WELCOME TO TECHNICAL SEMINAR

Saving Energy Make Sense

Ultra - Efficient Chilled Water Plant Automation

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Agenda

- Welcome Note
- Petrofac Team Intro
- About Petrofac Qatar
- Armstrong Team Intro
- About Armstrong Integrated Limited
- Saving Energy Make Sense: Ultra - Efficient Chilled Water Plant
  - Design Envelope Pumping
  - Integrated Plant Controller
  - Energy Transfer Stations
- Q/A
- Vote of Thanks
- Lunch

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Mechanical Division

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Sr. Sales Engineer
HVAC Solutions

Mr. Sunil Abraham Jacob
BDM/Project Manager

Ms. Jerylyn C. Rabadon
Marketing Executive

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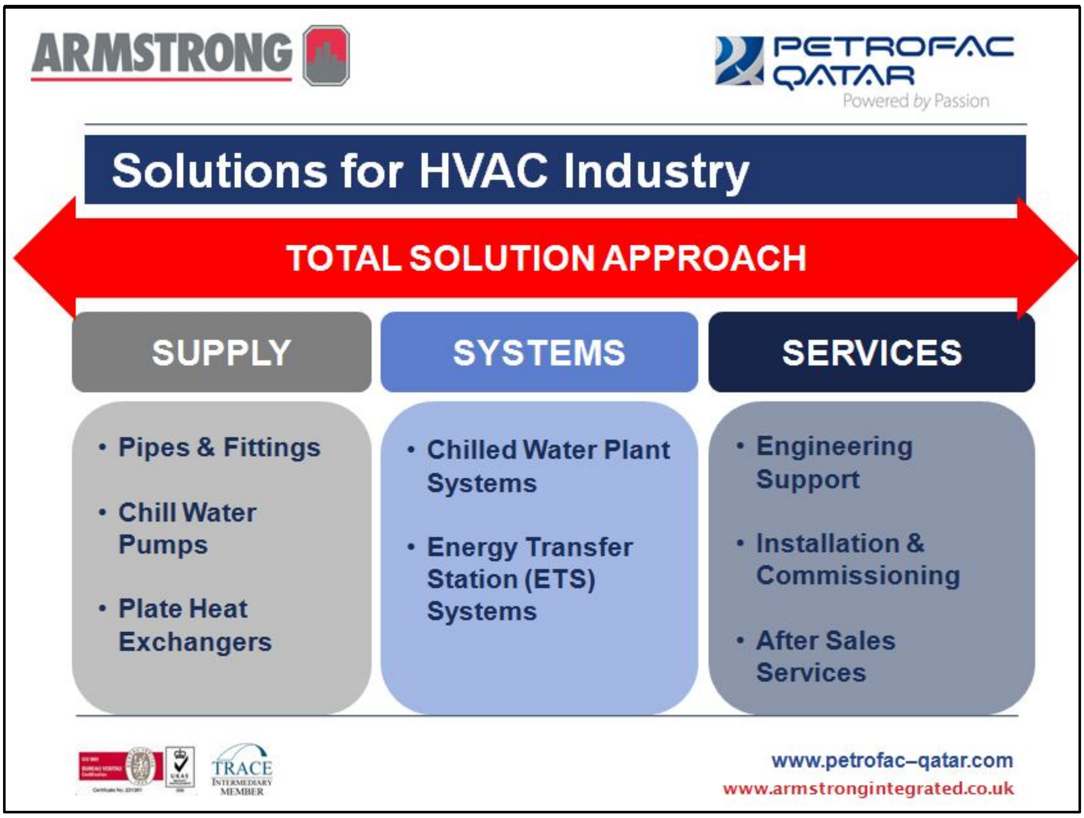
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AIL Managing Director

Mr. Dominic Cutts
AIL – Operations Director

Mr. Andy North
Sales Manager
EMEA

Mr. Peter Wolff
AIL – Business
Development Director

Mr. Gautham Belthur
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James Allan Carey Armstrong
Second Generation

Charles & James Armstrong
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Our Origins
Pumps

Today
Heating & Cooling Solutions

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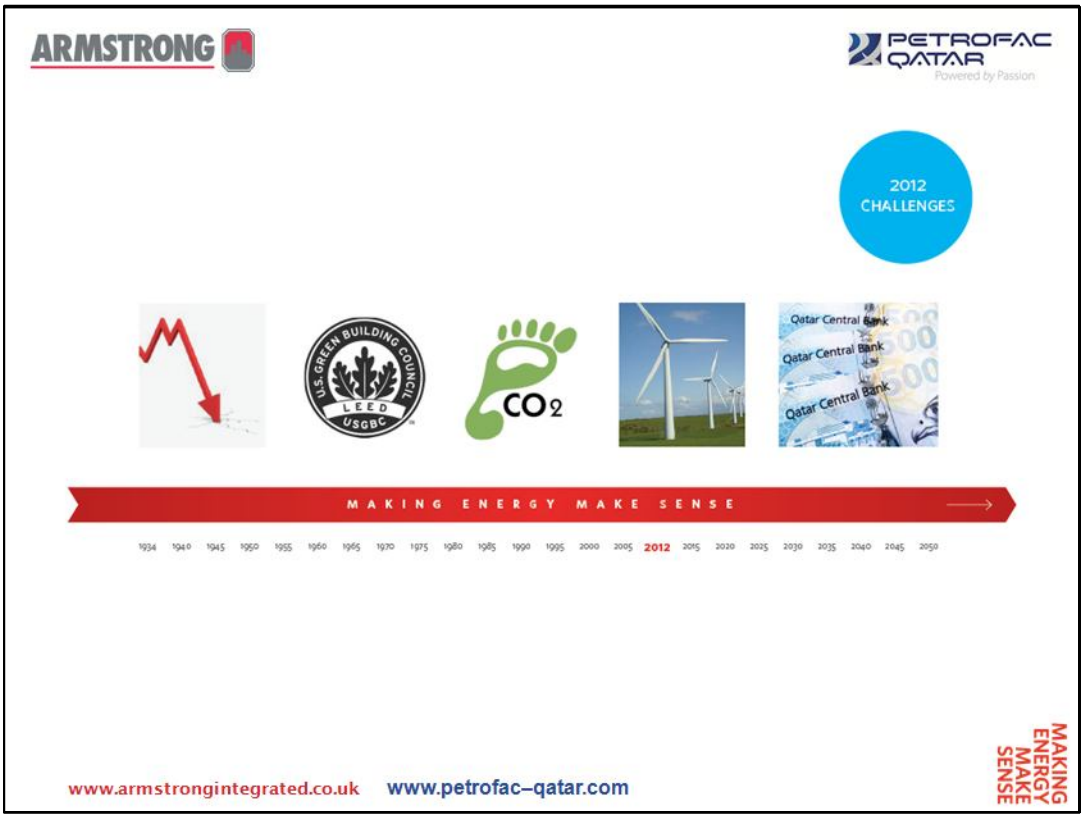
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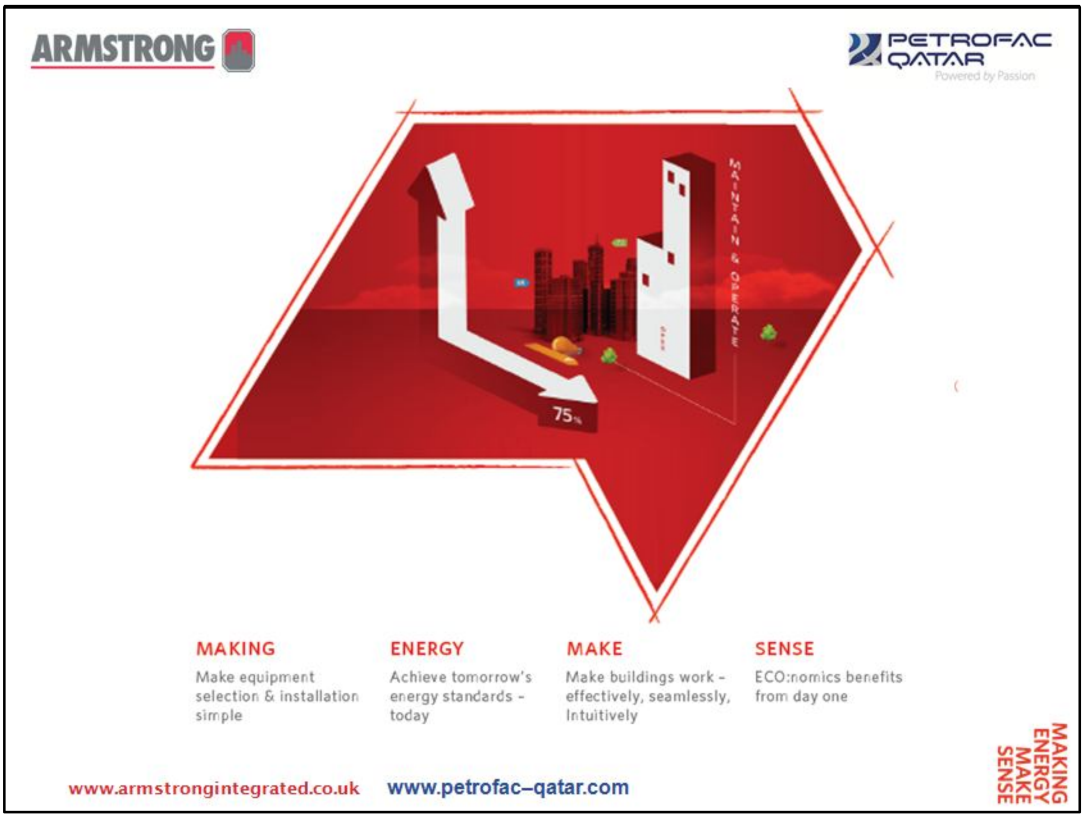
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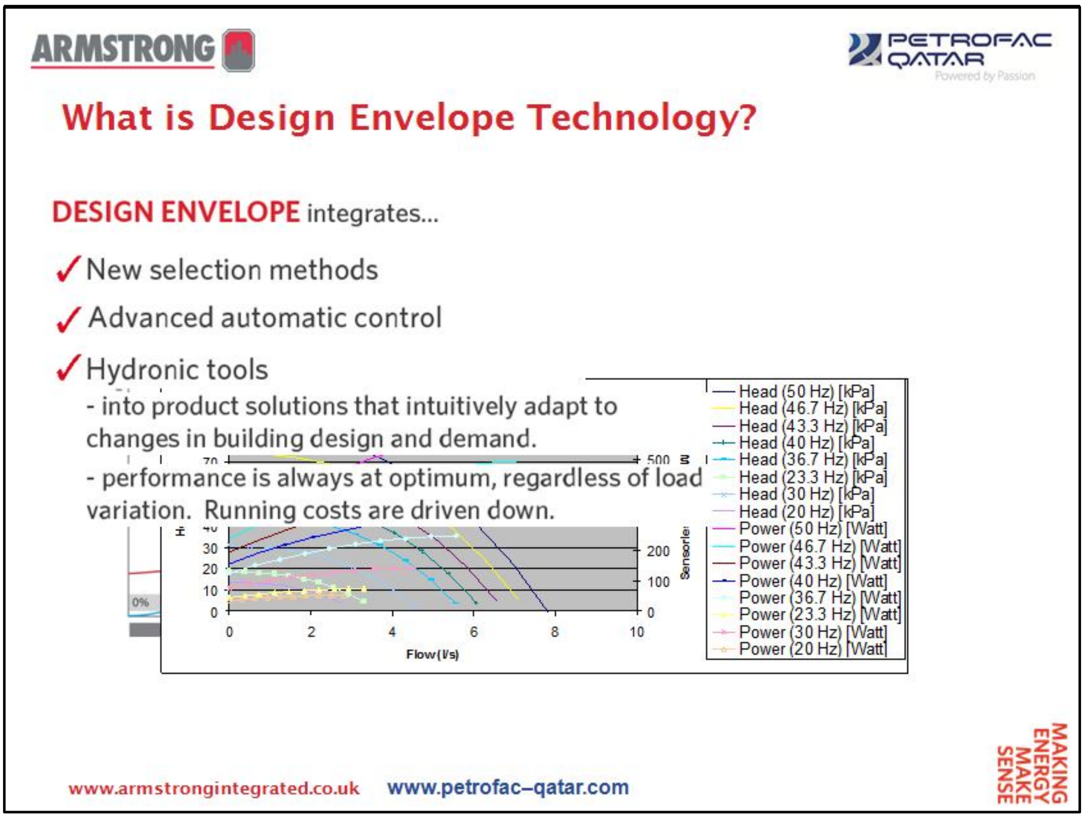
This presentation will explain how the new Armstrong Design Envelope pump range delivers benefits to all stakeholders in a building through its life, from concept, detailed design, installation, commissioning and through its operating lifespan, covering multiple changes of use and maintenance needs.

We will start by explaining the need for Design Envelope technology.

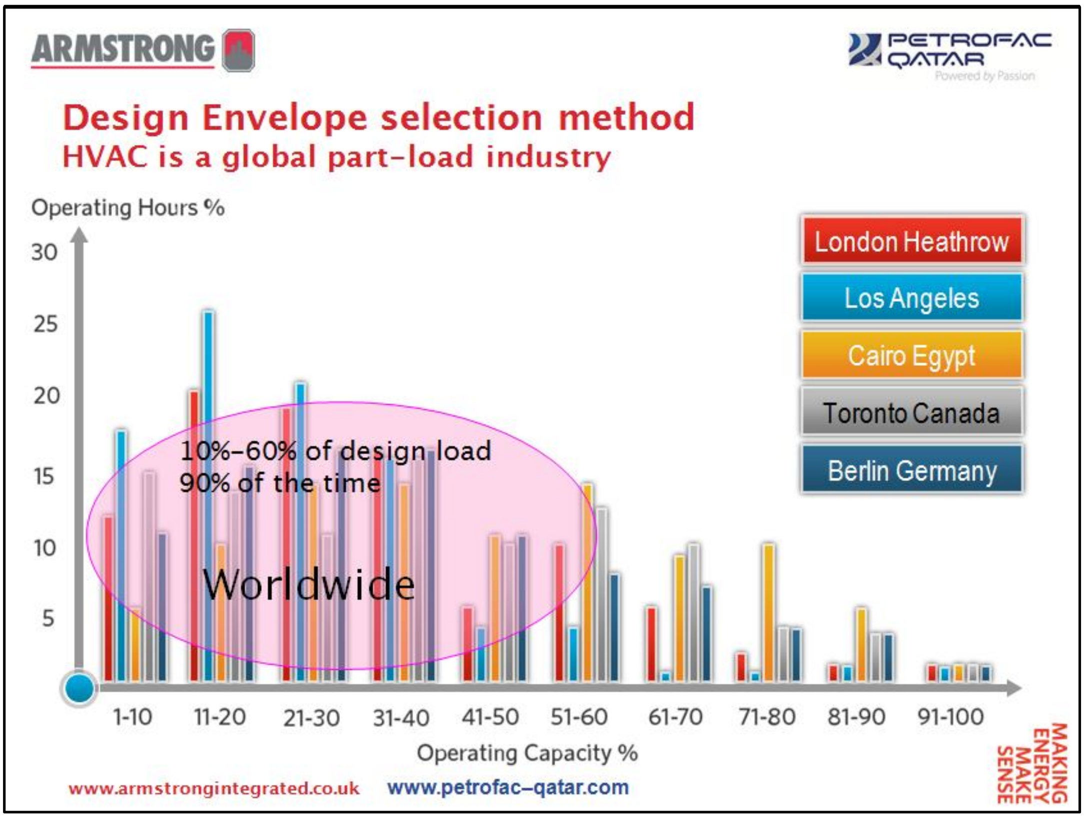
Next, we will talk about the key components of a pump, allowing us later on in the presentation to understand the benefits that Design Envelope pumps deliver.

Then, you will see the huge cost and operational benefits that accrue by applying best practice control to variable speed pumps. We'll start by looking at past and current conventional control methods.

This will help the understanding of how Design Envelope pump's automatic pump speed control dramatically reduces whole life cost.



Armstrong's controls and hydronic technology base is driving new ranges of HVAC equipment that are easy to select, have a wide operating range, operating efficiently at all points and adjust automatically to system demand changes.

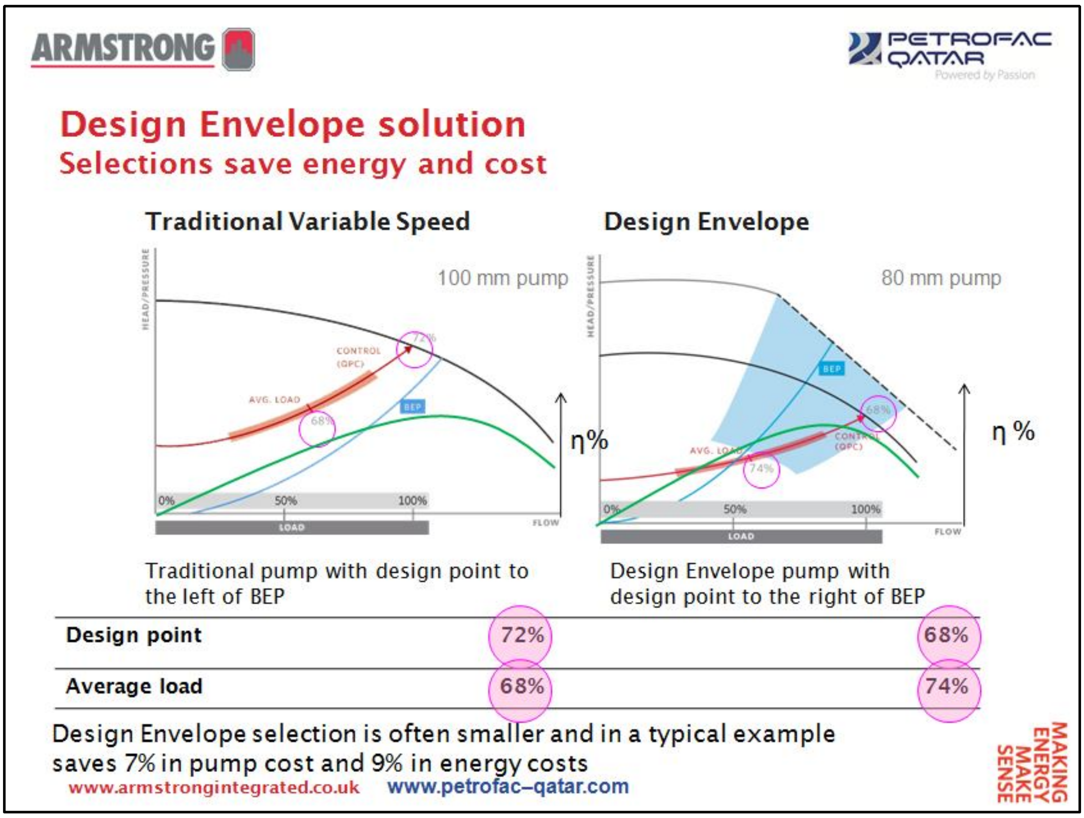


The HVAC industry recognises that although global temperatures may be rising, the demand for heating and cooling are a fraction of peak load for most parts of the year. The data on the graph shows that whether the climate be temperate in Europe, continental in Toronto, Mediterranean in Los Angeles or sub tropical in Cairo, demand rarely hits peak load.

The challenge for the industry has been to design, develop and operate systems that adjust their outputs to part load situations without losing efficiency.

This presentation will show how Design Envelope can deliver this promise.

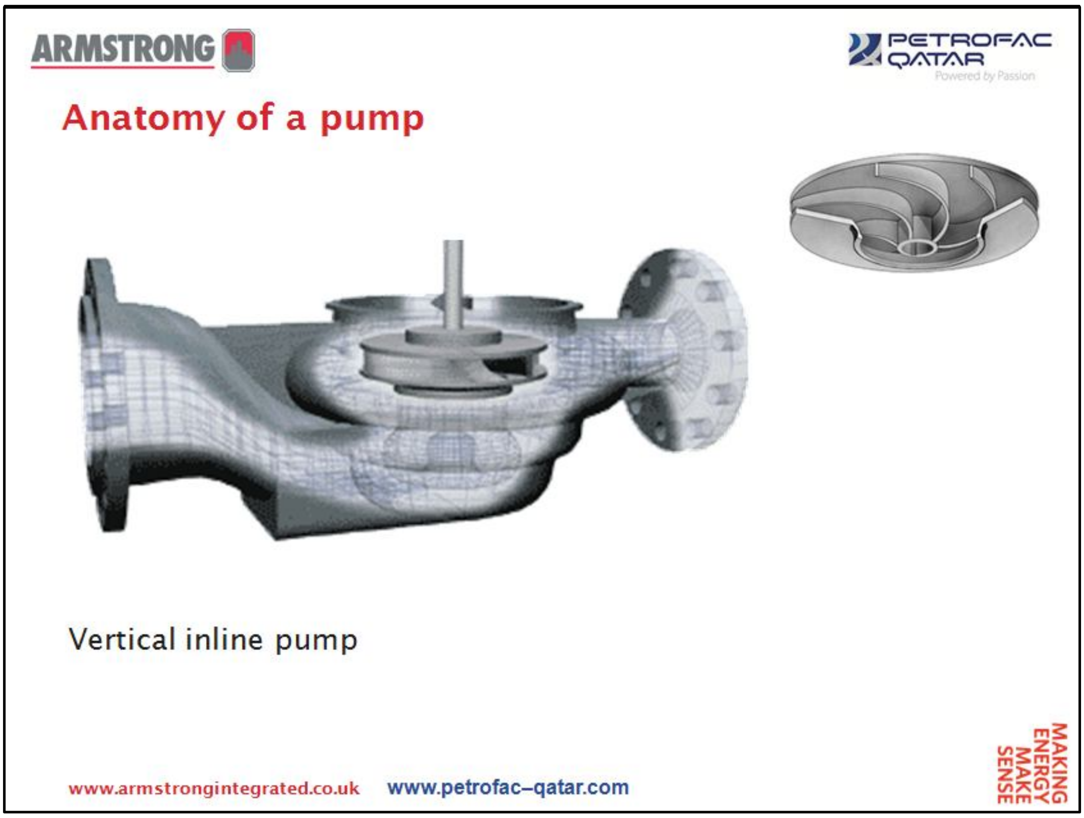
We have seen how Design Envelope pumps deliver lower lifetime operating costs through selection to meet part load efficiency. We will next see how they control to deliver best savings at part load.



But before we do so, we must first understand why, when pumps are going to operate at part load for most of the time, pump selection practice must change. Traditionally, pumps are selected so that the design point is at or near to the pump's best efficiency point. This makes sure that if a pump operates at this point all the time, then power consumption is minimised. But variable speed pumps rarely operate at full load, as we have just seen. So Design Envelope pumps are selected with the Design Point to the right of best efficiency point.

The result is that it's likely that a Design Envelope pump may have a smaller nominal bore size than a conventionally sized pump. In the illustration on the slide, an 80mm Design Envelope pump is contrasted with a 100 mm conventional selection. At Design Point, the Design Envelope pump is 4% less efficient.

