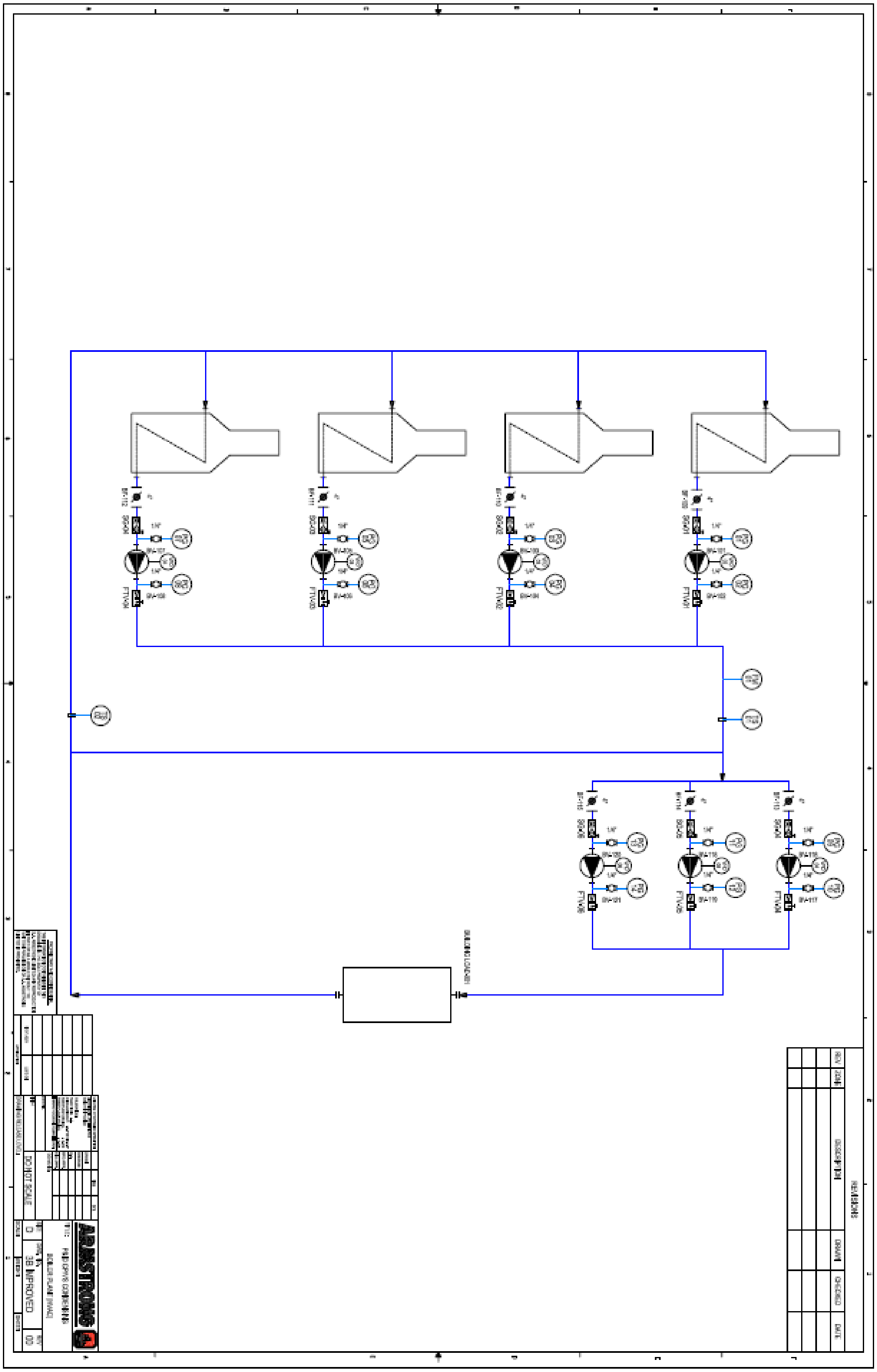
Risk to	Risk source	Design Envelope plant risk reduction	% of total mechanical project
General contractor	Commissioning delay and payment delay of hold back amounts	$615	0.3%
Owner (capital projects)	Inevitable design changes by different stakeholders	$214	0.1%
Owner (operations and maintenance)	Energy and operational savings not achieved	$0	0%
Engineer	Reputation deterioration and losing new business	$1,125	0%
Mechanical contractor	Commissioning delay and payment delay of hold back	$266	0.1%

In addition to the first cost and operating cost advantages, a Design Envelope solution minimizes the design and implementation risks of a project. Design Envelope pumps can accommodate the majority of changes in design and sizing, eliminating the need for re-selecting pumps in the middle of the design. Design Envelope accelerates the commissioning time and the vertical inline minimizes onsite installation time because there is no need for a concrete base or inertia pad so the installation fits into a tighter construction schedule. The factory design and testing minimizes the errors made during commissioning, in turn reducing the number of call backs.

SUMMARY:

The Design Envelope solution reduces first installed cost by 30% and lifecycle pumping cost by 40% with additional savings in natural gas consumption. It requires less material for the installation, leading to lower embodied energy and less greenhouse gases during installation and the better flow control also results in higher boiler efficiency.

PROCESS & INSTRUMENTATION DIAGRAM



TORONTO

23 BERTRAND AVENUE
TORONTO, ONTARIO
CANADA
M1L 2P3
+1 416 755 2291

BUFFALO

93 EAST AVENUE
NORTH TONAWANDA, NEW YORK
U.S.A.
14120-6594
+1 716 693 8813

BIRMINGHAM

HEYWOOD WHARF, MUCKLOW HILL
HALESOWEN, WEST MIDLANDS
UNITED KINGDOM
B62 8DJ
+44 (0) 8444 145 145

MANCHESTER

WOLVERTON STREET
MANCHESTER
UNITED KINGDOM
M11 2ET
+44 (0) 8444 145 145

BANGALORE

#59, FIRST FLOOR, 3RD MAIN
MARGOSA ROAD, MALLESWARAM
BANGALORE, INDIA
560 003
+91 (0) 80 4906 3555

SHANGHAI

NO. 1619 HU HANG ROAD, XI DU TOWNSHIP
FENG XIAN DISTRICT, SHANGHAI
P.R.C.
201401
+86 21 3756 6696

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