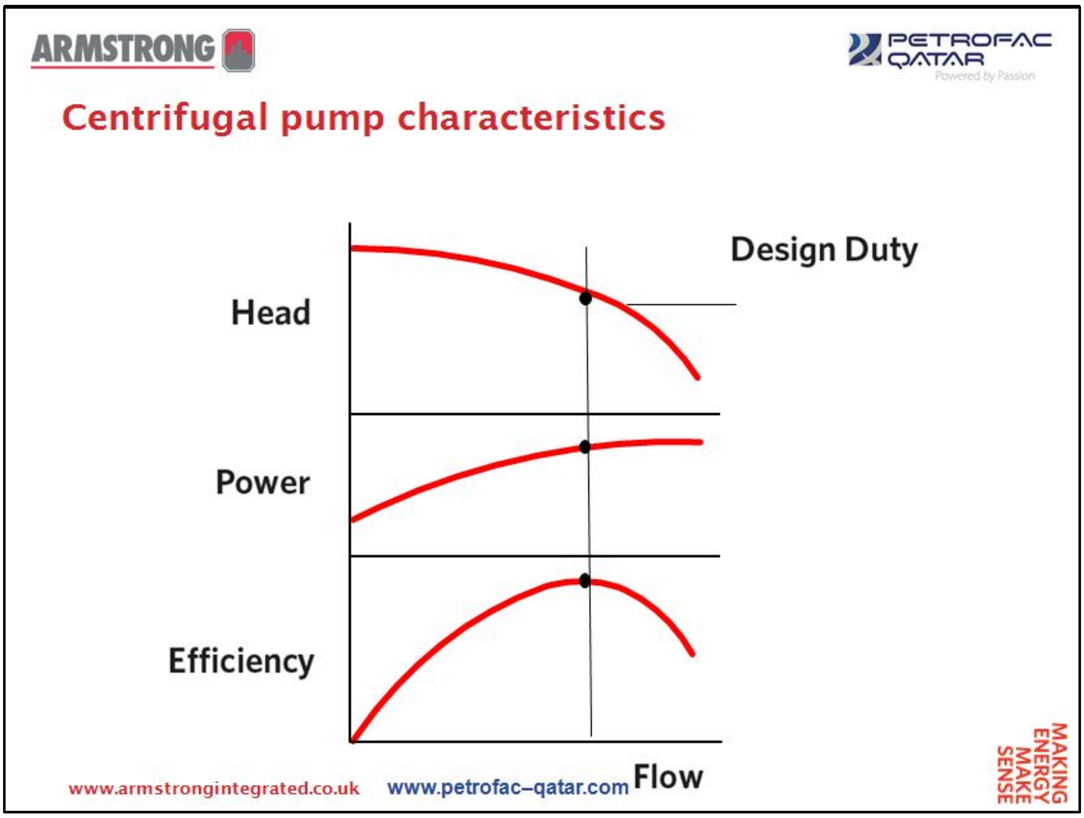
But at 50% of design, the 80mm pump is 6% more efficient. Given the typical load profile that variable speed pumps live though, the 80mm selection will consume less power through its operating cycle.



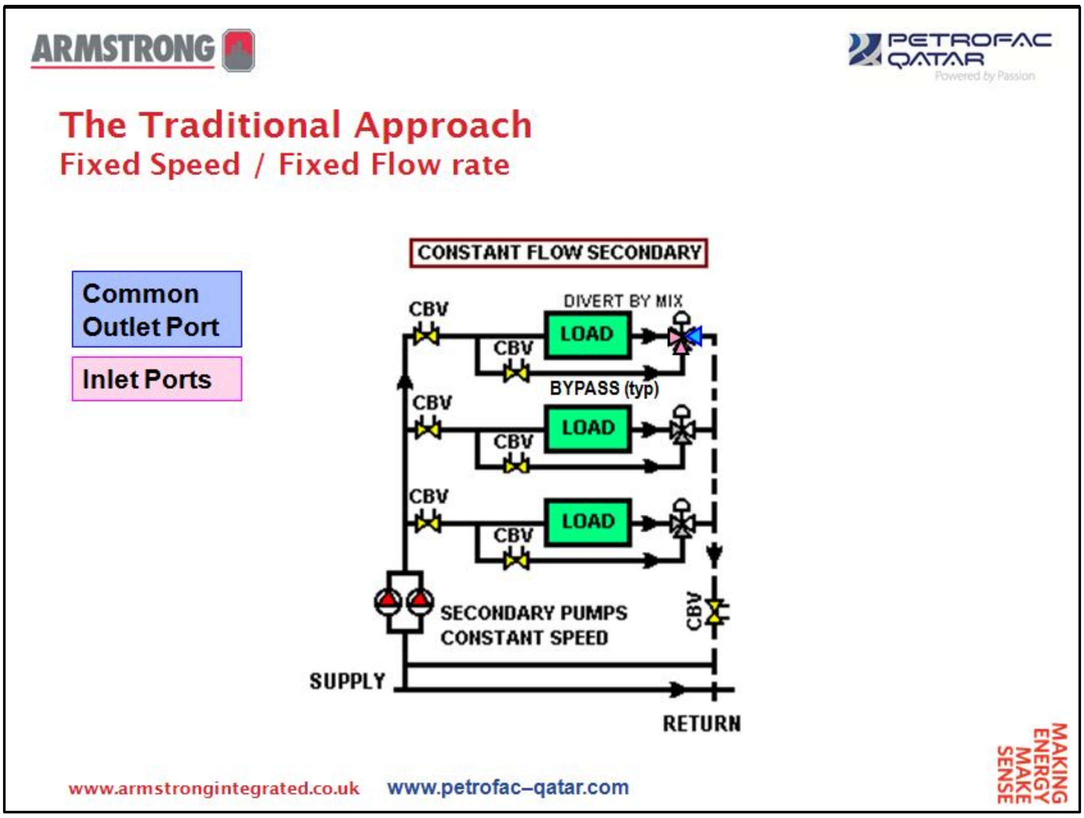
Centrifugal pumps work by converting electrical power from the mains supply to water power. Water power is measured as the product of flow rate multiplied by the pump generated pressure head.

Water is given velocity energy by the vanes of the impeller and enters the volute, whose internal volume, shaped like that of a snail shell, is designed to convert the velocity head to pressure head by slowing the water down when the volute cavity gradually increases in cross sectional area.

The water leaves the pump having accepted the electrical power transferred by the pump, with pressure head and water power.



The performance of a pump is displayed as a series of curves. With the horizontal axis indicating flow rate and zero being at the left end, the top curve shows the pressure that the pump generates reduces as the flow rate increases; the middle curve shows that the pump absorbs increasing power (from the electric motor that drives it) with increasing flow rate; and the lower curve shows that the efficiency of a pump is zero at zero flow rate (where no work is done by the pump whilst it absorbs power from the motor) but that the pump increases in efficiency as the flow rate increases, until the pump efficiency peaks at a point roughly two thirds of the way to the end of the pump curve. This point is known as the best efficiency point.

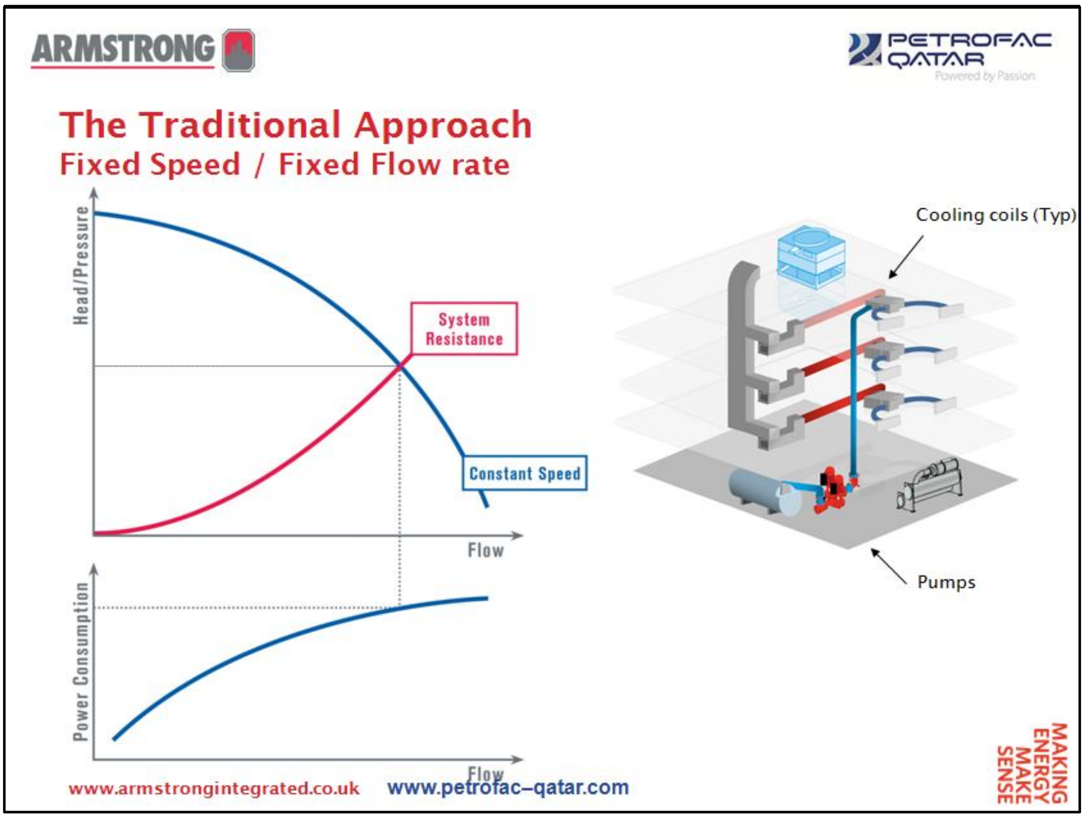


In the next sequence of slides, we'll be examining how secondary circulation systems have developed in recent years, looking at how the control systems work to handle water requirements at part load and how much pumping power has been required. We'll see how, as control systems improved, the pumping power requirement at part load has been reduced dramatically, saving on running cost.

In this first slide, we see an old fashioned fixed speed secondary pump, taking its supply from the low loss header at the bottom of the screen, serving multiple loads, such as AHUs, in parallel. The liquid flow to each AHU is controlled by a three port valve. The 3 port valve receives a control signal from a temperature sensor in the space being served. If the zone requires heating/cooling then the 3 port valve ducts the water through the coil in the AHU. If the zone is at design temperature, then the 3 port valve ducts water through the bypass instead.

The by pass is fitted with a balancing valve whose orifice is adjusted so that its pressure loss is the same as the coil in the AHU.

The key feature of this control configuration is that the secondary circulation pump runs at maximum speed, all of the time, and pumps the same flow rate and head, all of the time. The result is that at part load, when the 3 port valve is diverting flow through the by pass, a lot of pumping power is going to waste. Pump energy saving is zero %.



The pump curve shows a single fixed flow/head operating point and a single kW absorbed point when three port control valves and fixed speed pumps work together. At part load condition, the pump duty point remains unchanged. There is considerable scope here for saving energy. As installed however, this configuration delivers none at all.

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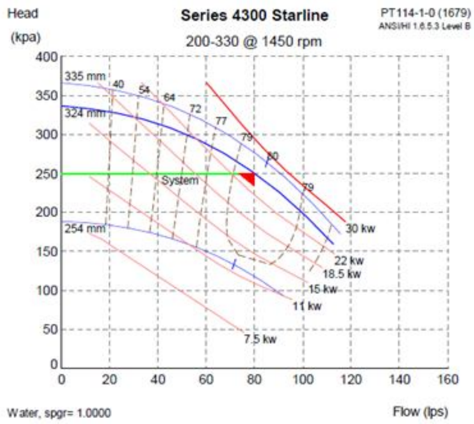
The Traditional Approach
Variable flow / Constant Speed

Flow (l/s)	Head (kPa)	Pump rpm	Power absorbed (kW	Efficiency %
80	250	1450	25.2	79



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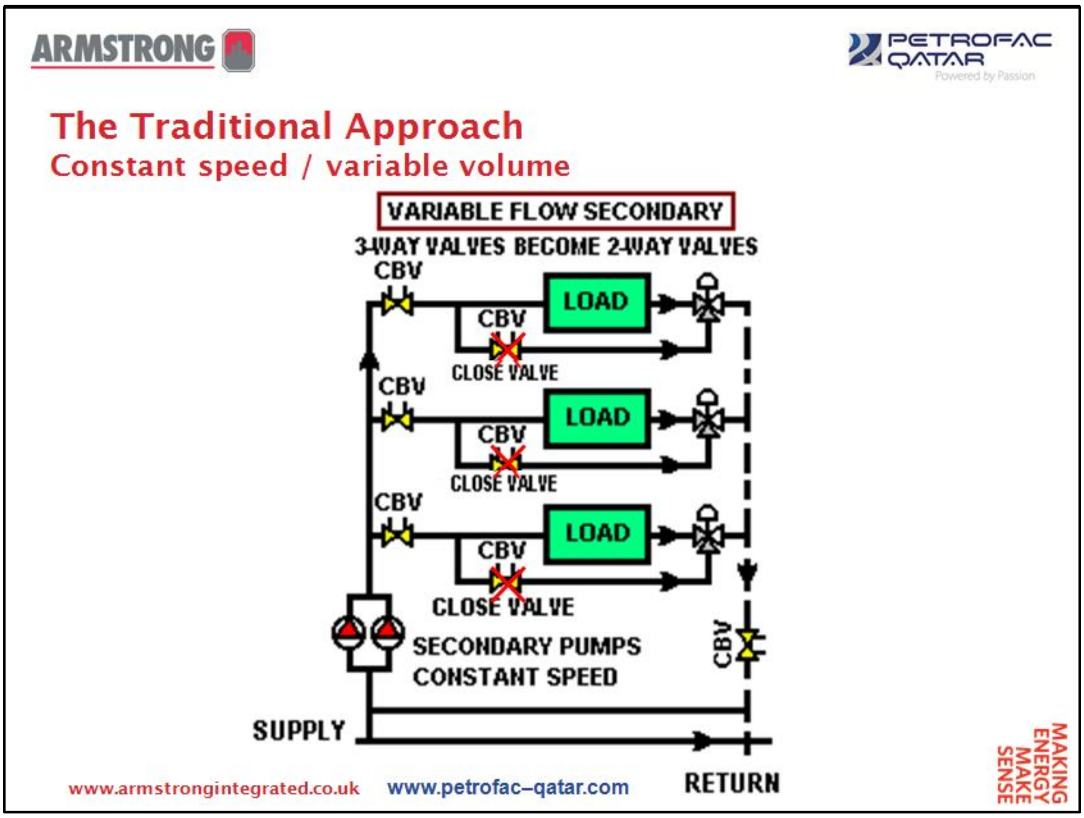
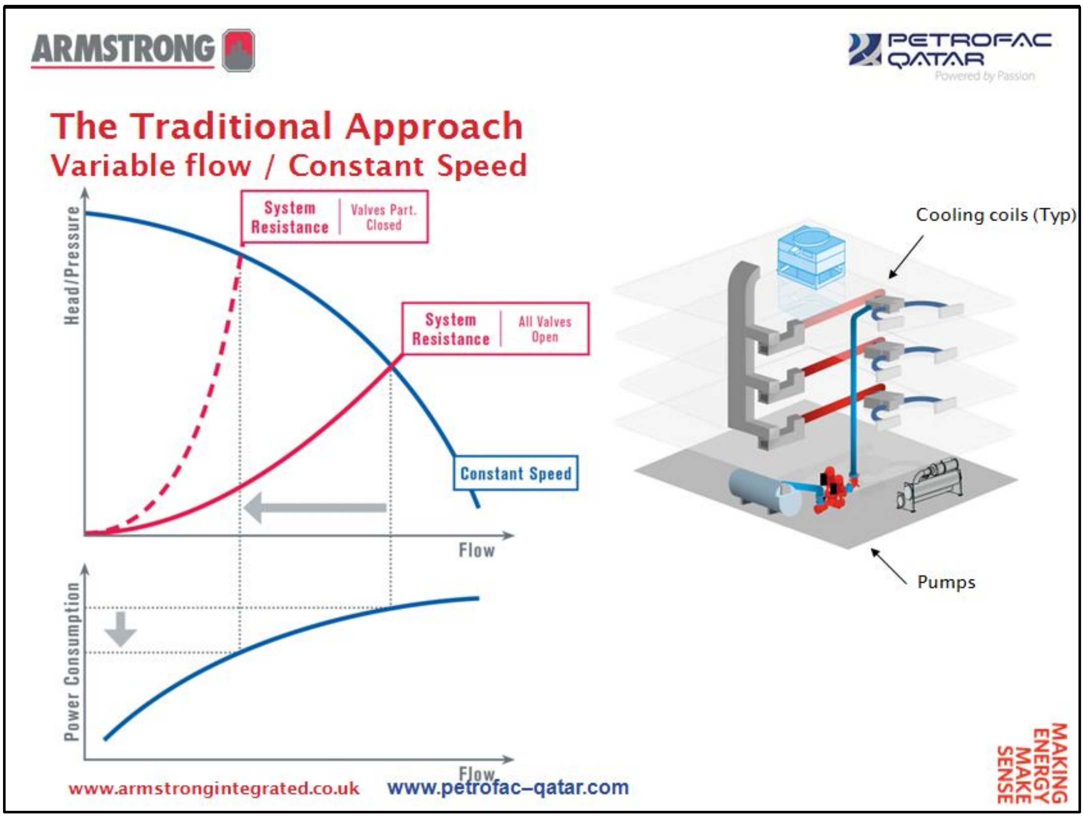
This picture, taken from Armstrong Ace pump selection software. Shows how the duty point sits on the pump curve. Ace tells us the pumping data us entered in the table above.

We shall use this pump, the 200-330, this typical duty 80 l/s at 250 kPa, to demonstrate the changes in absorbed power at part load under several different control methods.

With the first method, three port diverting valve control, using a fixed speed pump operating on a fixed duty point, the 200-330 absorbs 25.2 kW continuously.



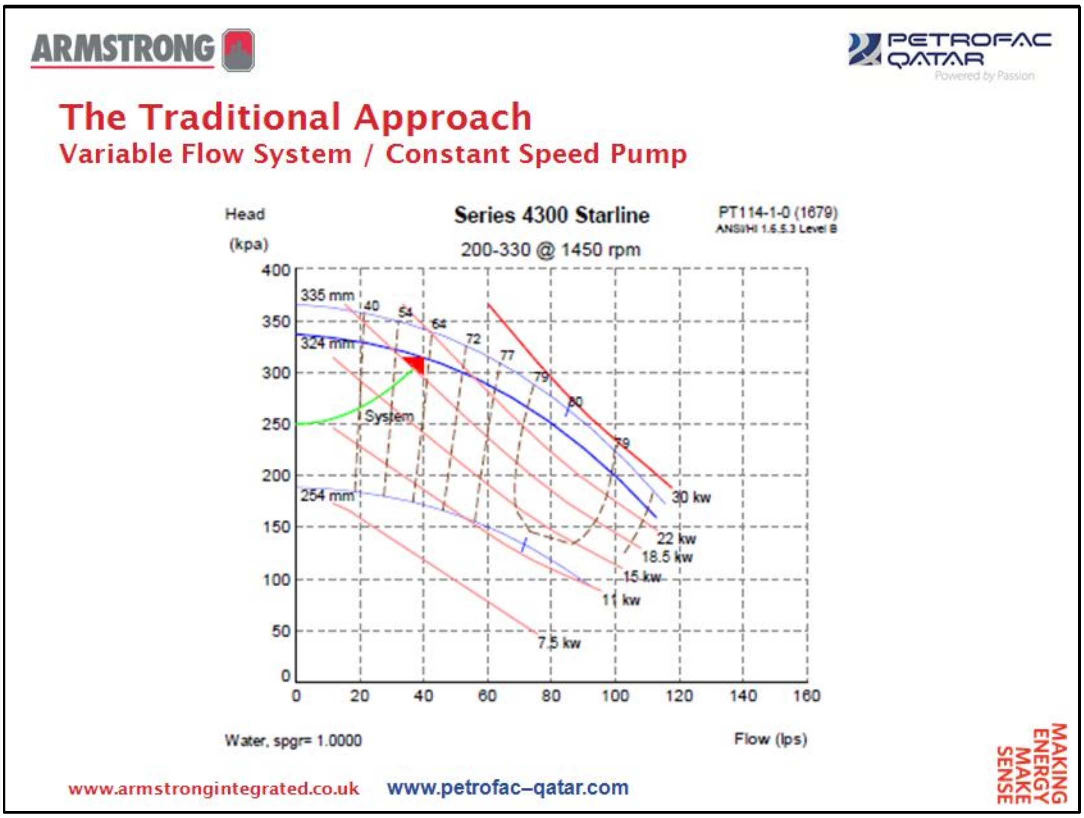
The schematic drawing shows that the commissioning valve set has been closed, shutting off the by pass line and thus converting de facto the three port valve to a two port valve. The pump speed remains constant in this second scenario. Let's see on the next slide how the pump performs at part load.



We see that the duty point has ridden up the pump curve to the point indicated by valves part closed. Remember that the operating point of a pump is where the system curve intersects the pump curve, nowhere else.

By riding the pump curve, the power absorbed by the pump will fall, developing a running cost saving. The next slide will advise the exact quantity of power saved at part flow. It will not be a lot..

This saving is minimal compared to what can be realised with variable speed drives combined with best practice controls.



Ace shows that duty point has ridden up the pump curve to 50% flow (40 l/s).

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The Traditional Approach
Variable Flow System / Constant Speed Pump

Flow (l/s)	Head (kPa)	Pump rpm	Power absorbed (kW	Efficiency %
80	250	1450	25.2	79
40	310	1450	20.1	62.6
		Power saving	20%	

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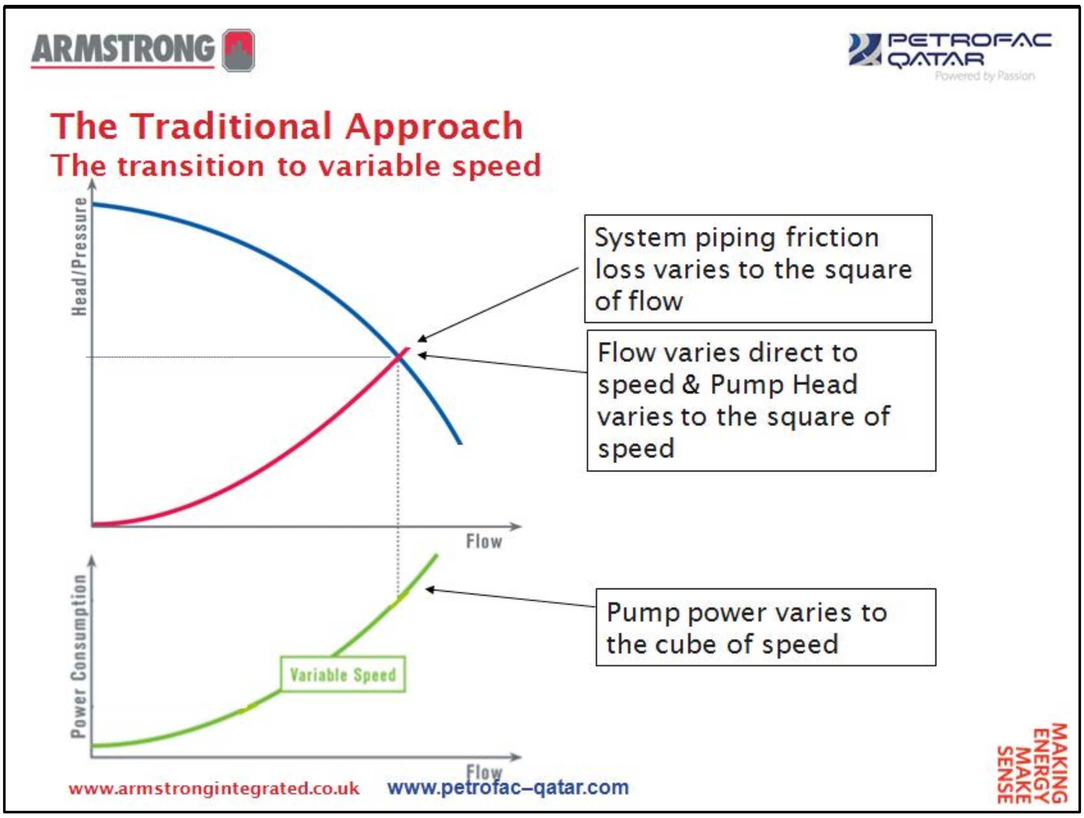
...and Ace tells us that at 40 l/s, the pump generates 310 kPA and absorbs 20.1 kW, a 20% saving in power.

So a 50% reduction in flow rate, but only a 20% reduction in power absorbed. We can do much better as the next slides will show...



With variable speed and good control, we can now realise substantial power savings. The reason why is because pump performance obeys three simple rules, which are called the Affinity Laws:

Rule 1: Pump flow rate is directly proportional to its speed.

Rule 2: Pump head pressure is proportional to the square of its speed. So, doubling the speed of a pump increases its pressure capability by 4.

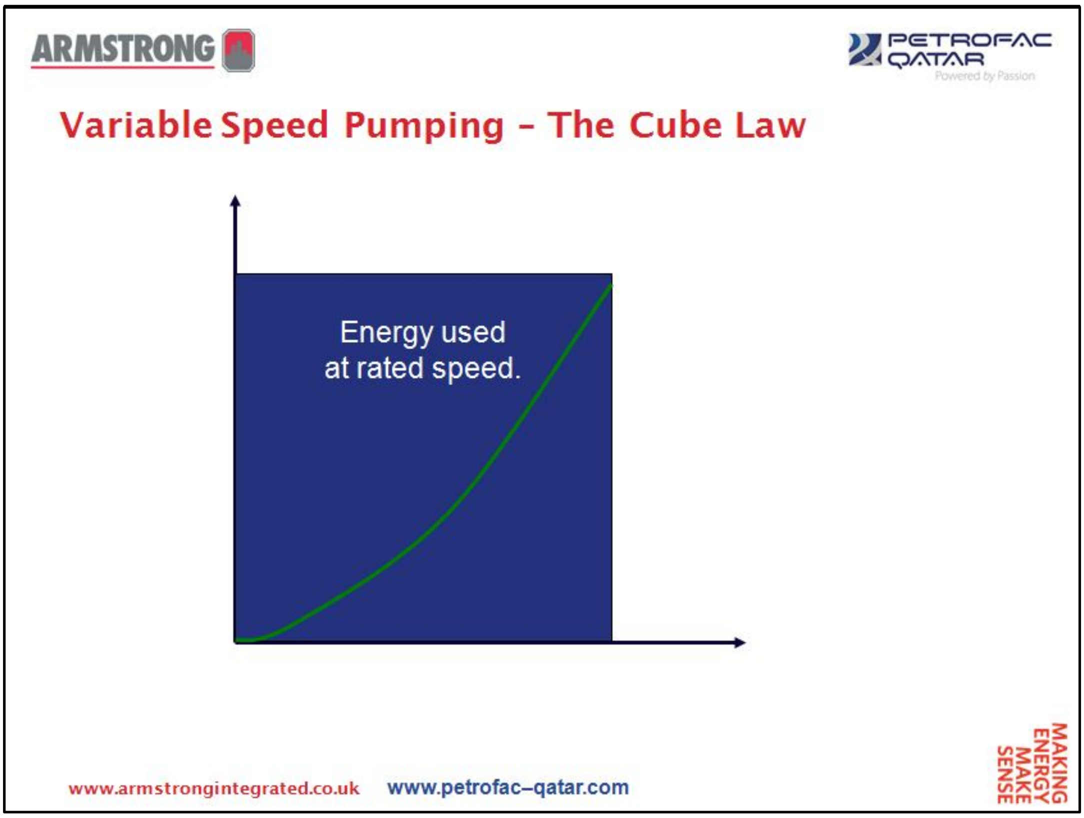
And Rule 3: Pump power absorbed is proportional to the cube of its speed. Doubling the pump speed increases its power absorbed by 2 to the power of 3, which is 8 times.

This rule works in reverse. If a pump speed is halved, its power absorbed will be reduced to 1/8 of the original power required – an 88% saving.

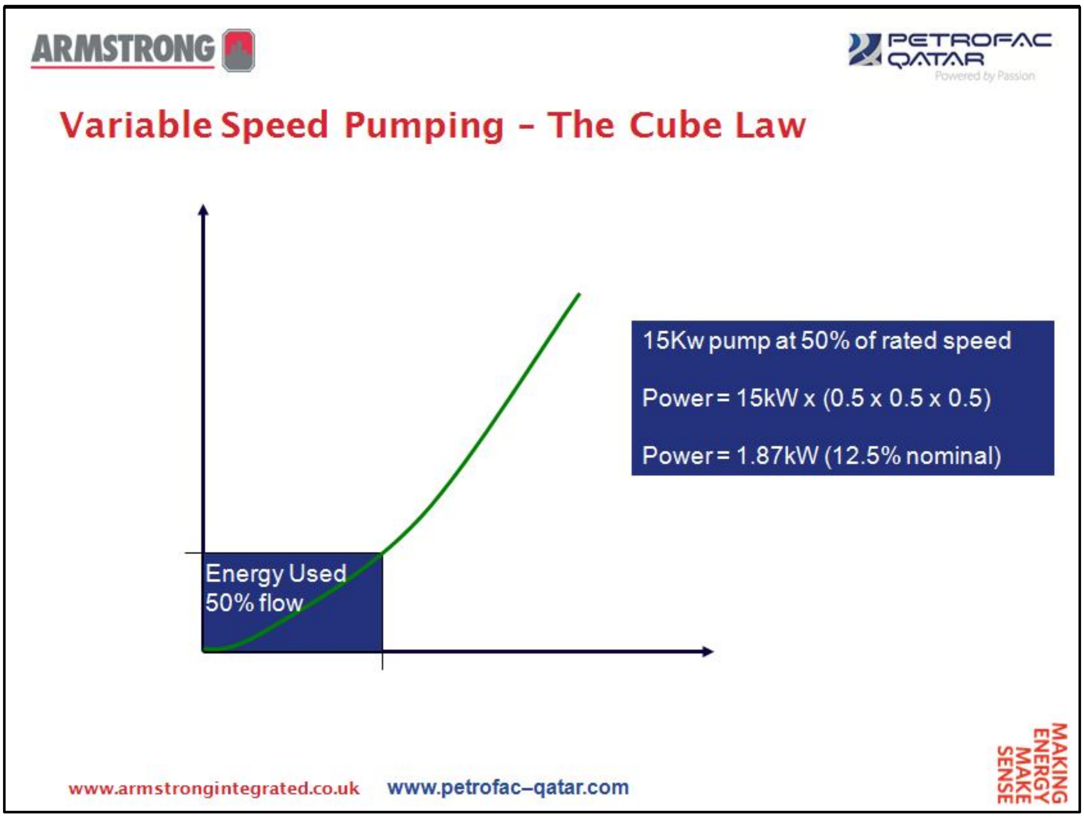
It is clear now why variable speed is so powerful an assistant to the drive for energy savings. It’s essential that speed turn down is maximised to get best saving.

Note also that the system friction curve also follows a square law rule. Note well that pressure head required by the system to circulate the water around will be, at 50% design, 75% less than at design flow.

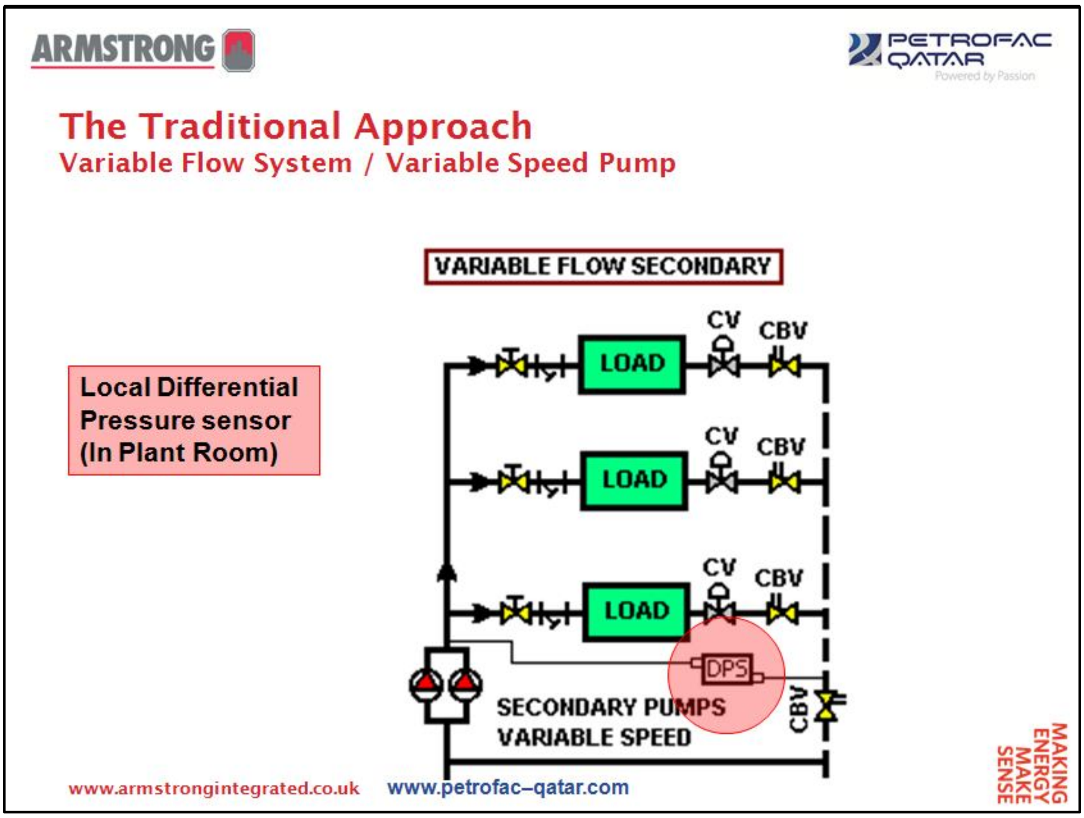
If controls engineers can track this reducing system pressure requirement accurately, the scope for power reductions and running cost savings can be maximised.



This graphic gives a pictorial indication of the scope for power saving at part load. This blue square indicates the power needed to pump full load...



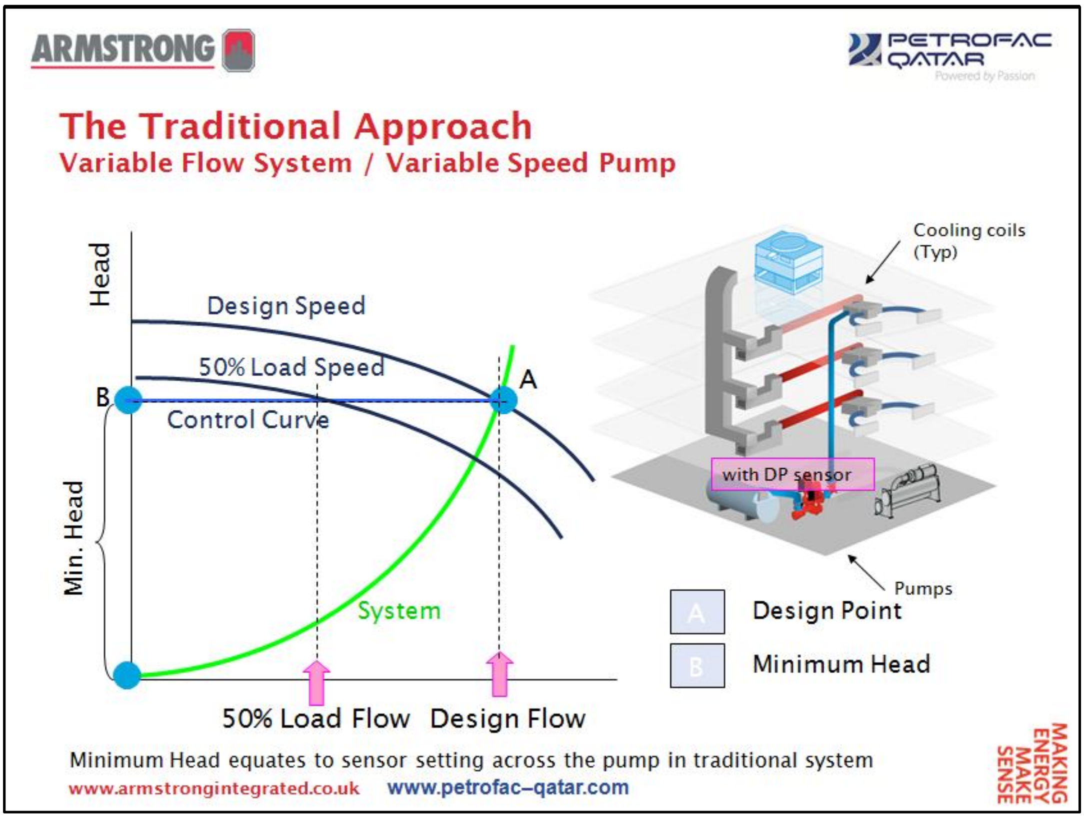
...and this much, much smaller blue square shows the power needed to pump half the design flow rate. 87.5% less than at design flow rate. The next slides will show how we can get very close to this ideal saving.



In this third scenario, we have two port valve water flow control and variable speed pumps. The question is, how is the pump speed to be controlled? The answer is, by measuring differential pressure between two points in the pipe system and then applying a control system to keep this pressure constant. In this traditional scenario, the pressure is measured between the inlet and the outlet of the pump in the plantroom, seen lower down the schematic drawing. A differential pressure transducer is used to measure the pressure and send a voltage signal proportional to pressureto a pressure set point controller. The controller compares the pressure signal with a reference pressure and then sends a signal to the drive to instruct it to speed up or slow down the pump so as to keep the measured pressure equal to the reference pressure.

The second question here is, what should the reference pressure be set at? The answer is that, as the pumped fluid needs to find its way beyond the pressure transducer all the way to the furthest load and all the way back, and at times of maximum load, the set point pressure must be set to the maximum design pump pressure.

We shall see later on that locating the pressure transducer on the pump limits the capacity for pump speed turn down and power saving.

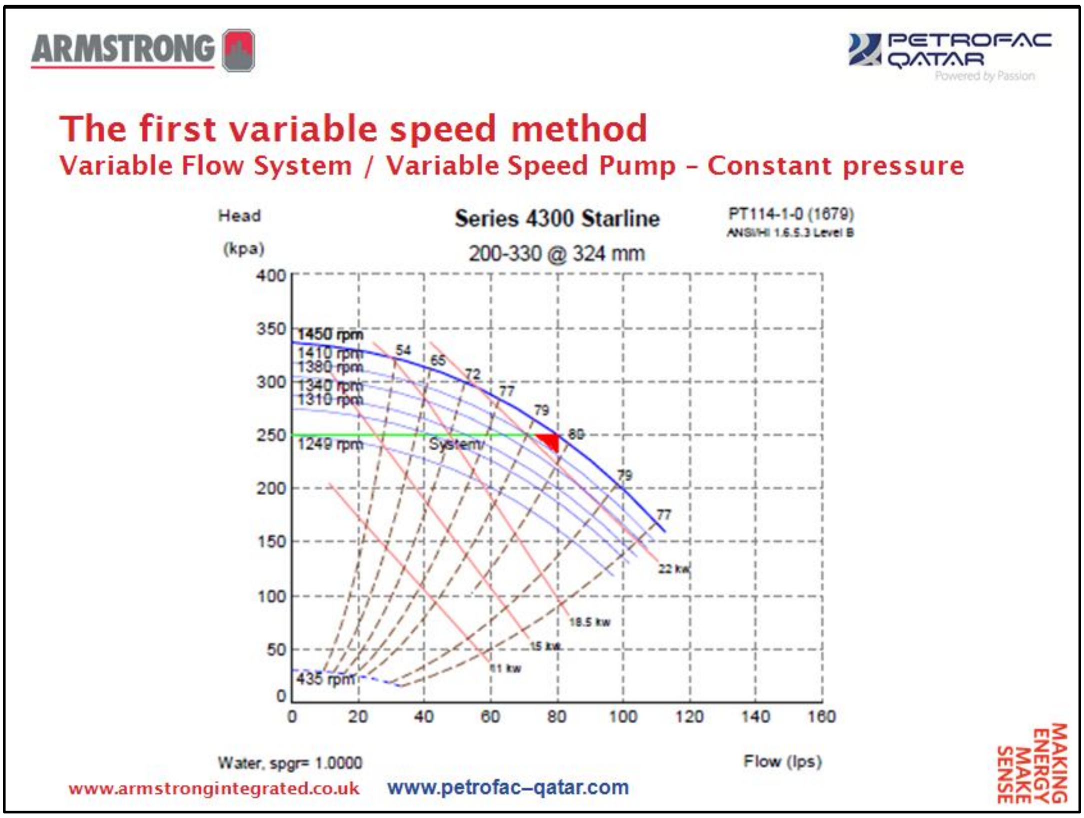


In a chilled water system, a building's temperature controls are connected to control valves that manage the amount of flow rate to the cooling coils. As the control valves open for more cooling, the differential pressure across the cooling coil, valve and piping will begin to decrease, and the IVS controls react to this change by speeding up the pump to maintain the pressure setpoint. If the control valve closes for less cooling, the differential pressure across the coil will increase, and the IVS controls slow down the pump to maintain the pressure set point.

As we related in the previous slide, to ensure the coil gets sufficient water flow through it, the pump pressure is set so that the pressure drops across the loads in the system are always satisfied and there's also enough head to overcome the friction loss in the flow and return pipework. The pump curve will track the Control Curve (in blue).

The pump speed will vary between design speed, to meet the design duty A and at minimum speed to meet to meet the minimum head at minimum flow rate, point B.

In practice, the speed will reduce at 50% design flow such that the power demand from the pump drops by 40%. Not bad, but this result can be improved even further by cleverer control thinking. The next slides will show how.



This picture from Ace selection software shows the range of pump operating speeds, from maximum (1450 rpm) to minimum (1249 rpm) in order to maintain a constant differential pressure across the pump inlet and outlet.

This speed change, approximately 200 rpm, limits the power savings to...

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The first variable speed method

Variable Flow System / Variable Speed Pump – Constant pressure

		Flow (l/s)	Head (kPa)	Pump rpm	Power absorbed (kW	Efficiency %
Fixed Speed	Fixed volume	80	250	1450	25.2	79
Variable speed	Variable volume	40	250	1310	15.0	67
			Power saving		40.5%	

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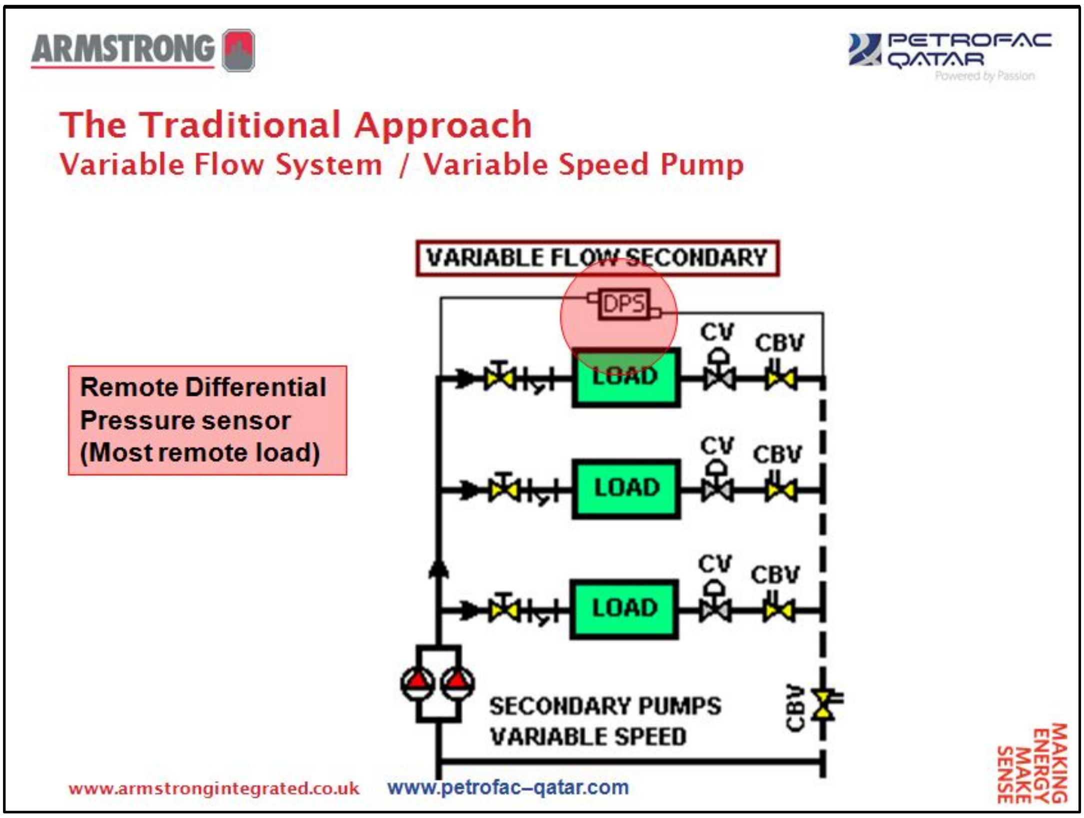
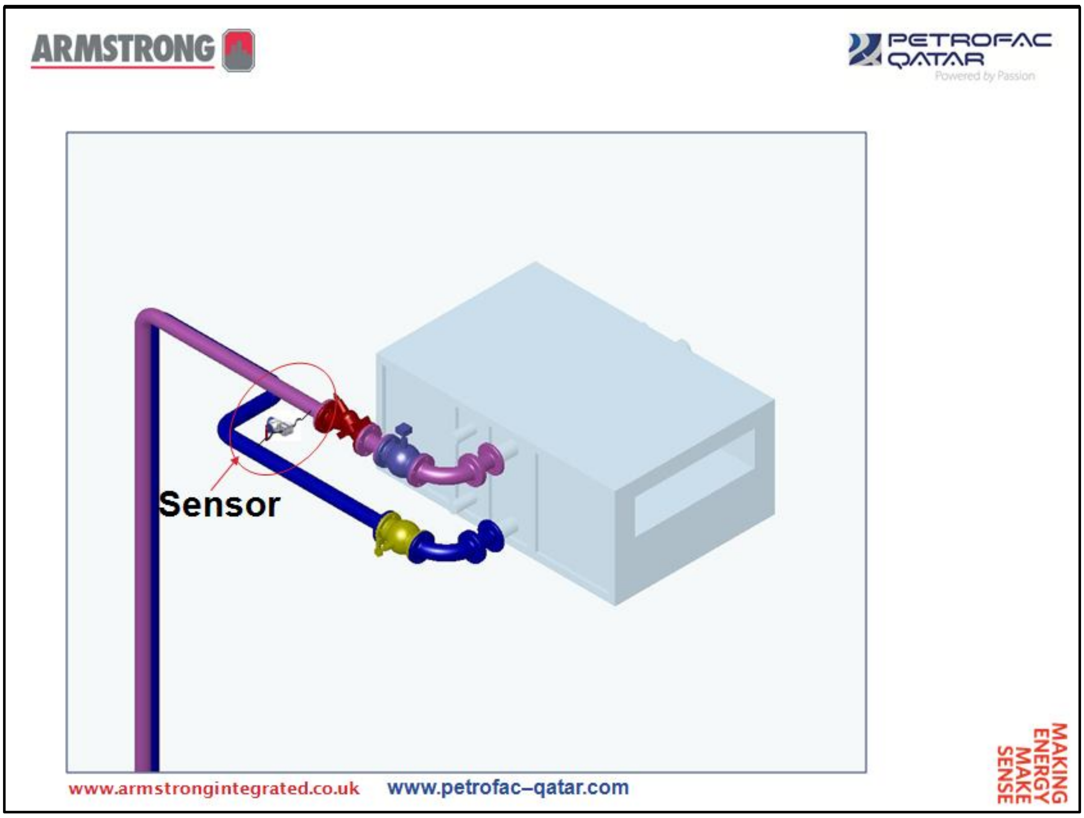
...9.2kW, a 40% reduction in power absorbed at the 50% design duty point. We're still not saving as much power as we have reduced flow rate, not have we got near to the ideal 88% reduction in power.

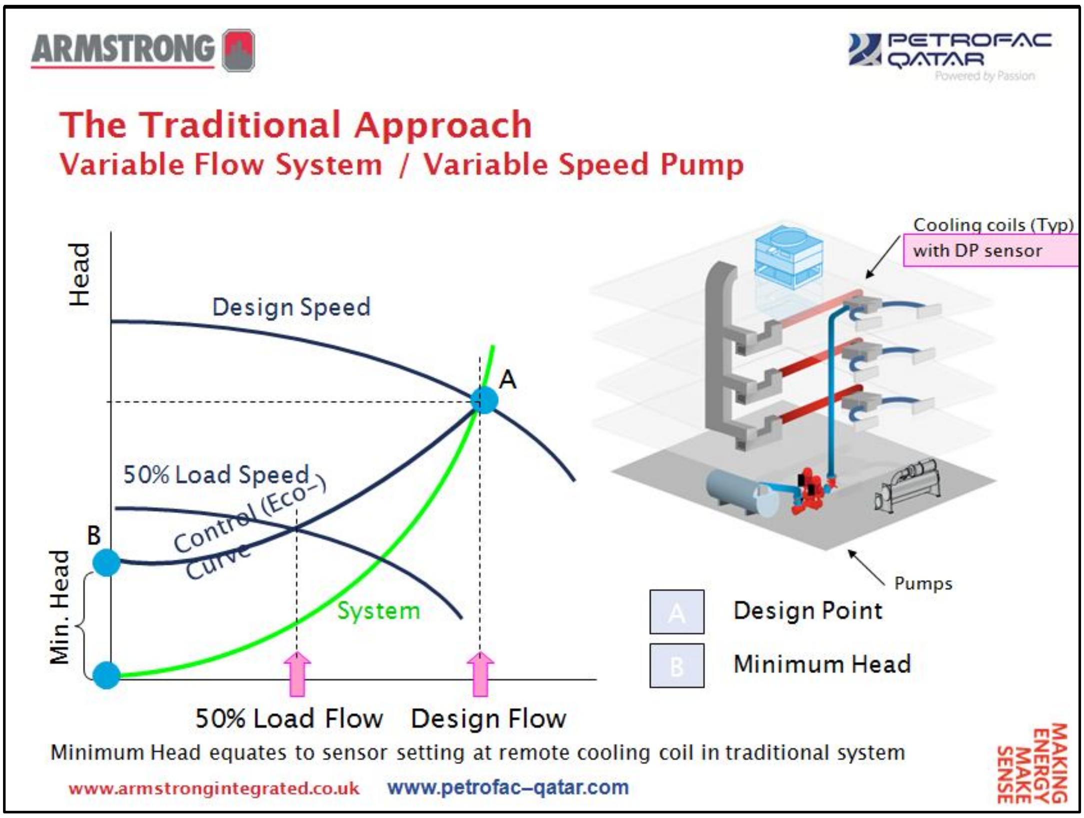


In this further refinement of system control, the pressure transducer is taken out of the plantroom and re-located across the index load, at the far end of the system. As a result, the control system will now be maintaining constant pressure at this distant point. What else is going to change? Well, the answer is the set point pressure. At the index point, the set pressure number no longer has to allow for the pressure needed to get the water from the plant room and back through the distribution pipework. All the new set point pressure has to allow for is enough pressure drop from design water flow across the coil and the control valve. If the pump is supplying adequate water flow at this remote location, then it will be doing likewise at nearer loads on the same system.

The set point pressure is now considerably reduced. This will be beneficial ramifications for power usage as we shall see…

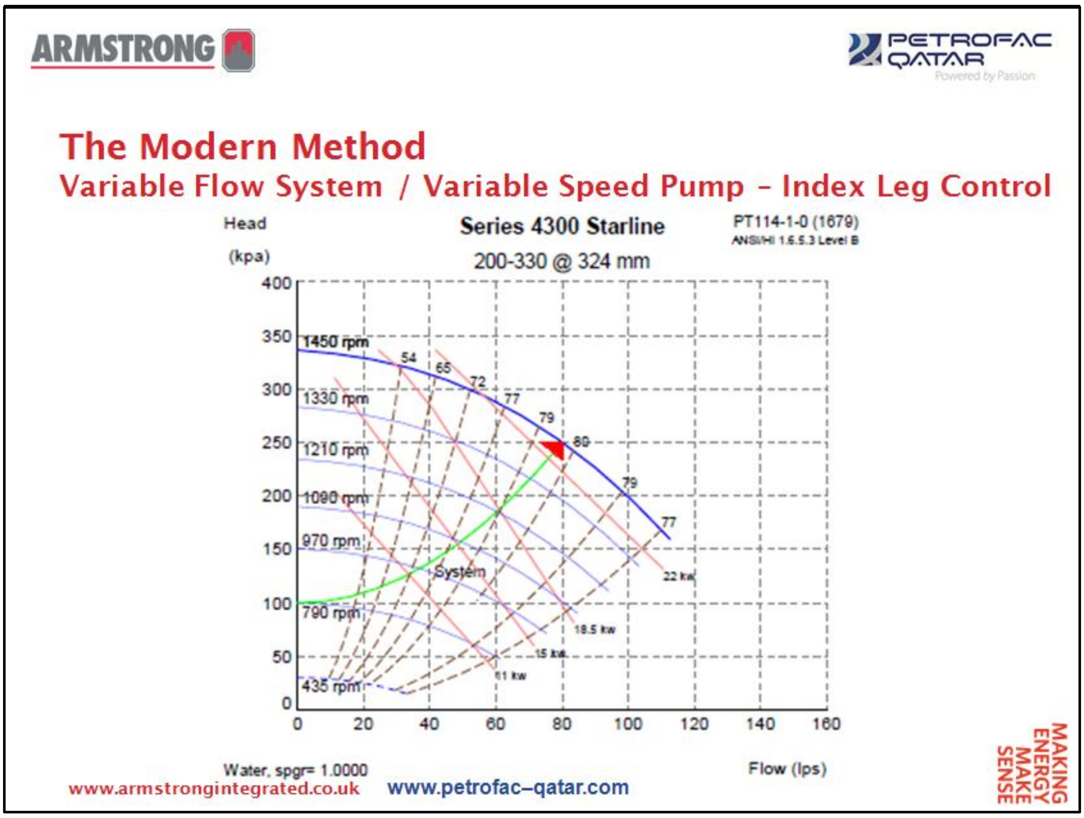


So we've now moved the sensor out to furthest load, across the supply and return piping to the load & valve.



We see now the new set point pressure B. This is much lower than it was when the transducer was in the plant room. The pump will still generate the design head A at Design Speed when all control valves are full open and maximum design flow is required from the pump. But as the valves start to close when the zones served reach design temperature, then the pump speed will fall as the control system recognises that the pump pressure at the index becomes excessive.

The pump will track down a system control curve which follows a near quadratic shape between the two points A and B.



Francesca,

Another new slide.

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The Modern Method
Variable Flow System / Variable Speed Pump – Index Leg Control

		Flow (l/s)	Head (kPa)	Pump rpm	Power absorbed (kW	Efficiency %
Fixed Speed	Fixed volume	80	250	1450	25.2	79
Variable speed	Variable volume	40	130	1010	7.5	74
			Power saving		70%	

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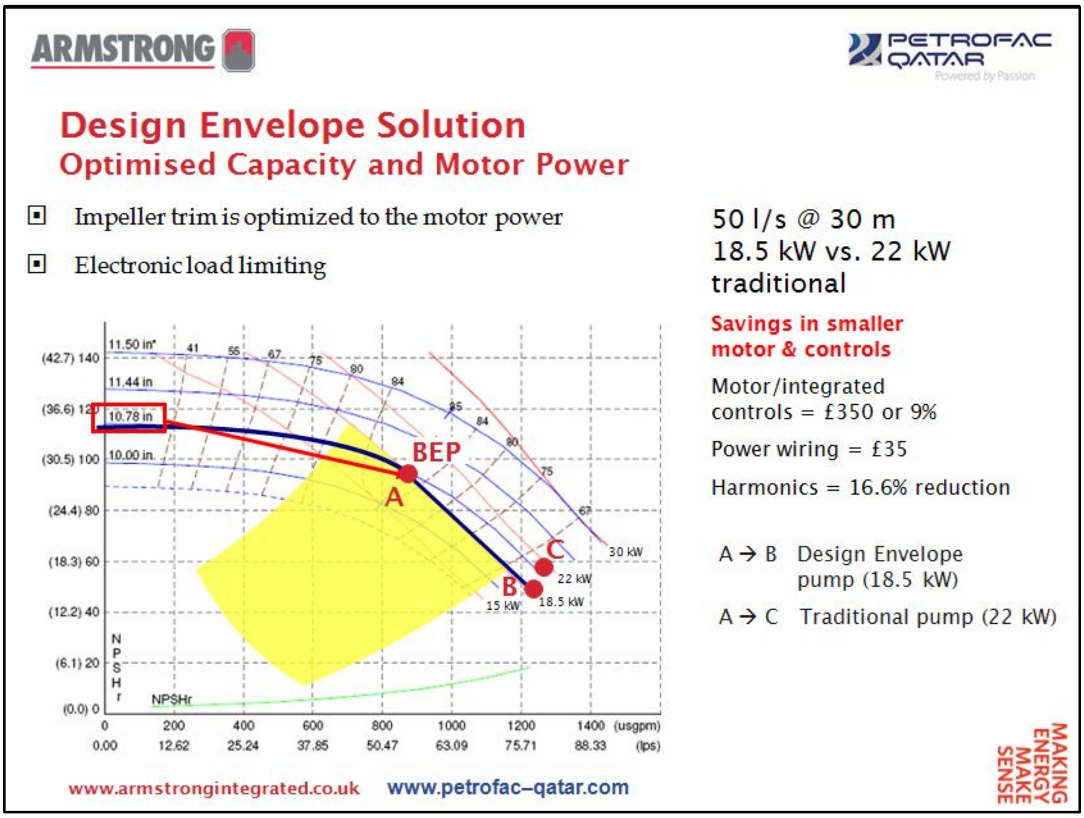
MAKING ENERGY MAKE SENSE

At 50% design flow, if the minimum pressure head is set to 40% of design head, then the power absorbed by the pump will drop by 70%.



Design Envelope pump selections also take a new look at how to size the impeller. Using advanced drive technology, smaller motors and drives can be selected.

Impeller trims are optimized to the motor power at the pump BEP. What exactly does that mean? It means we look for the intersection of the motor bhp line with the pump BEP and set our impeller trim to that motor.

In this example, a 1529 pump

30 kW uses an 11.50" impeller

22 kW uses a 11.44" impeller

18.5 hp uses a 10.78" impeller

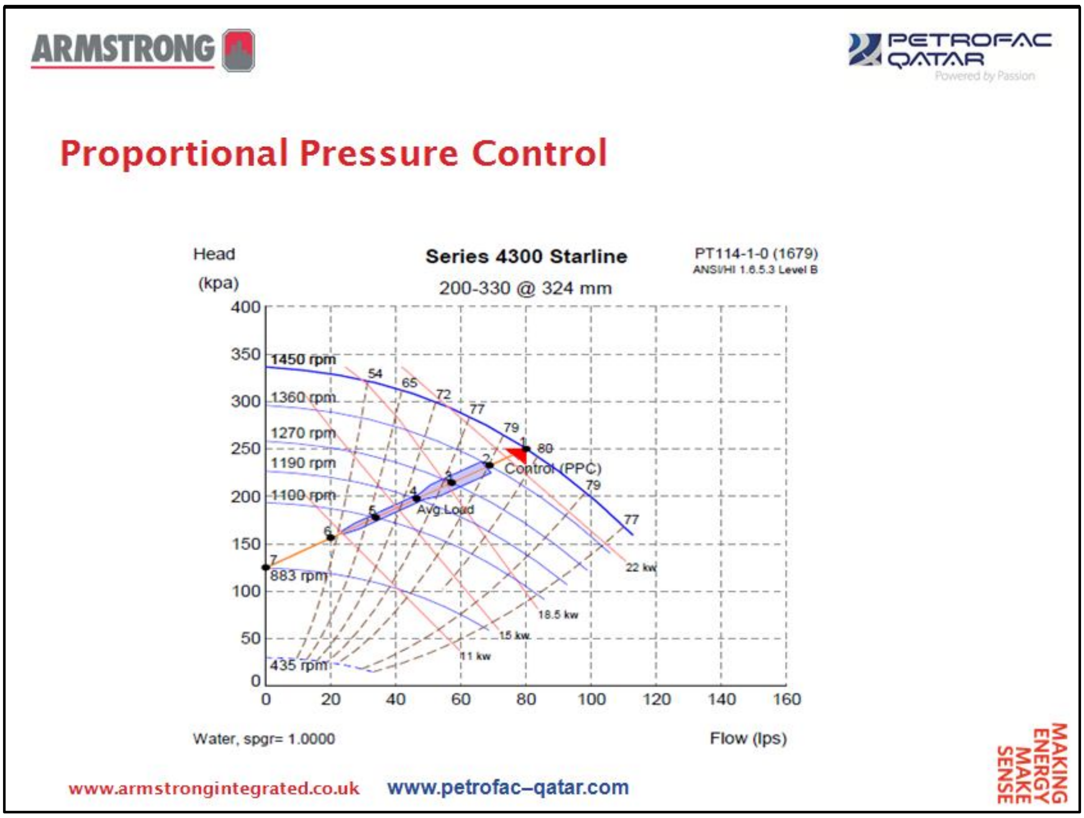
And a 15 kW uses a 10.00" impeller

Any operating point in between the pre-set impeller trims is achieved by varying the speed.

Why don't we use the largest impeller?... This is the most efficient trim... This is true hydraulically. But through testing and experience, we found that the common asynchronous motor torque is not constant and at lower frequencies typically around 48Hz, the mechanical losses start to have an effect. Thus we have distinct impeller trims for each motor.

Harmonics => 25/30 = 16.6% (no £ cost per Danfoss) Total harmonic distortion reduction.

*NOTE if anyone asks: impeller trims are based on water. For other fluids, the trim diameter is different.



Some pump control systems use local transducers, mounted on the pump's flanges, and a Proportional Pressure Control system in the controls, that delivers an approximation to the likely reduced pressure requirement at reduced flow rate.

The approximation takes the form of a straight line, not a quadratic curve, between the design pressure and the pressure at zero flow rate.

And the pressure at zero flow rate is fixed to a number 50% of the design head.

Both features, the straight line (not curve) and the 50% minimum head (not lower) are likely to limit its capability to deliver most power savings.

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Proportional Pressure Control

		Flow (l/s)	Head (kPa)	Pump rpm	Power absorbed (kW	Efficiency %
Fixed Speed	Fixed volume	80	250	1450	25.2	79
Variable speed	Variable volume	40	175	1100	10	72
			Power saving		60%	

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MAKING ENERGY MAKE SENSE

A variable speed pump with local transducers and proportional pressure control saves 60%. At 50% design flow rate, the pump absorbs 33% more power (10 versus 7.5kW) than the pump when controlled by the index leg fitted transducer.

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Summary

		Pump Control Method	Flow (l/s)	Head (kPa)	Pump rpm	Power absorb (kW	Eff'y %	Power Saving %
Fixed Speed	Fixed volume	None	80	250	1450	25.2	79	0
Fixed speed	Variable volume	Two port	40	310	1450	20.1	62.6	20
V. S.	V.V	Local T'ducer	40	250	1310	15.0	67	40.5
V.S.	V.V	PPC	40	175	1110	10	72	60
V.S	V.V.	Remote T'ducer	40	130	1010	7.5	74	70

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MAKING ENERGY MAKE SENSE

So, to summarise, a fixed speed pump with three port control valves saves no power at all at 50% load.

A fixed speed pump riding its curve on two port control valves saves 20% at 50%

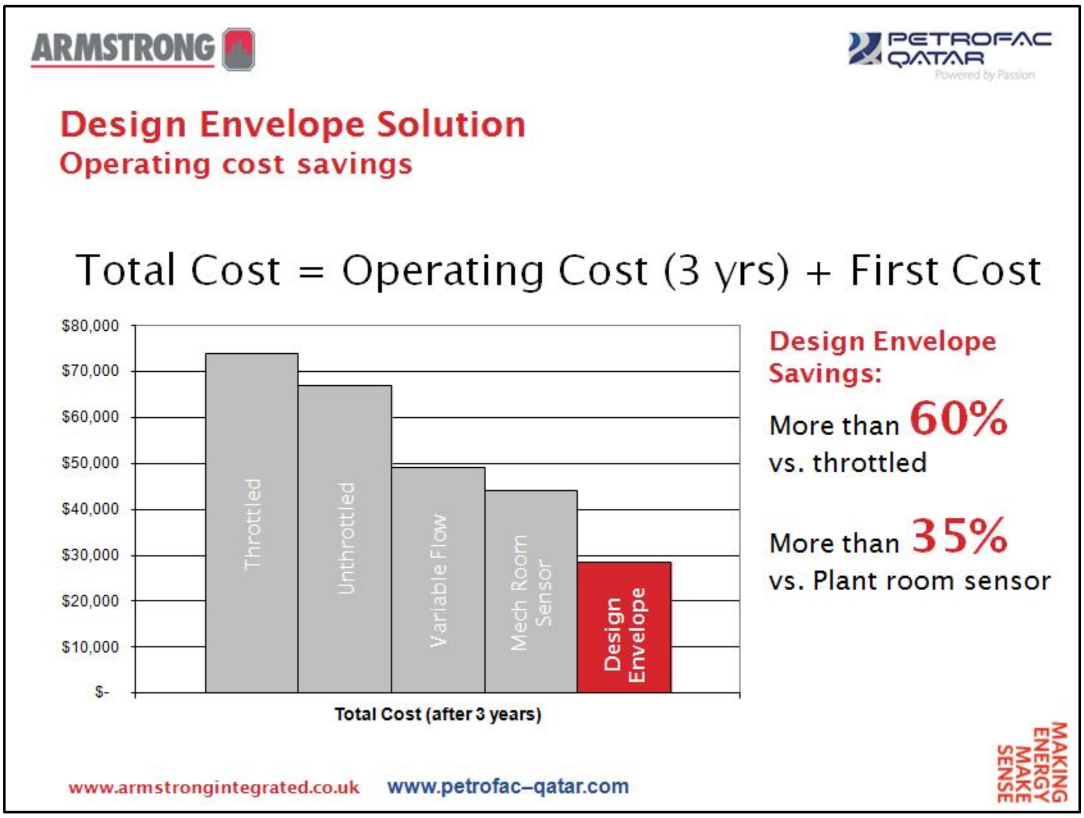
A variable speed pump with local transducers saves 40% at 50% load

A variable speed pump with local transducers and proportional pressure control saves 60%.

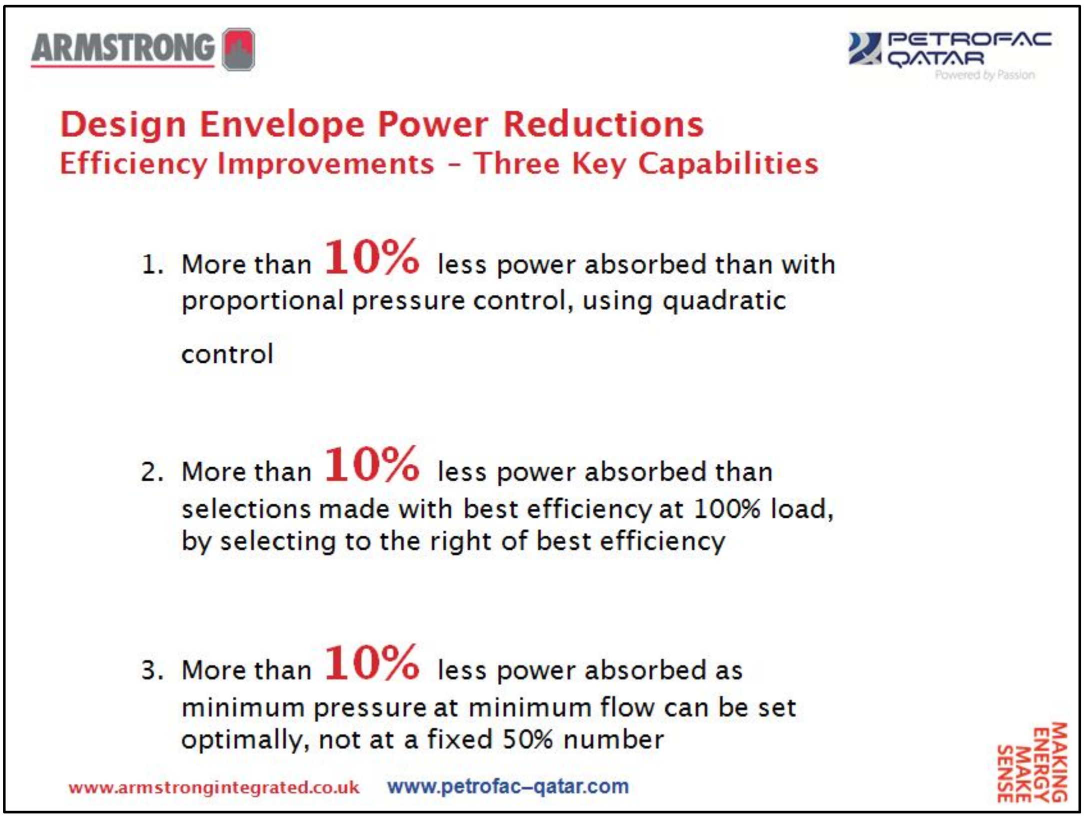
And a variable speed with remote transducers saves over 70% power at 50% load.

Given that most variable speed pumps work at 50% flow rate, then typically, a pump fitted a 30kW motor that absorbs 25kW at design duty will save 70,000 kWhr per year if it works 50% of the time. At 10 p per kwhr. That's £7,000 per year saved.

We will show next how Design Envelope can deliver these savings – without the need to fit transducers or install and programme a building management system.

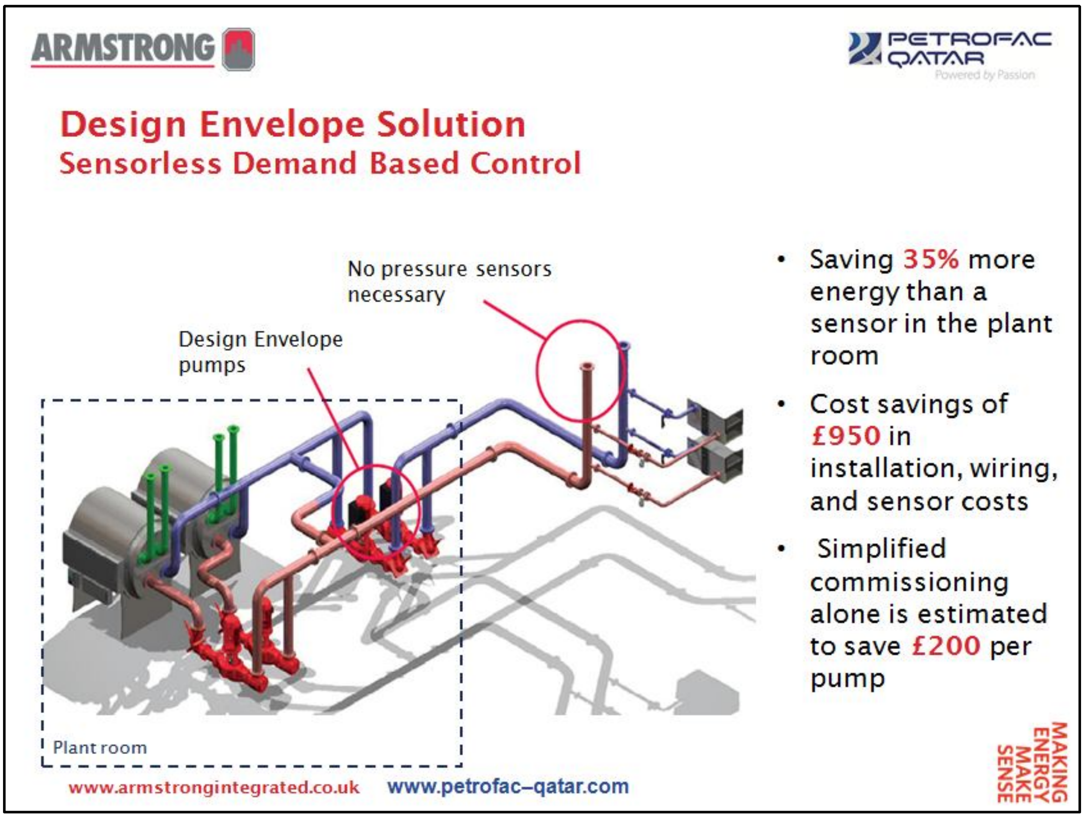


We have seen that Design Envelope pumps deliver lowest operating costs compared to many other control methods.



Design Envelope variable speed pumps use three capabilities, not available anywhere else on an integrated drive variable speed product, to extract the most pump power reductions:

1) Control to a quadratic system curve – not a straight line proportional curve. The area between the straight line and the curve represents the power that can be saved. We have seen that at 50% of design, proportional control absorbs 25% more power than quadratic control.
2) Selection point made to the right of BEP, not to the left. Pump efficiency increases initially on reduced flow rate, not reduces immediately on reduced flow rate. This can extract a further 10% power saving.
3) Adjustable minimum pressure set point, with factory default setting of 40% of design head. This number is 10 points less than other offers and on high head systems can be adjusted downwards further to allow for the reduced distribution pipework friction losses at part flow. The control curve arising sits further below the proportional curve, driving a reduced pump speed at part load and lower power consumed, saving money.
4) These three capabilities cumulate to a major energy cost reduction over most other control systems. Combined with the fact that all three are supplied with Design Envelope pumps as standard and are easy to set up and commission, makes this product a compelling proposition to the system designer, installer and utility bill payer



There is no need to pay controls companies £950 to install transducers, cabling, bms points, bms programming and calibration to deliver a control system for a pair of pumps. Keep it in your pocket!

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Conventional Variable Speed Pump Controls

The cost premium

Engineering Hours Calculated from Points Schedule					
Item name	Qty	Notes	Engineering	Software	Commissioning
MASTER PLANT POINTS AI	1	The AI is the remote pressure sensor	0.50	0.32	0.65
MASTER PLANT POINTS AO	2	The AO are the points that would be to control the Inverters	1.00	0.64	1.30
Total Calculated Hours			1.50	0.96	1.95

Labour cost Rates in 2010					
Project Manager 7% of costs	£ 40.00	£ 12.40			
Engineering/ Software etc	£ 35.00		£ 52.50	£ 33.60	
Commissioning	£ 35.00				£ 68.25

Hardware in 2010		QTY	
Pressure transmitter	£ 185.00	1	£ 185.00
Panel work Terminations and wiring	£ 4.00	5	£ 20.00
AI Points in an Outstation	£ 24.00	1	£ 24.00
AO Points in an Outstation	£ 38.00	2	£ 76.00

	Hardware	PM	Engineering	Software	Commissioning
Cost Summaries of all extra costs	£ 305.00	£ 12.40	£ 52.50	£ 35.60	£ 68.25

BMS Sub Total	£ 473.75
Installation Costs - See attached tab	£ 229.91
Total Costs	£ 703.66
Total including Margin @ 25% GM	£ 938.21

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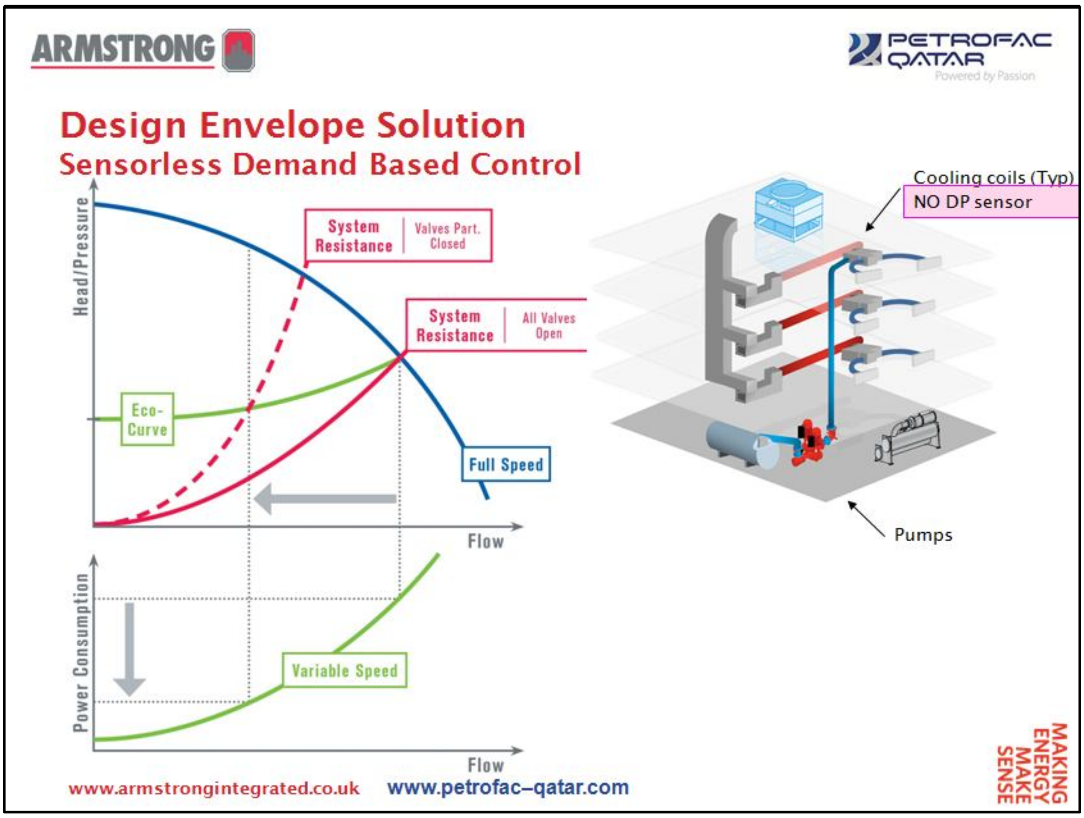
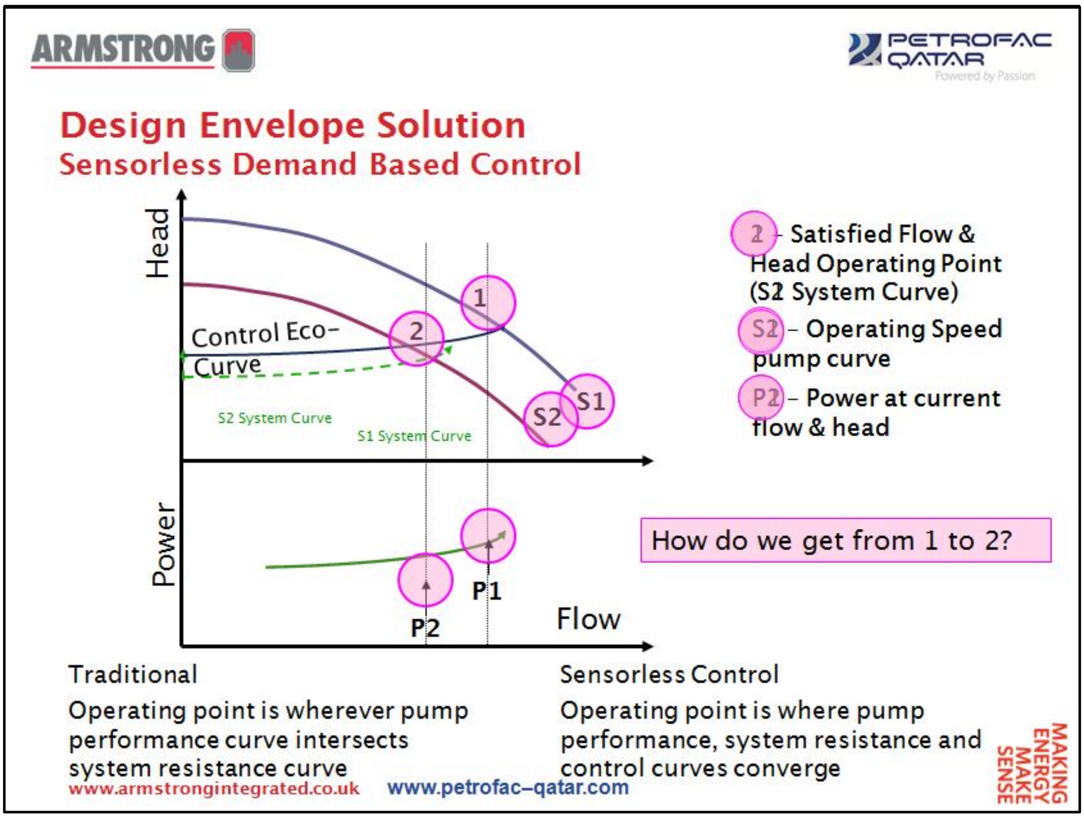
MAKING ENERGY MAKE SENSE

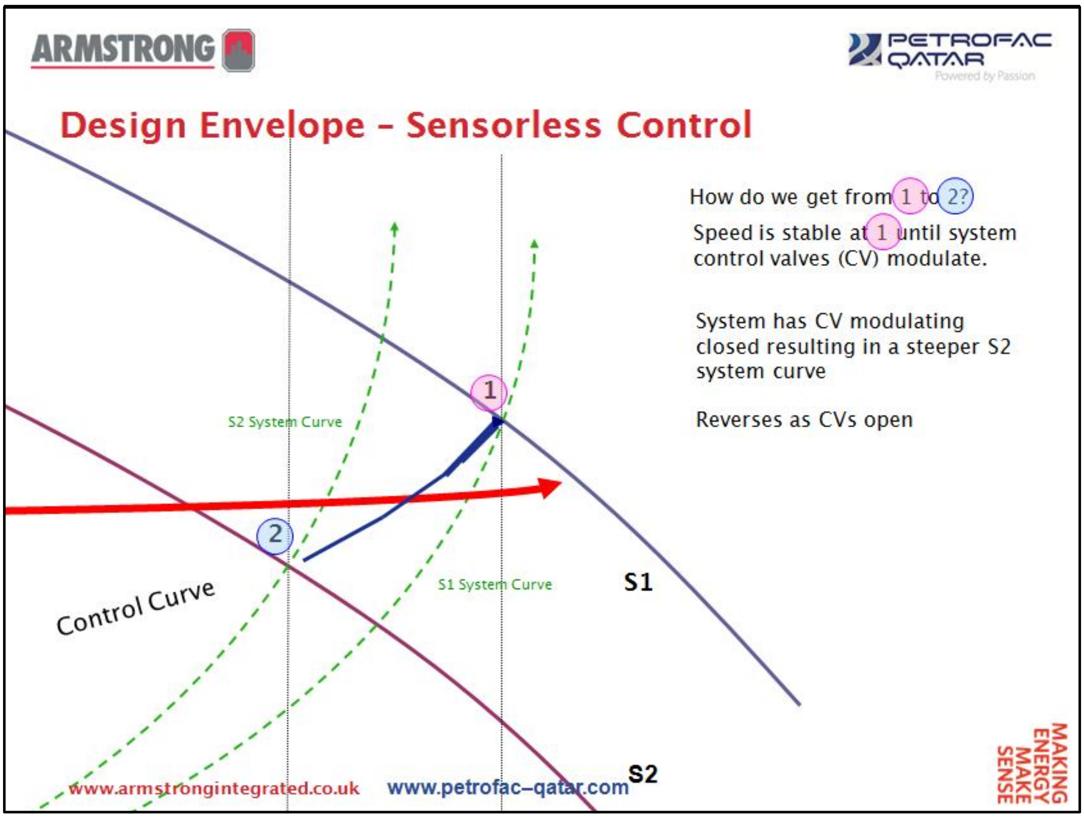
This detailed cost plant shows how a controls company compile their fees for programming, design, installation and set up of a control system for a pair of duty/standby variable speed pumps. The sum of £938 is saved by specifying Design Envelope pumps with their on-board automatic speed adjustment. The BMS is used to enable and disable the pumps and to monitor for alarms and operating information as required. Why pay the £938?



Having looked at conventional methods of controlling secondary circulation pumps, both fixed and variable speed we will now explain how the Design Envelope pump automatic self adjusting speed control system works. We call it Sensorless control.



The slide is illustrating a system friction design curve [S1 System curve] A pump performance curve at full design speed (S1) is selected to intersect the system curve at the design flow and head conditions. The corresponding power drawn is shown below the performance curves. The control curve is set via the VFD graphical interface device by the input of the design flow, head and minimum system pressure (On the vertical [y] axis). As the building conditioned spaces reach the high tolerances levels for the set point conditions, the system 2-way control valves will modulate closed, increasing the resistance to flow and creating a new system resistance curve (Similar to the S2 System curve). This will cause the pump to move left on the S1 performance curve (1), and will pump less water because of the valves throttling to a higher pressure. The power at the new operating point will take less power (2) than the original operating conditions and the Sensorless Control logic recognizes that this power reading is incorrect for the current operating speed and thus reduces the motor speed (Pump curve S2) until the power and speed converge on the control curve (3 & 4). The unit will operate at the new operating point (3) at the reduced power (4) until the control valves react again to conditioned space environment change and modulate appropriately. Thus the IVS Sensorless Controlled pumping package will react in an identical manner to a pump controlled by feedback from a remotely mounted system DP sensor, without the need to purchase, install and wire the remote sensor. It’s a virtual transducer, in effect.



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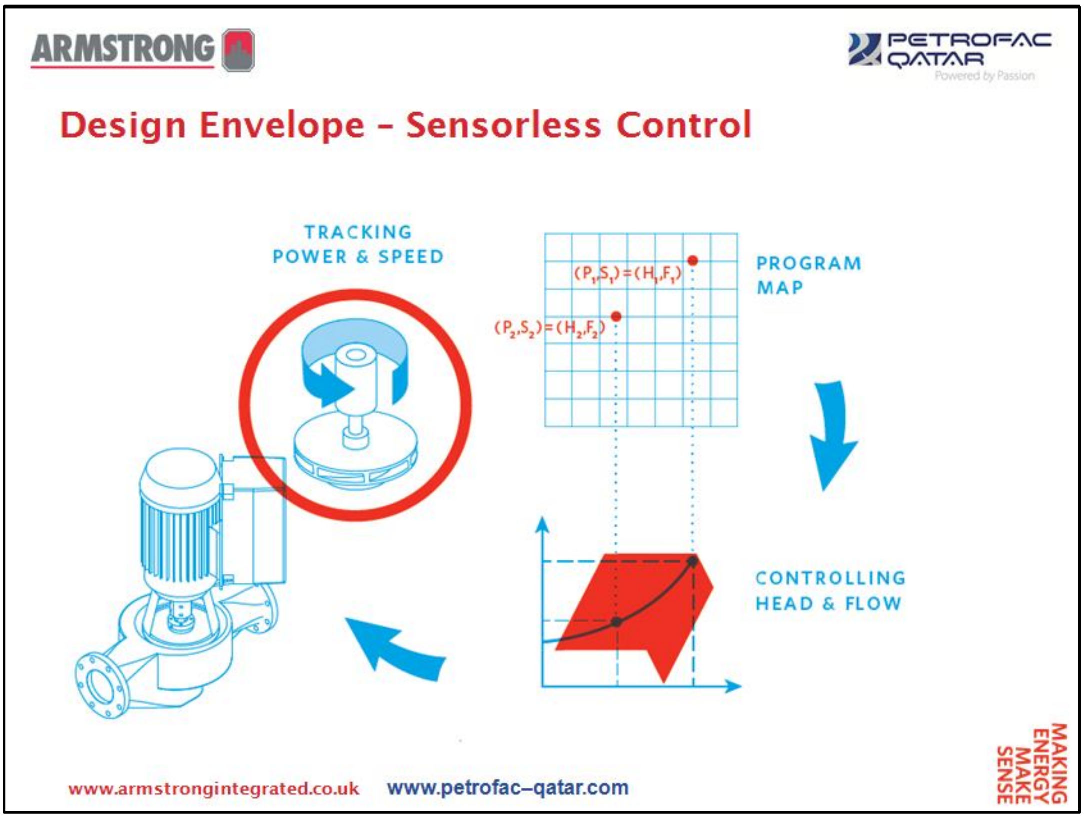
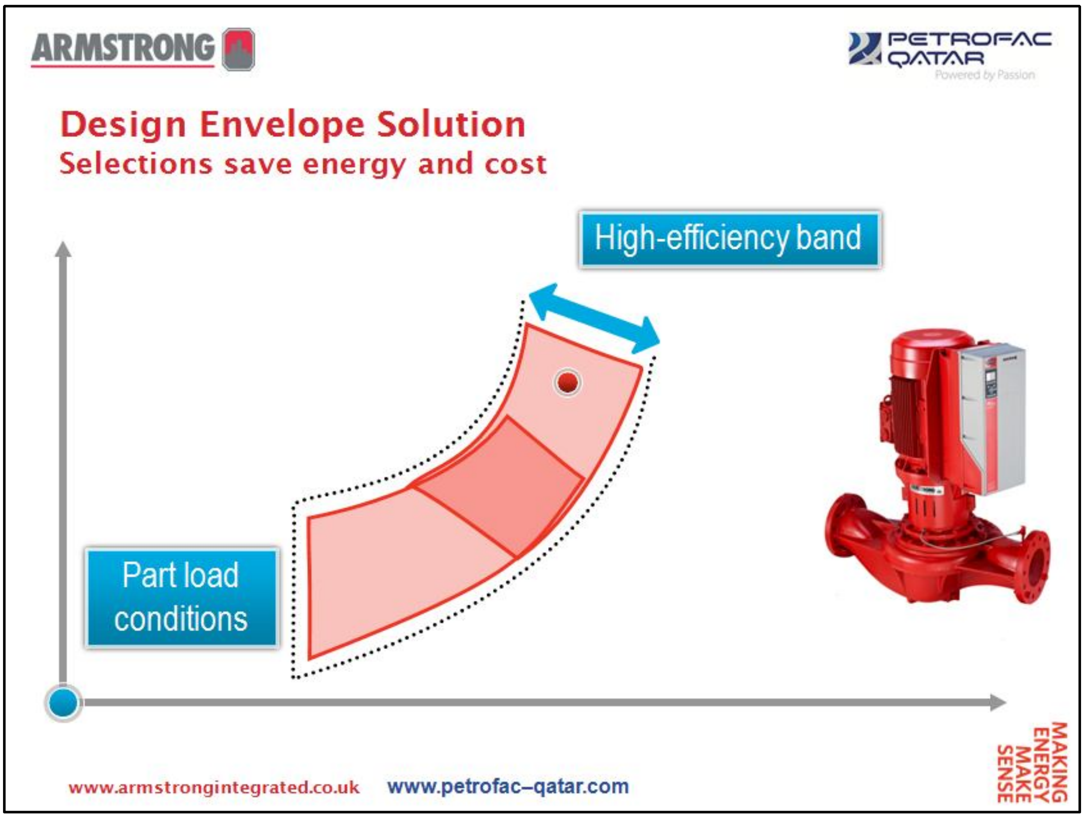


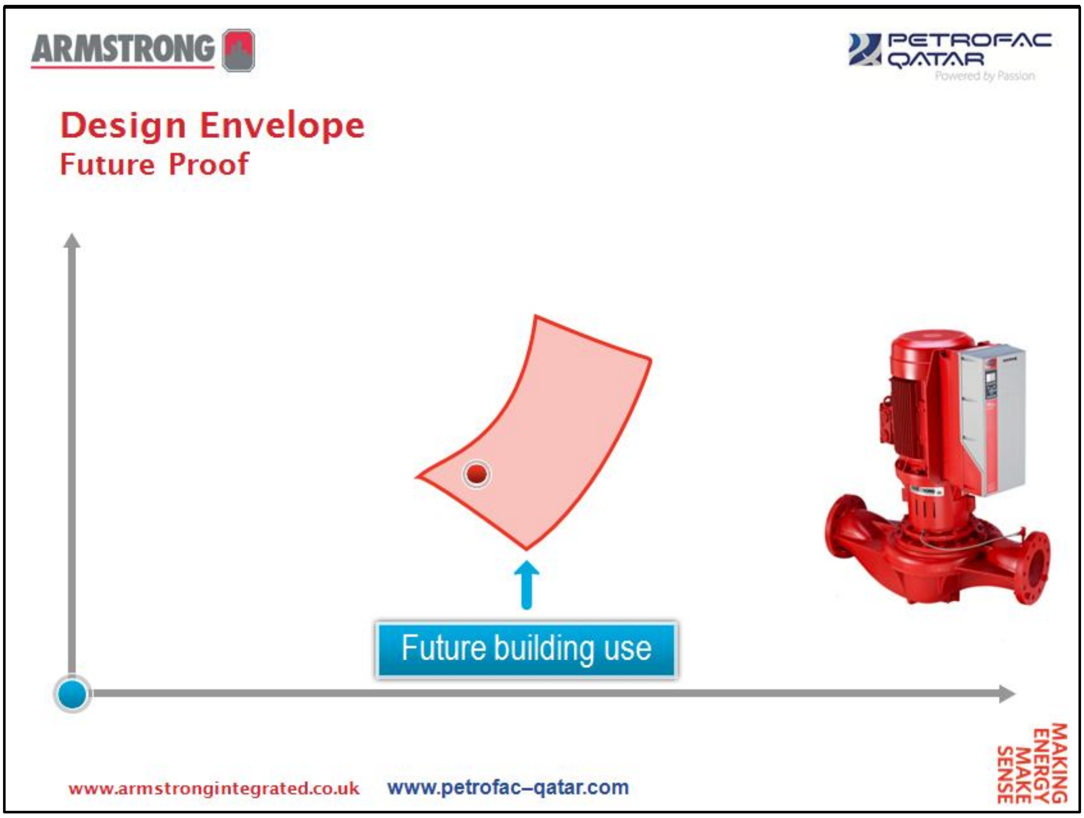
If equipped with the IVS Sensorless feature, the pump's performance curves against power and speed are pre-programmed into the controls. During operation, the power and speed of the pump are monitored, enabling the controller to establish the hydraulic performance and position the pump's head-flow characteristic to the system requirements. As the building's control valves open or close to manage load, the IVS Sensorless controls can intelligently slow down or speed up the pump to maintain the pressure setpoint.

The built-in PID controller converts the pressure setpoint to head.

Head squared is proportional to flow, flow is proportional to speed.



Firstly, Design Envelope pump curves are presented differently. They show the complete operating envelope of the system, showing where the pump performs efficiently, at full and at part load.

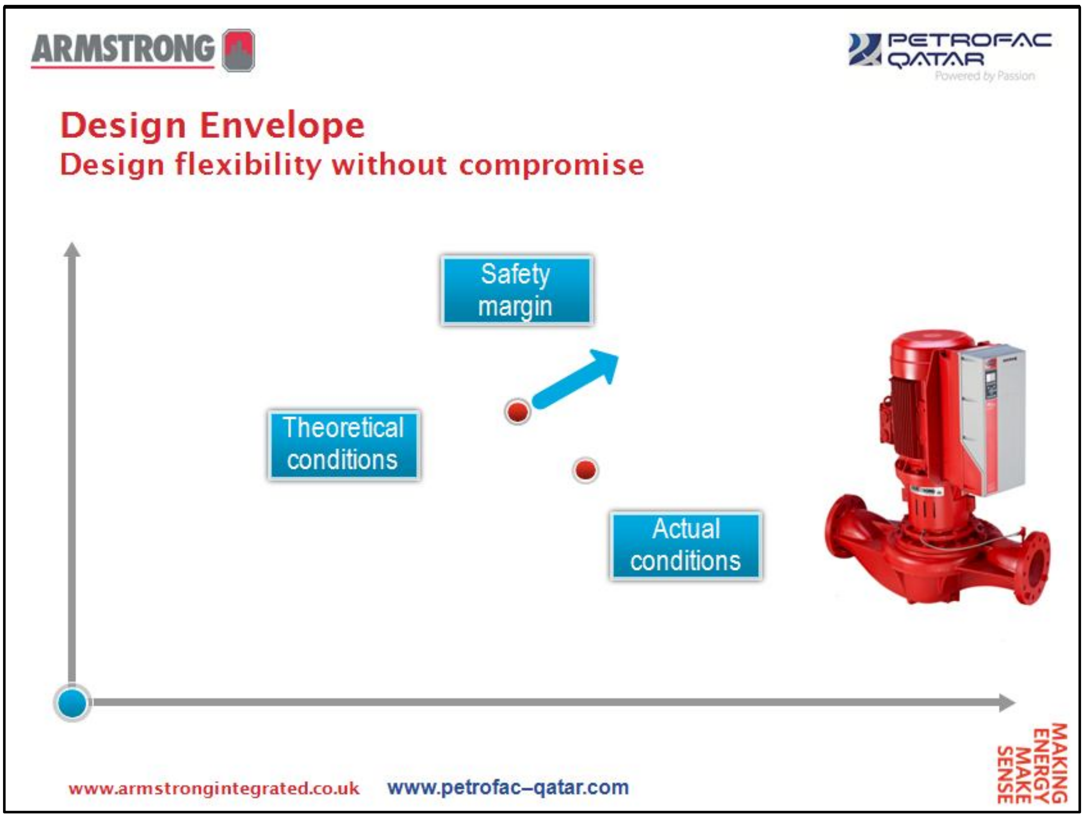


Design Envelope pump selections allow consultant engineers, installation contractors, end users and developers the luxury of duty flexibility. All Design Envelope have a defined operating envelope where they are guaranteed to offer efficient, controllable performance.

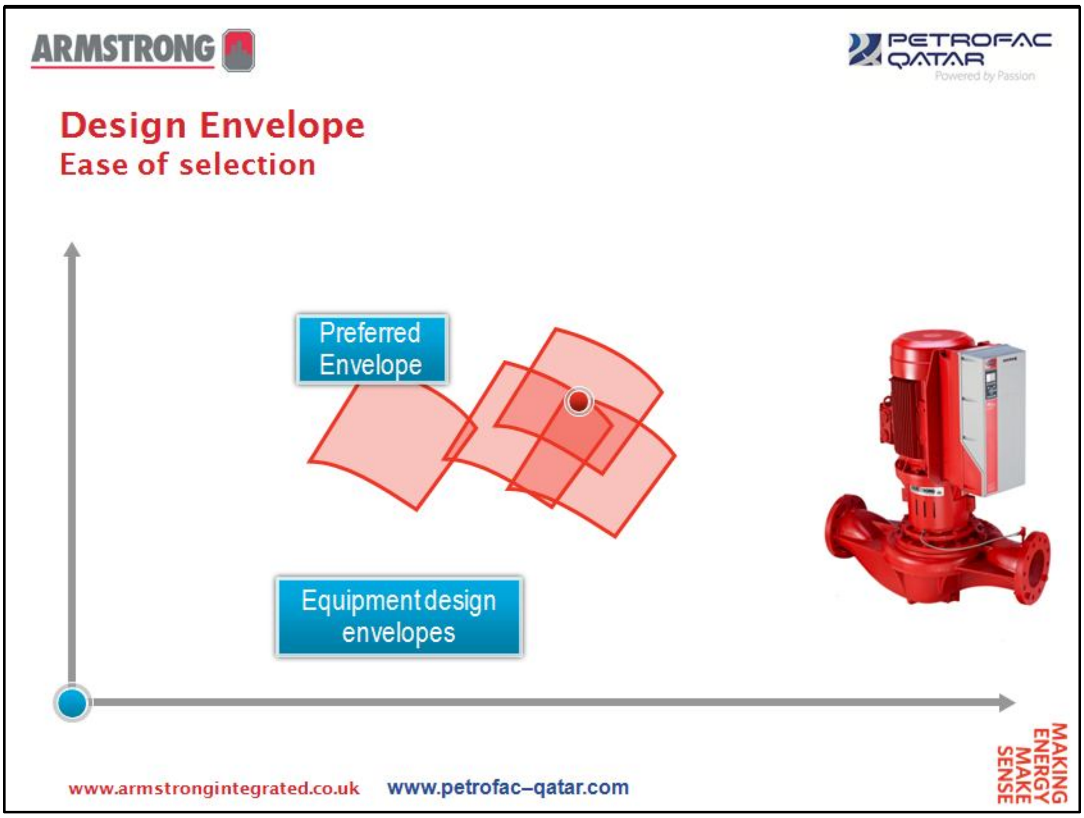
Pump selections are made knowing exactly what the operating limits are of the pump.

This certainty takes away the guessing about the future capability of the installation. Duty point adjustments for any reason, be it a change of use, a re-calculation of system resistance or change of pipeline components, can be made with full knowledge of the pump capability.

This capability de-risks the installation to a great degree.

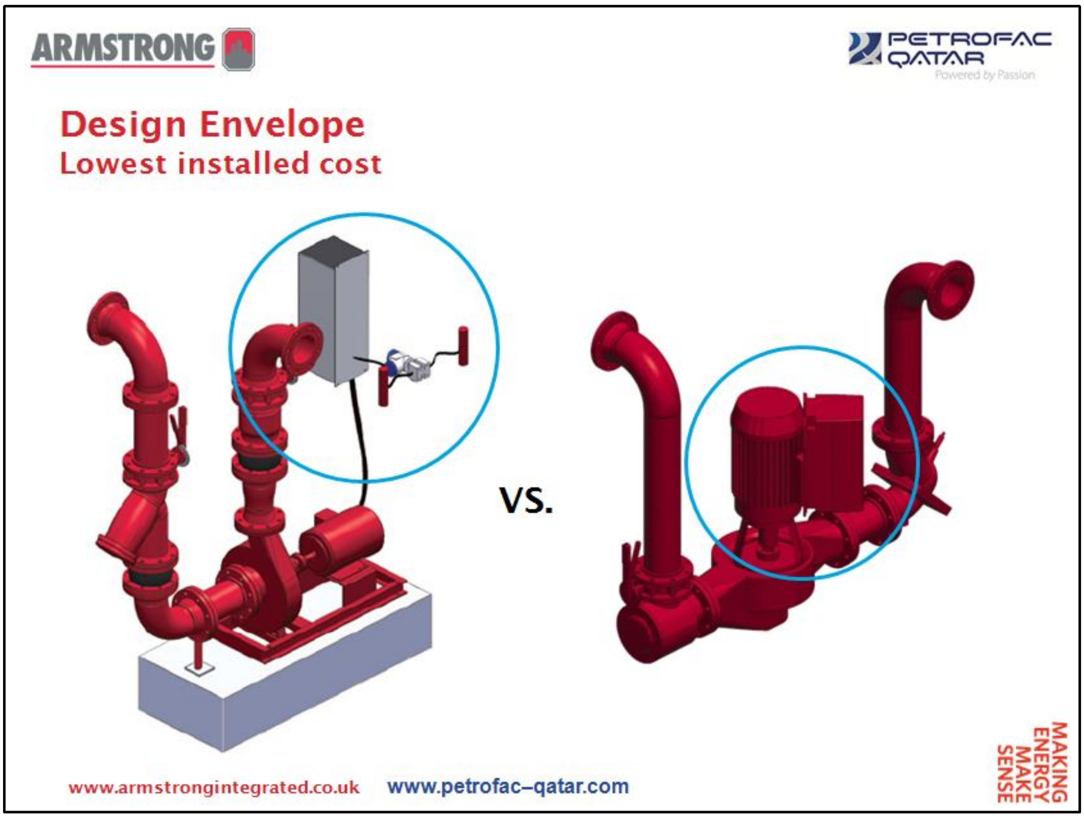


Design Envelope pump selections can be made for a theoretical condition and allow for a safety margin, future proofing the installation.



When Design Envelope pumps are selected in Armstrong's Ace software, you can look at a range of performance envelopes and decide which envelope suits your likely present and future needs.

Again, this reduces risk, helps avoid budget overruns and can make future duty changes cost free.



Design Envelope pumps deliver lowest installed cost. A Design Envelope pump installation can be made leaving out the concrete plinth or concrete filled inertia base, flexible connectors, with the drive already installed, programmed and ready to work.

Not only does this save large sums of money but it also takes the risk out of the installation. There is no flexible connector to burst and no base to bottom out or otherwise fail to perform.

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Design Envelope
Lowest installed cost

Potential wiring savings — with 30 kW motor and controls, the savings costed at **£300 per pump.**

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MAKING ENERGY MAKE SENSE

Design Envelope pumps save money by having integrated drives, reducing the need to install expensive high specification cabling. The much shortened cable length from drive to motor reduces the risk of harmonic issues, dv/dt voltage spikes destroying the motor insulation and reduces the chance for EMC issues.

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Site…Example of Remotely Mounted Inverter……

Location………3m from Inverter…………………………………………………………

Meterage	Ext QTY	Med QTY	Local Quantity		Unit	Local 10x5m <15m	Med 15x10m <35m	External 30x15m <100m	Total
				Controls Wiring					
				Mount Damper/Actuator	£20.70				£0.00
				Mount Plantroom Device	£13.80				£0.00
				Mount Remote Device	£17.50				£0.00
				Label Device	£5.00				£0.00
			0	Fitting Room Device	£27.20				£0.00
				Screeened Controls Wiring Single		£101.00	£123.00	£174.00	£0.00
			0	Screened Controls Wiring Multiple		£117.00	£160.00	£235.00	£0.00
				Singles Interlock wiring		£104.00	£138.00	£217.00	£0.00
				Plantroom Containment	33.59	£1,000.00	£1,500.00	£2,500.00	£0.00
				Fire interface to Plant	£60.00				£0.00
				Firemans Override Wiring	9.25				£0.00
				CONTROLS WIRING TOTAL					£0.00
				Power Wiring					
				Starter Feed <2kw VSD, DOL or FF		£250.00	£350.00	£500.00	£0.00
				Starter Feed <5.5 kw VSD, DOL or FF		£290.00	£390.00	£621.00	£0.00

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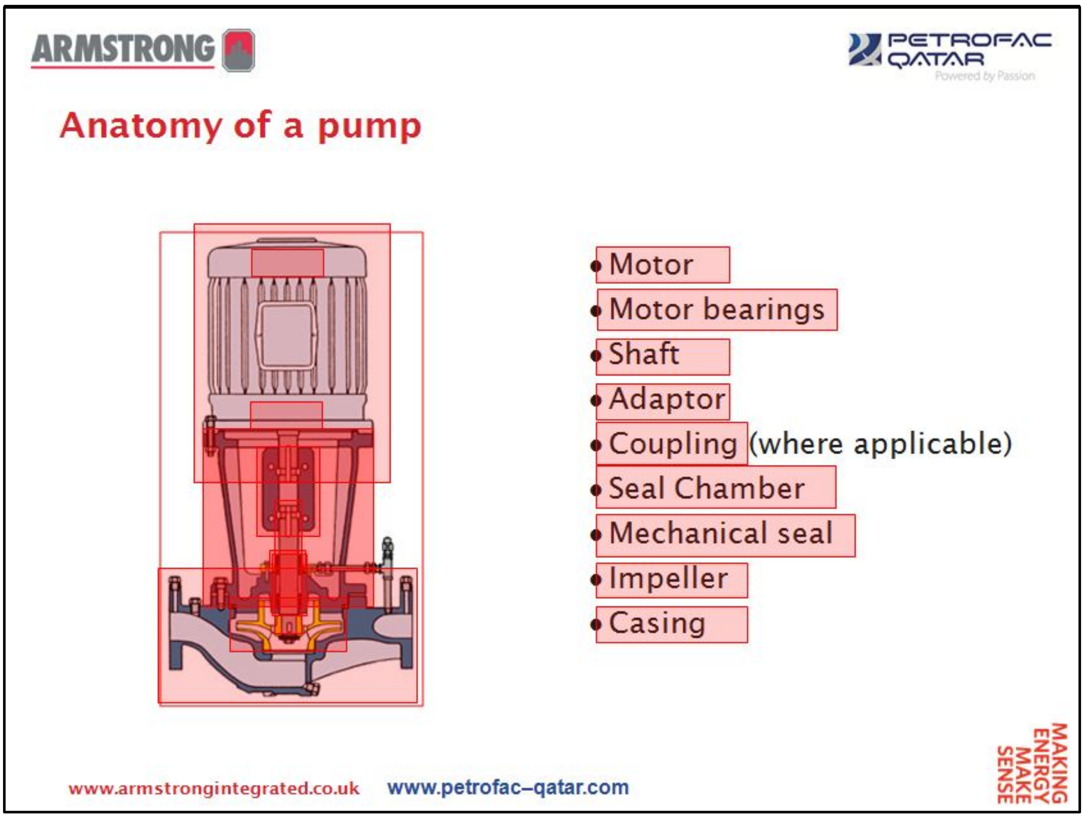
MAKING ENERGY MAKE SENSE

dclayton:
2 off 3m (6m/15m)connections with glands at 30kw

	Starter Feed < 15kw VSD or FF		£449.00	£662.00	£1,288.00	£0.00
0	Starter Feed < 15kw ASD		£561.00	£831.00	£1,695.00	£0.00
0.4	Starter Feed <30kw VSD or FF		£607.00	£953.00	£2,060.00	£242.80
	Starter Feed <30kw ASD		£717.00	£1,115.00	£2,390.00	£0.00
	Starter Feed <45kw VSD or FF		£655.00	£1,013.00	£2,161.00	£0.00
	Starter Feed <45kw ASD		£722.00	£1,121.00	£2,396.00	£0.00
	Starter Feed <80kw VSD or FF		£1,258.00	£2,171.00	£5,060.00	£0.00
0	Terminal Unit Power Feed Link (2m)	£25.00				£0.00
1	Mount Inverter	£220.00				£220.00
	Mount Router panels	£95.00				£0.00
	Mount and Position Wall Panel	£160.00				£0.00
	Fix and Position Floor Standing Panel	£320.00				£0.00
	POWER WIRING TOTAL					**£462.80**
	Network wiring					
	IP CAT 5 Backbone	£9.50	per Metre			£0.00
	Between Panels	£125.00				£0.00
	Between Local Terminal Devices	£112.00				£0.00
	Set point adjust or Room controller on Terminal	£76.00				£0.00
	Between Buildings	£11.00	per Metre			£0.00
	Head End Terminal Connection	£120.00				£0.00
	NETWORK TOTAL					**£0.00**
	Preliminaries					
8%	Supervisory management	£462.80				£34.71
5%	Storage & Containment Requirememts	£462.80				£20.83
5%	Plant - Scaffolding and Tools etc	£462.80				£23.14
	Full Time Electrical Site Management	£475.00				£0.00
	PRELIMS TOTAL					**£78.68**
	PROJECT TOTAL					**£541.48**
	Sell to Customer	@12% GM				£615.31



We'll be discussing customer benefits in this presentation from highly efficient motors, reducing the load on motor bearings, how the split coupled shaft and adaptor reduces whole life cost, high quality mechanical seals installed in the latest design of seal chambers, impellers trimmed to optimise the motor and casings ruggedly designed to accept the weight of the pump and pipe strain.

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Design Envelope
4300, 4312 and 4302 Split Coupled – Maintenance Savings

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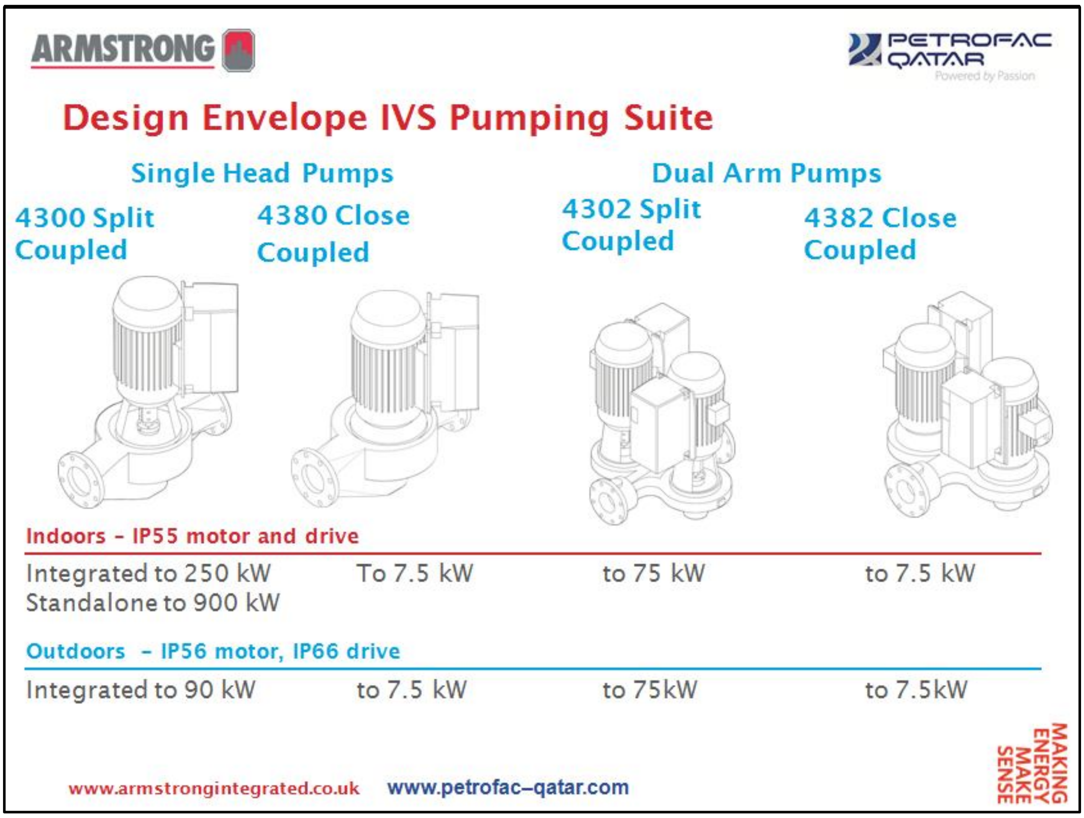
MAKING ENERGY MAKE SENSE

The most common replaced item on pumps is the mechanical seal. Seal changeout is much faster 30mins versus 2 hrs compared to base-mount. Also 4300 VILs don’t use bearings which dramatically reduces failures and maintenance costs.

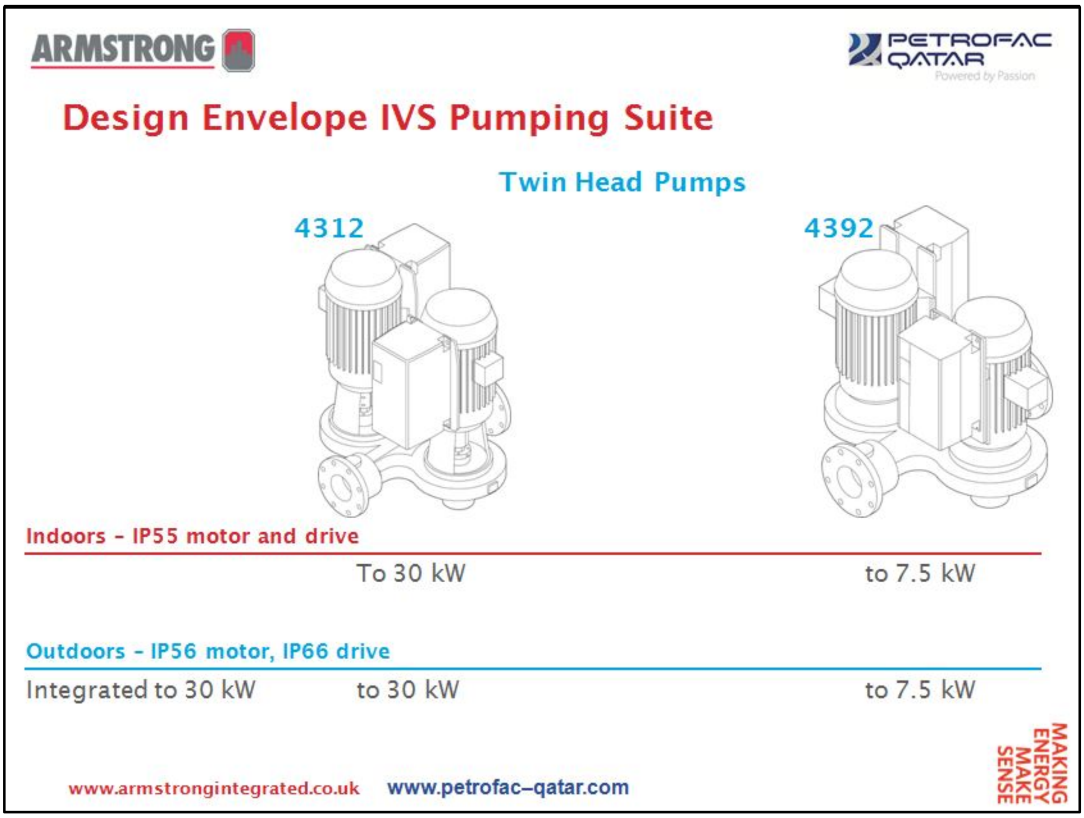
Integrated motor drives saves plant room wall space.



Armstrong Vertical inline pumps with Design Envelope IVS integrated controls.

Series 4300 pumps are available up to 250 kW with integrated controls.

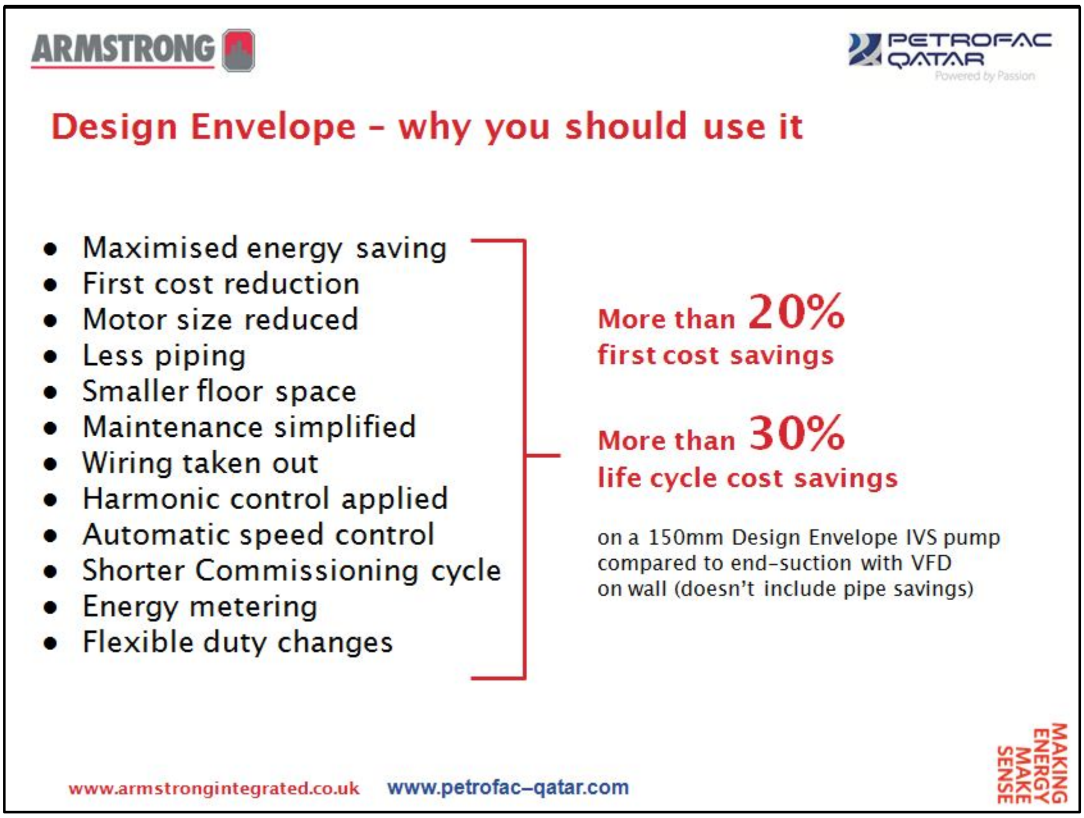
Series 4380 close-coupled pumps are available up to 7.5 kW with integrated controls.



Armstrong Vertical inline pumps with Design Envelope IVS integrated controls.

Series 4312 pumps are available up to 30 kW with integrated controls.

Series 43892 close-coupled pumps are available up to 7.5 kW with integrated controls.



A long list of savings that adds up to a LCC and a true value based offering.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Ultra-Efficient Chilled Water Plant Automation

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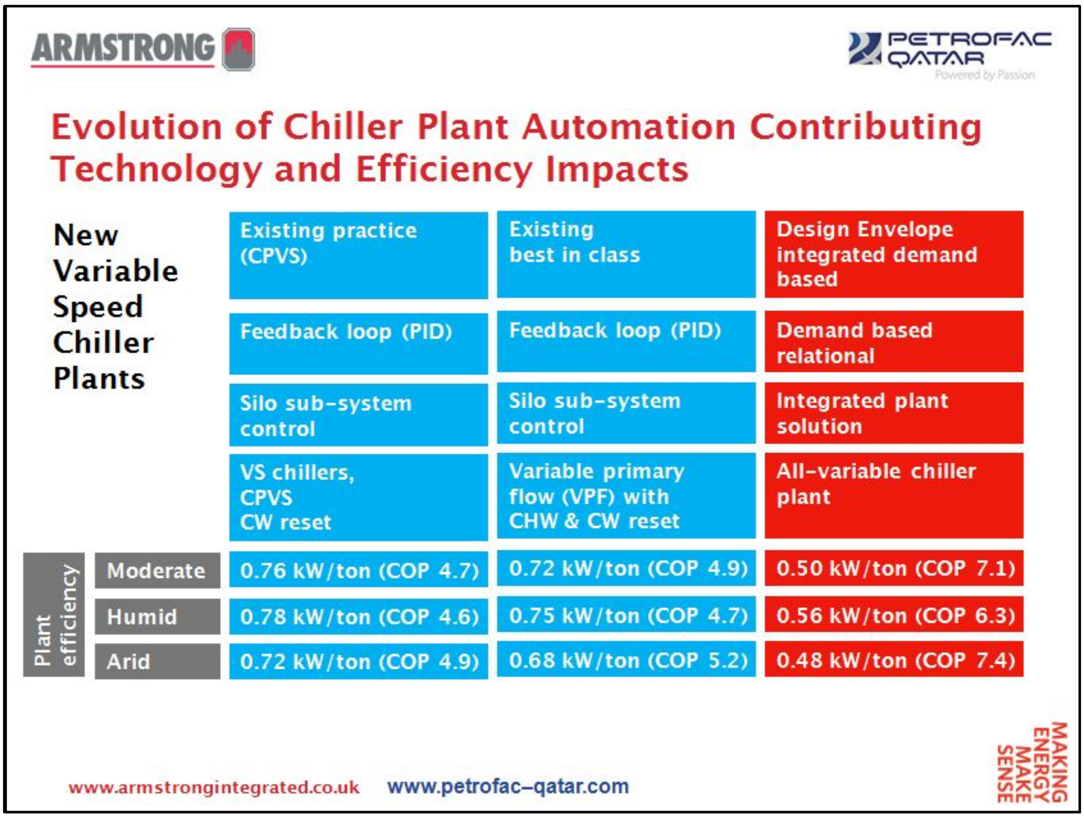
SAVE FOSSIL FUEL ENERGY

SIGIFICANT ENERGY COST SAVINGS WITHOUT CAPITAL COST INCREASE

REDUCE CO2 EMMISSIONS, REDUCE CARBON FOOTPRING



Evolution of Chiller Plant Automation Contributing Technology and Efficiency Impacts

New Variable Speed Chiller Plants		Existing practice (CPVS)	Existing best in class	Design Envelope integrated demand based
		Feedback loop (PID)	Feedback loop (PID)	Demand based relational
		Silo sub-system control	Silo sub-system control	Integrated plant solution
		VS chillers, CPVS CW reset	Variable primary flow (VPF) with CHW & CW reset	All-variable chiller plant
Plant efficiency	Moderate	0.76 kW/ton (COP 4.7)	0.72 kW/ton (COP 4.9)	0.50 kW/ton (COP 7.1)
	Humid	0.78 kW/ton (COP 4.6)	0.75 kW/ton (COP 4.7)	0.56 kW/ton (COP 6.3)
	Arid	0.72 kW/ton (COP 4.9)	0.68 kW/ton (COP 5.2)	0.48 kW/ton (COP 7.4)

What do we mean by “ULTRA EFFICIENT” ?

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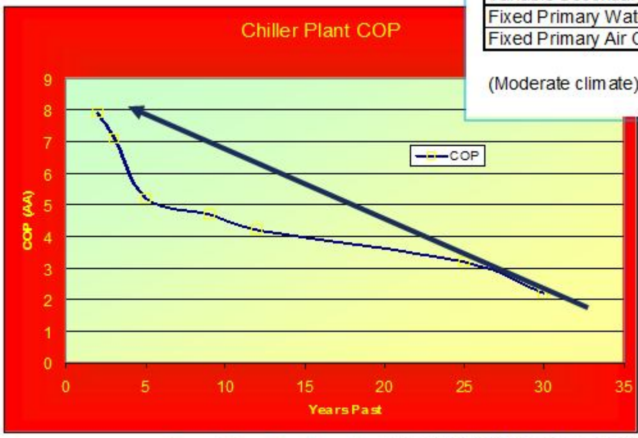
Implementation

The all-variable speed CHW Plant

System Description (2-4 chiller plant <5000 ton)	Plant Efficiency (AA) COP	kW/ton	Annual Savings
DE IPP-CHW Water Cooled	7.9	0.45	0%
All-Vari Hartman LOOP WC	7.1	0.50	10%
All-Variable Water Cooled	5.2	0.68	34%
Variable Primary WC	4.7	0.75	40%
Variable Secondary WC	4.2	0.84	46%
Fixed Primary Water Cooled	3.2	1.10	59%
Fixed Primary Air Cooled	2.2	1.60	72%

(Moderate climate)



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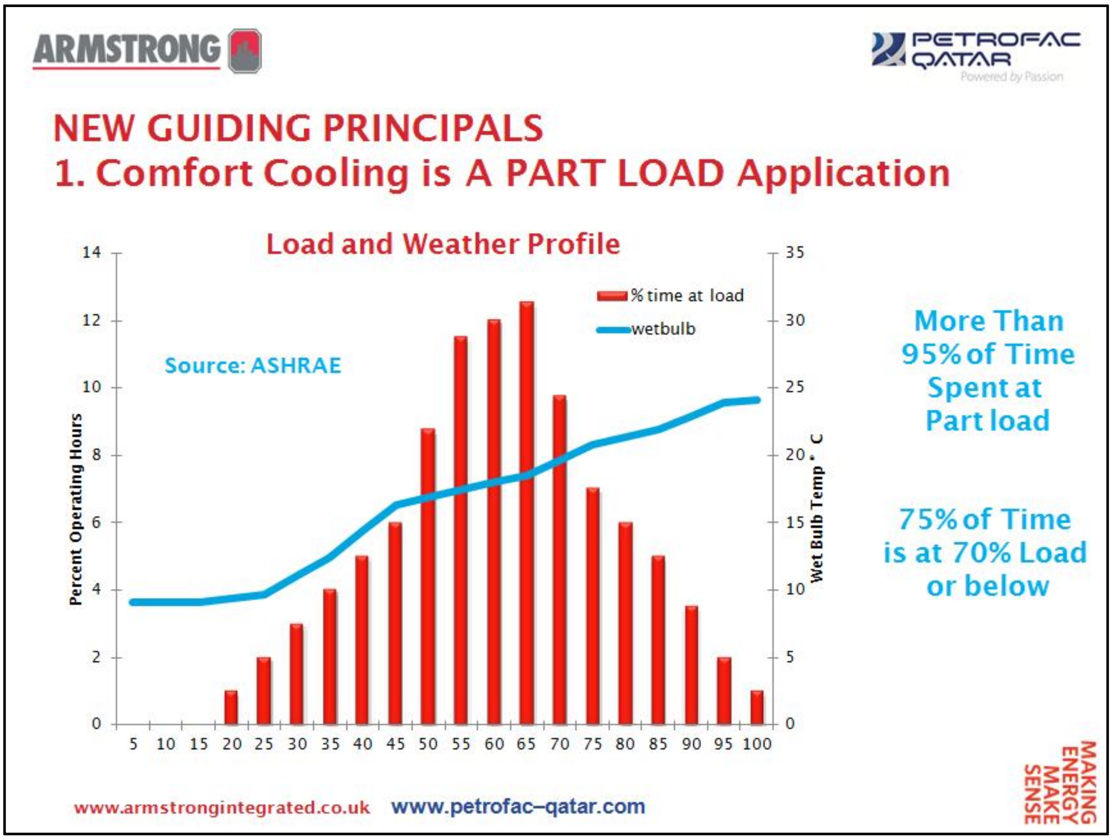
These charts show the progression in typical chiller plant efficiencies over the past 30 years from the days of all constant speed plant through today's more efficient all variable speed plants to the quantum leap with IPC Ultra-efficient plants.



The IPC control methodology is predicated on two facts.

The first fact is that comfort cooling is a part load application. Regardless of the city or country that a plant designer is addressing, the plant must be sized to accommodate a “design day”, a coincident event of peak cooling load from the building and peak external ambient temperature. This “design day” cooling load event occurs maybe for maybe a handful of hours each year. But the vast majority of the plant’s operating hours are spent at some fraction of the plants design day capacity.

In this typical example which is data for DUBAI, 75% of the annual operating hours are spent at or below 70% load.

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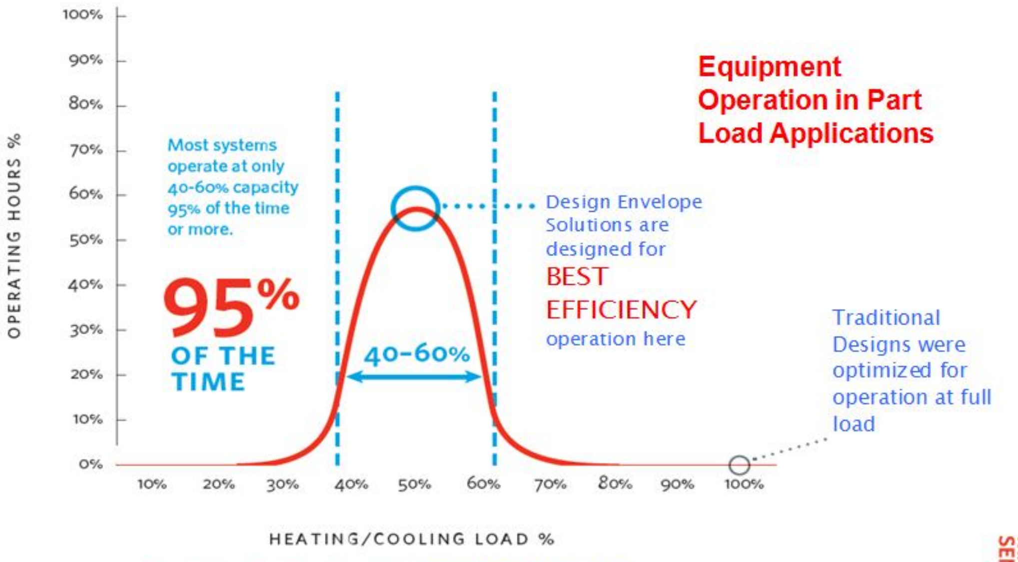
NEW GUIDING PRINCIPALS
1. Comfort Cooling is A PART LOAD Application



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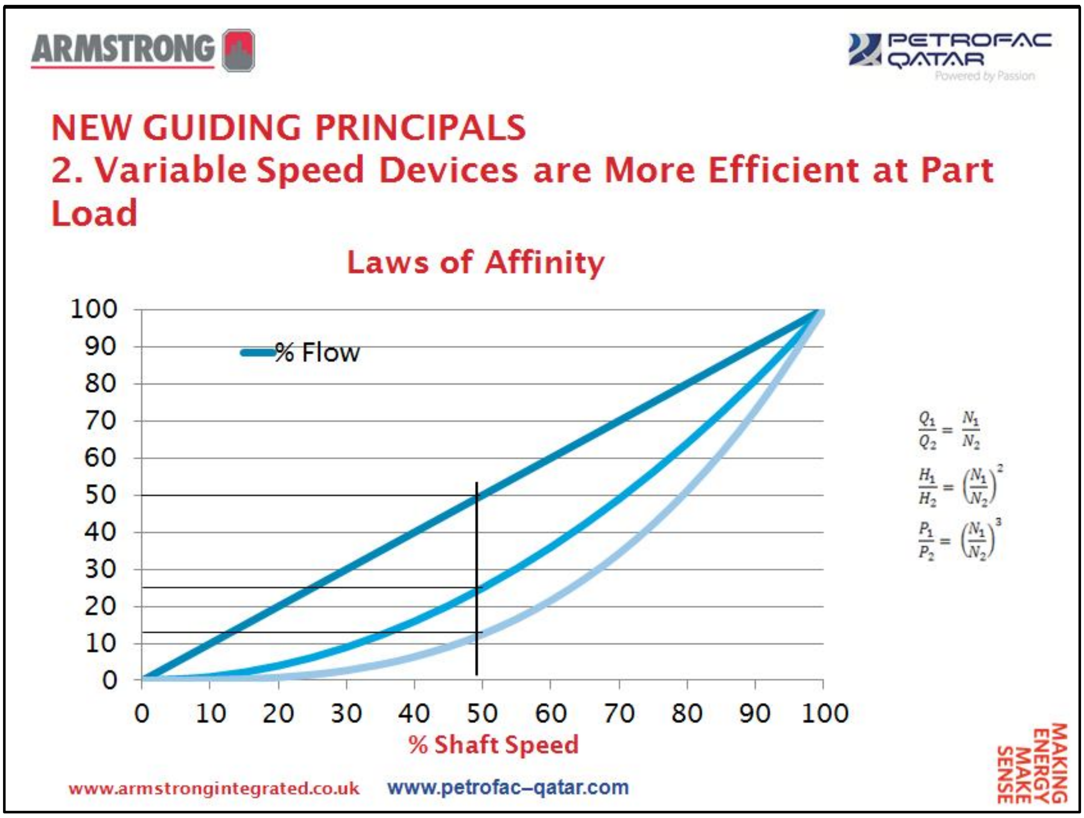


Laws of affinity state that

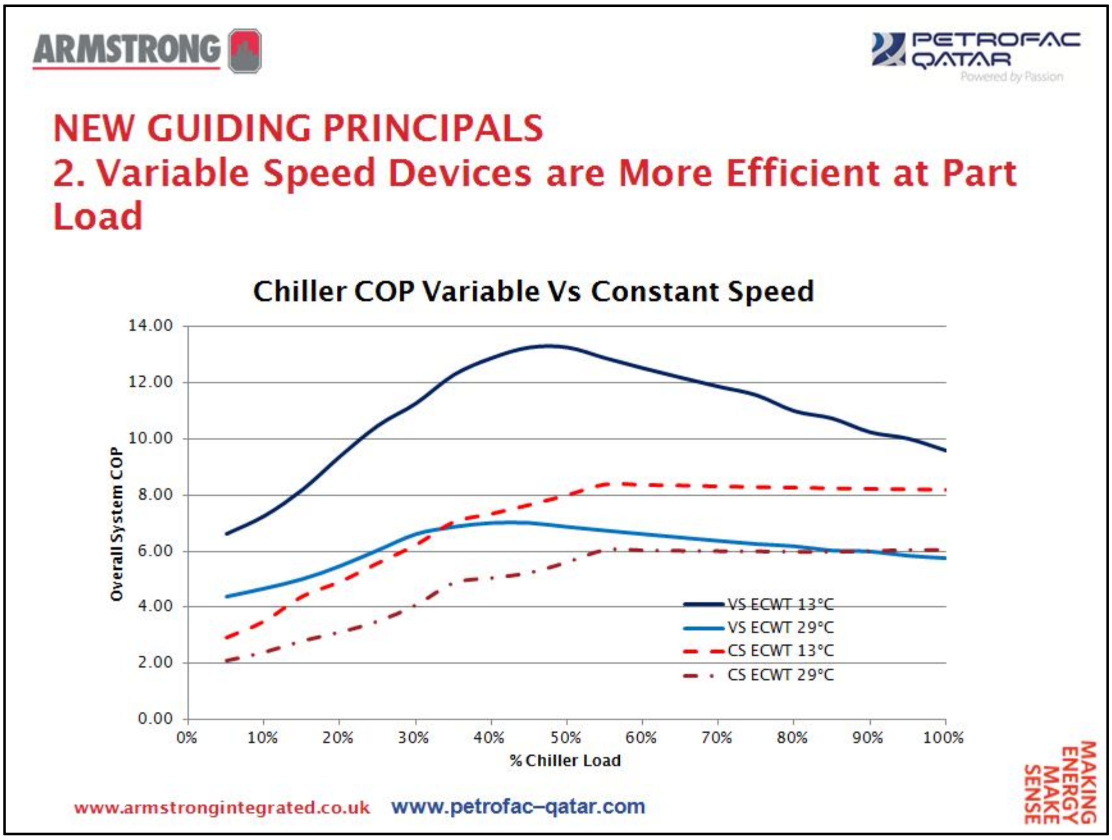
Halfling the speed gives Half the flow

Half the Speed gives the Square root of the head (i.e .25)

Half the Speed gives the Cube root of the power (i.e .125)

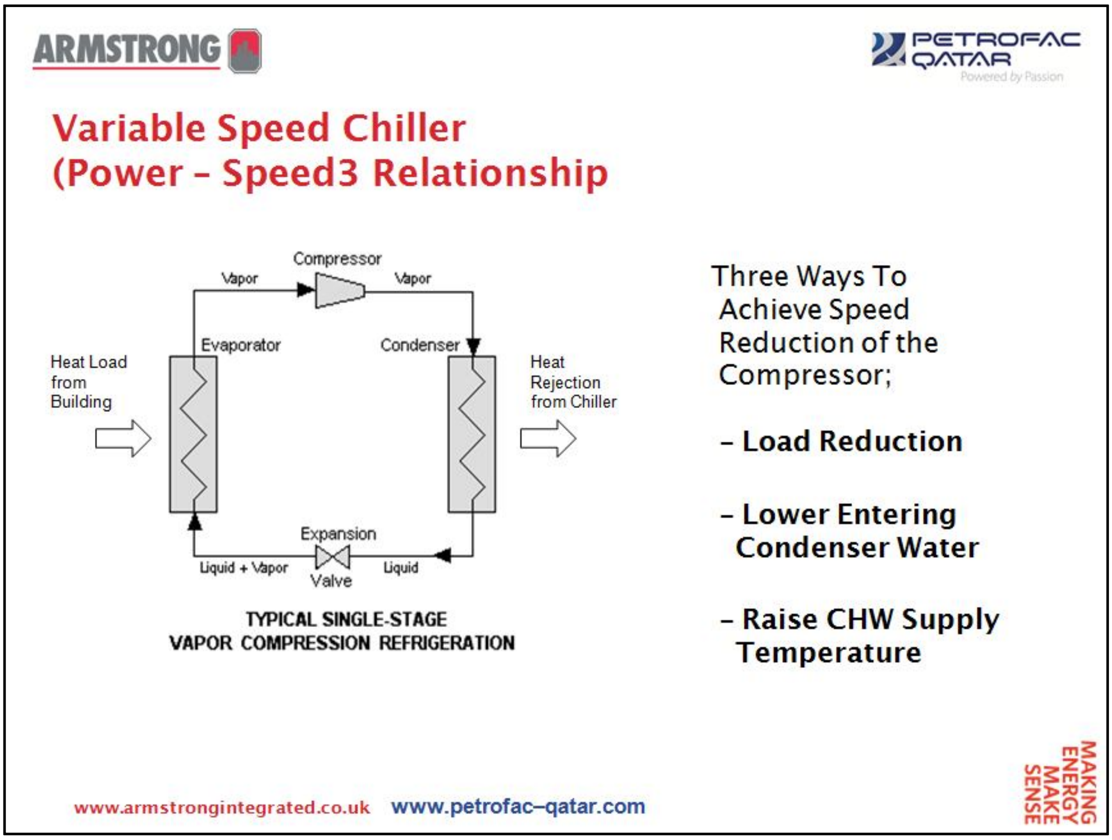
This can be applied to all motors i.e Fans, Pumps, Compressors

In similar principle using les volume through items like heat exchangers (cooling towers) also creates an increase in efficiency due to the relative increase of surface area to fluid volume.



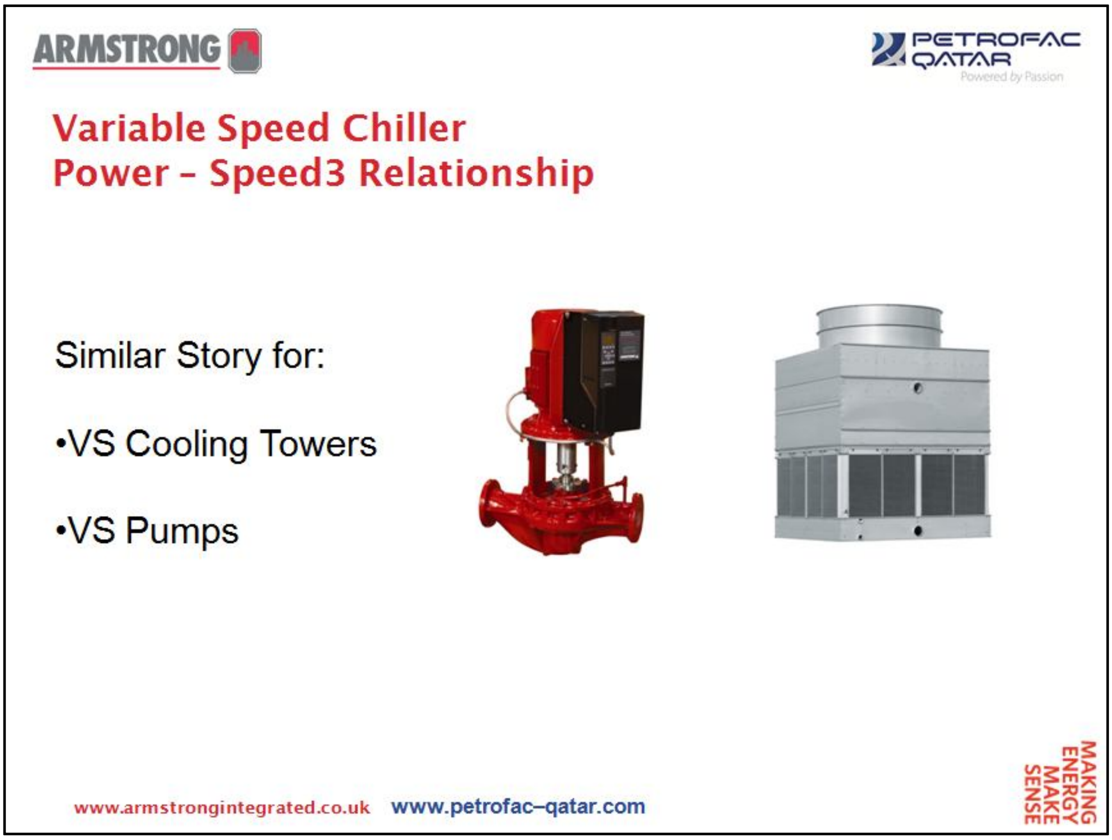
Today’s modern variable speed devices are significantly more efficient at part load, whereas more traditional fixed speed devices were designed for peak efficiency at maximum load. This graph represents typical part load efficiencies for variable speed chiller vs constant speed chillers for differing entering condenser water temperatures.

As we can see, at 50% load a variable speed chiller can be as much as 50% more efficient than a constant speed, and at 10% load as much as 150% more efficient for the same ECWT.



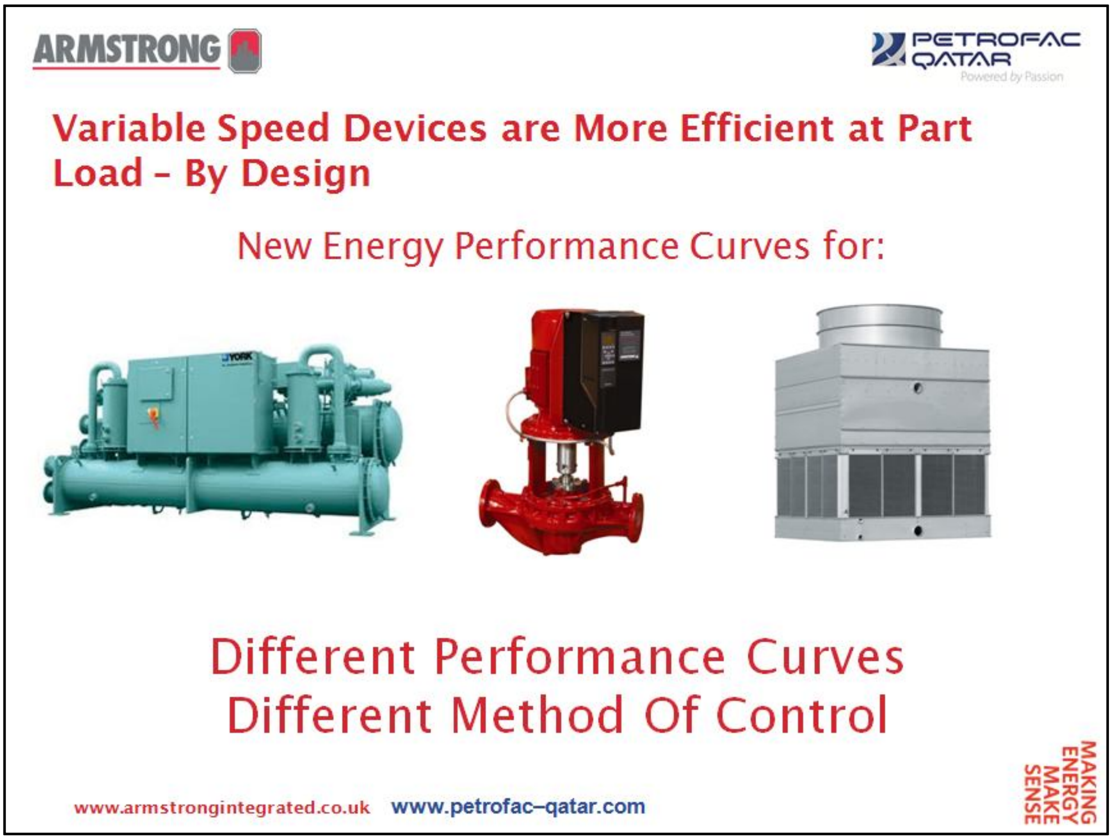
So how do we reduce the speed of chiller compressors?

3 ways…

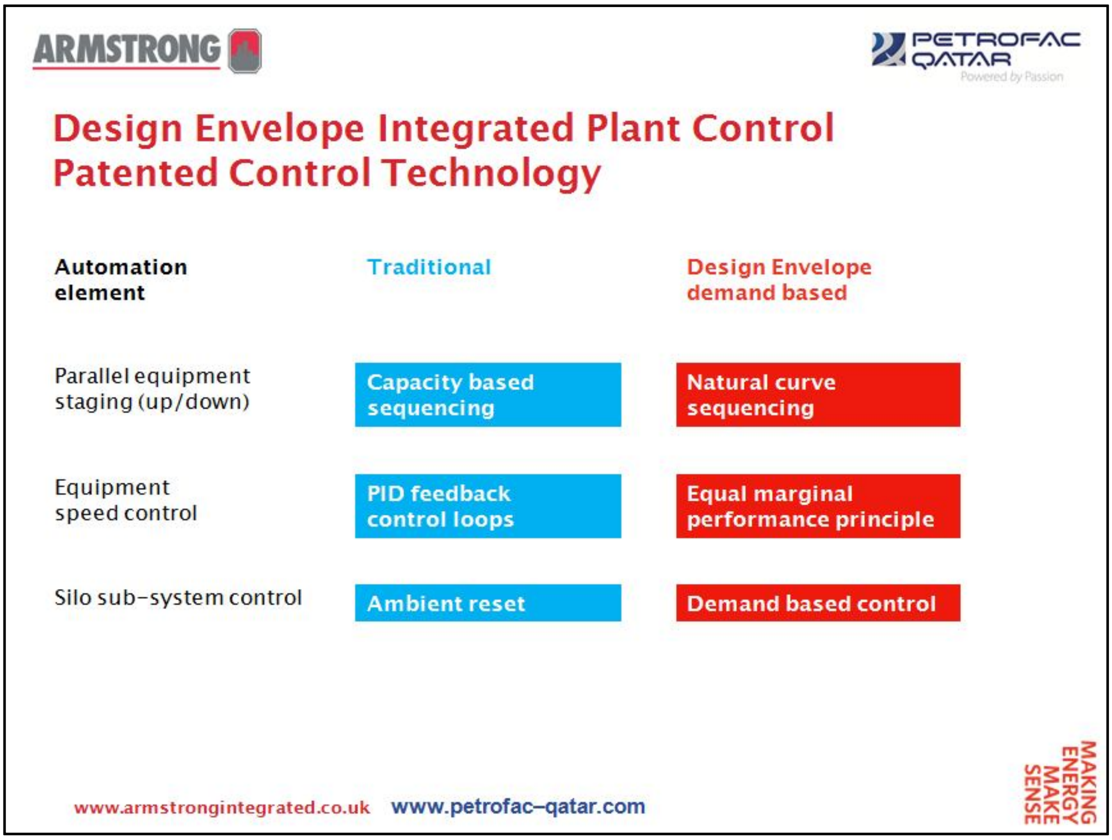


For pumps, reduce the required flow

For towers reduce load / reduce Approach temperature

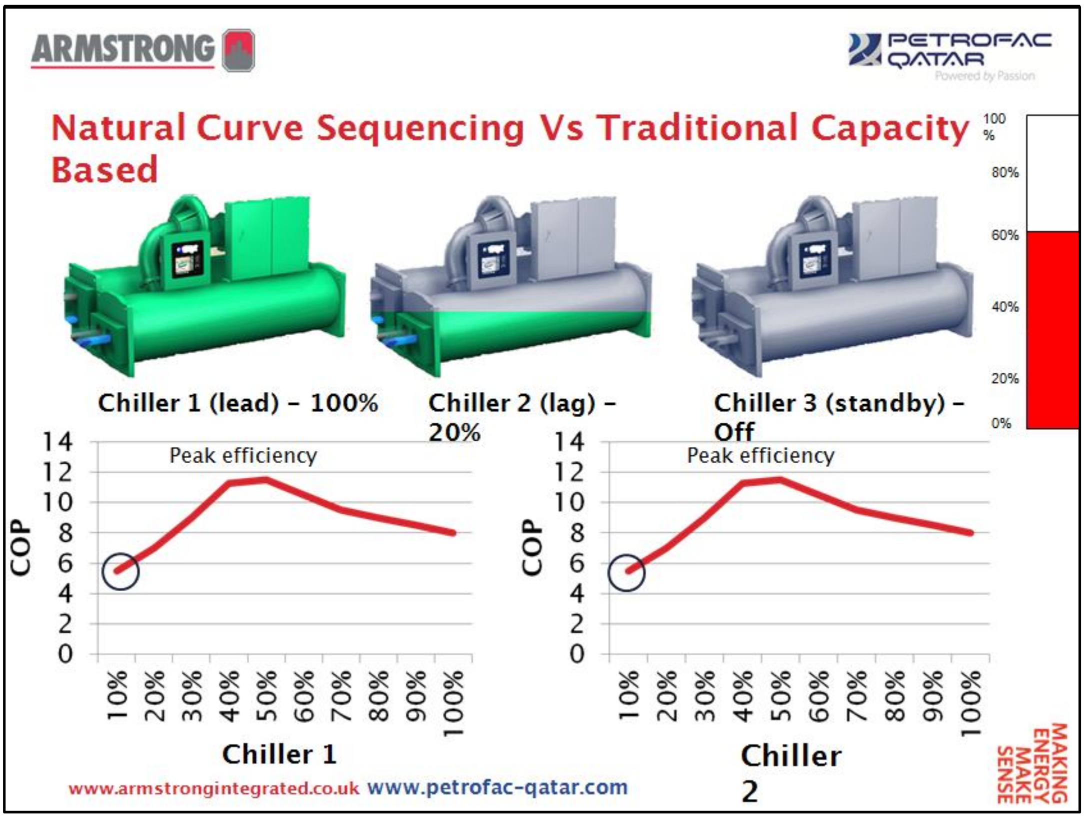


SO now we have identified an opportunity for significant energy savings, how do we take advantage of it…



So how do we control these elements for best efficiency?

Here we see today’s practise vs PATENTED design envelope IPC methodology

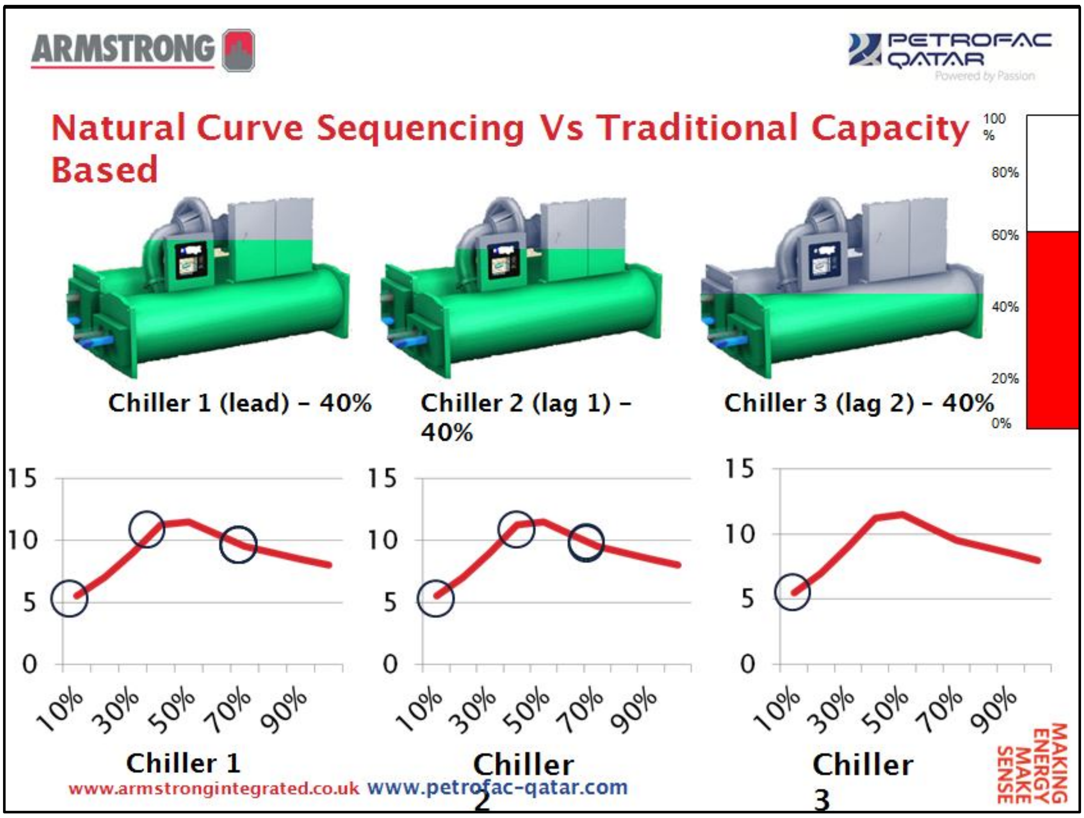


This slide illustrates a 3 chiller (D / D / S) plant running at 60% of full load duty (where it spends a lot of its life) being sequenced in a traditional capacity based manor.

Chiller 1 (lead) is running at 100%; chiller 2 (assist) is running at 20% and chiller 3 (standby) is off. Nothing unusual here. This was great when we were staging constant speed chillers that were at peak efficiency at full load

But look where each of the chillers is operating on its energy performance curve for a variable speed machine – nowhere near peak efficiency…

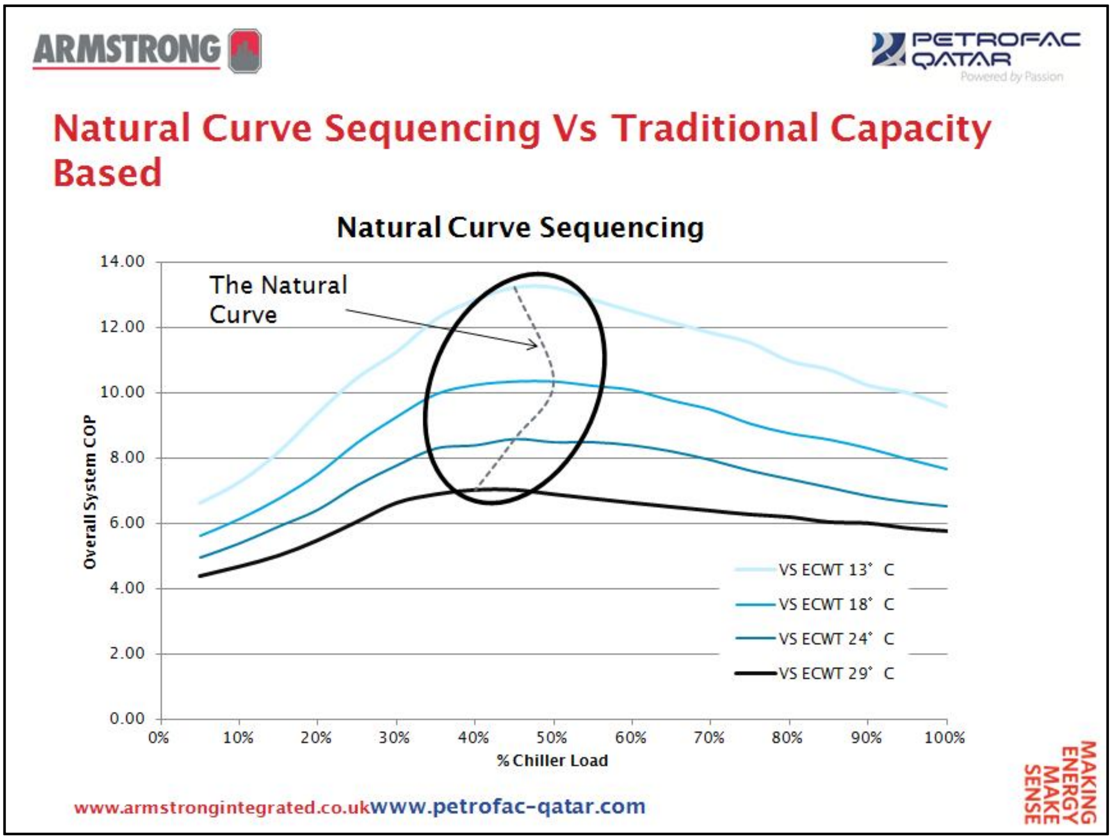
So here chiller COP will average below 8.0



This sequence shows the chillers loading up based on natural curve principles such that the chillers spend as much time at or around the peak efficiency point as possible.

In this scenario, at 60% cooling load with all three chillers operating at 40% of capacity, very close to their peak efficiency, chiller COP will be above 11.0.

A 40% increase in chiller efficiency….!!!

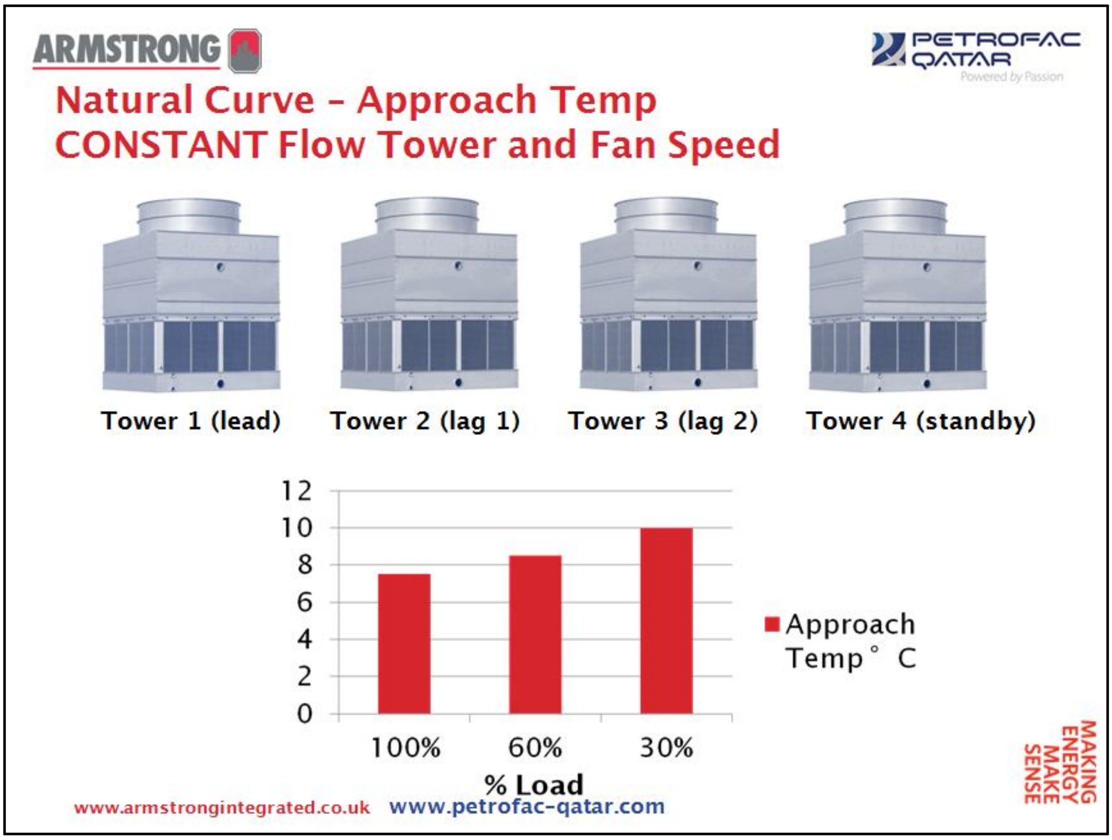


Ok, so that's great, we can now stage our chillers on and off in order to spend as much operating time at or close to peak efficiency as possible and gain huge increases in efficiency as a result.

But there are other variables in the system. And how we stage and control our pumps and cooling towers in the condenser circuit can vary the condenser water temperature entering the chillers – and this has a big impact on chiller COP.

Here we see a range of energy performance curves for a typical V.S. chiller based on different ECWT. As you can see and fairly obviously, the lower the ECWT, the greater efficiency we can get from our chillers.

Now if you looked at those curves and plotted a line between the peak efficiency points of them all you get a new curve – and it is this curve that we call the Natural Curve. And now we can look at how to ride up that curve for maximum efficiency.



Tower ETW Approach Temperature For 3 a Tower System

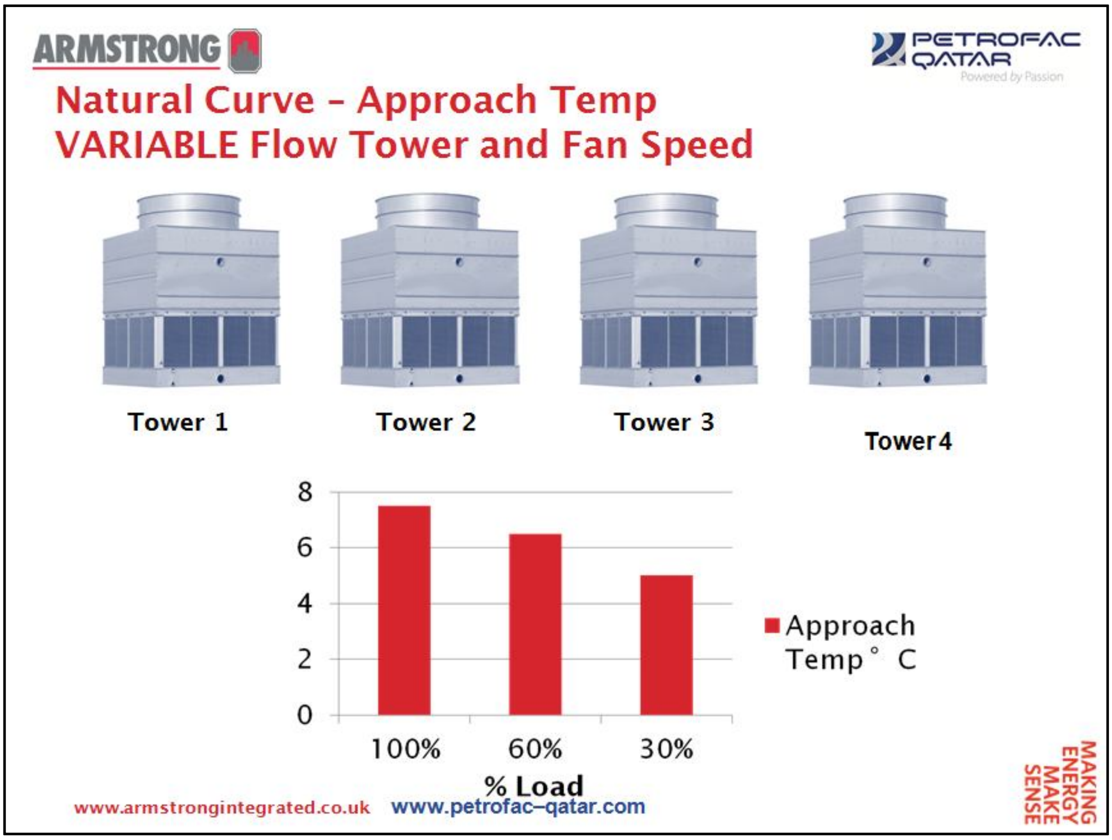
Now lets take a bigger perspective and see the impact of natural curve sequencing on the "all variable speed" plant, not just the chiller as a stand alone device, and compare this to a traditional capacity based sequenced plant with constant flow cooling towers.

The approach temperature of the cooling tower is defined as the difference between the leaving tower water temperature and the ambient wet bulb temperature.

So it is preferable to reduce the tower approach to temperatures closer to the ambient web bulb in order to reduce ECWT to generate chiller efficiencies.

Now, on a 2/3rd load day the capacity sequenced plant will destage one chiller and destage one cooling tower. So all operating chillers and cooling towers are at 100%, this configuration has the same sq m of tower surface area per kW load of cooling effect as was present on design day. However The ambient temperature on the 2/3rd load day will be cooler, and as the air temperature is cooler, it has less moisture capacity than the design day air temperature, and as a result the evaporative effect of the cooling tower is not as great as it was on design day and the approach temperature of the towers will go up.

Similarly on a 30% load day where the ambient wet bulb will be even lower, the approach will be higher again.

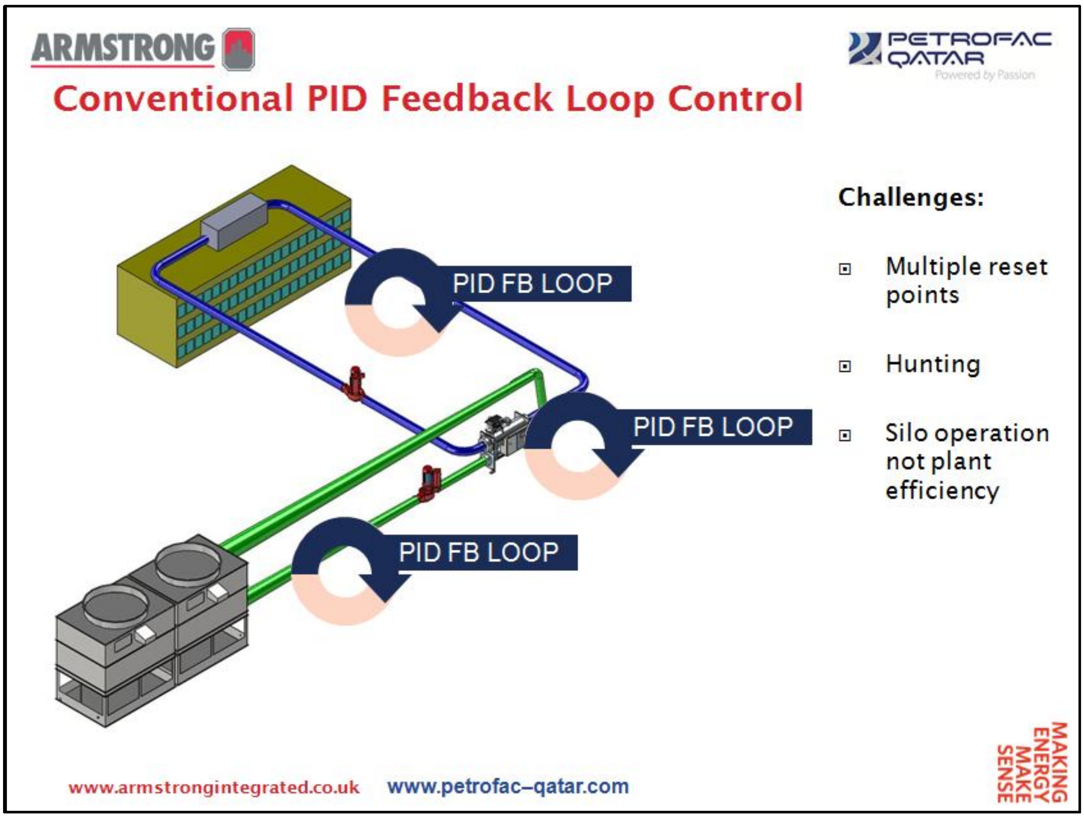


With the all variable speed plant, we will keep all three cooling towers and chillers running, but just slow the fan speed down to meet the new load point. In this configuration we are leveraging the full design day cooling tower surface area, and keeping it all active for maximum evaporative effect at part flow. The result is that we are actually able to reduce the approach temperature and we gain significant advantages over the capacity based sequenced plant

This effect is even more favorable on a 30% load day

So by slowing tower fans at part load conditions rather than staging towers off we achieve greater re-cooling efficiencies in return for the same pump and fan power consumed in traditional capacity based control.

So for part load, comfort cooling applications, we sequence chillers and towers on and off to be as close to the Natural Curve as possible, then deploy the next element of Hartman Loop technology to generate further efficiency gains...



Stable operation cannot be achieved via PID loop control with 3 control loops and 4 variables.

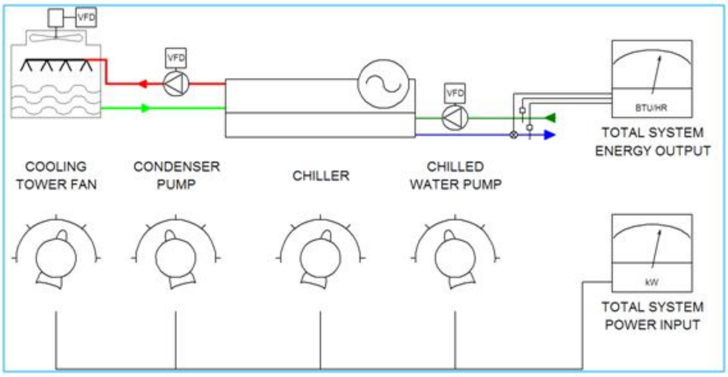
Each of the control loops works against the other so the plant will always be hunting for equilibrium but never finds it.

Traditionally this problem has been tackled in control logic by long delay timers and broad dead bands.

This is contradictory to finding best efficiency

So a new approach is needed – the EMPP…

Equal Marginal performance Principle



Minimum plant power consumption when at EMPP.

3 loops and 4 variables can not be controlled by PID feedback loop control

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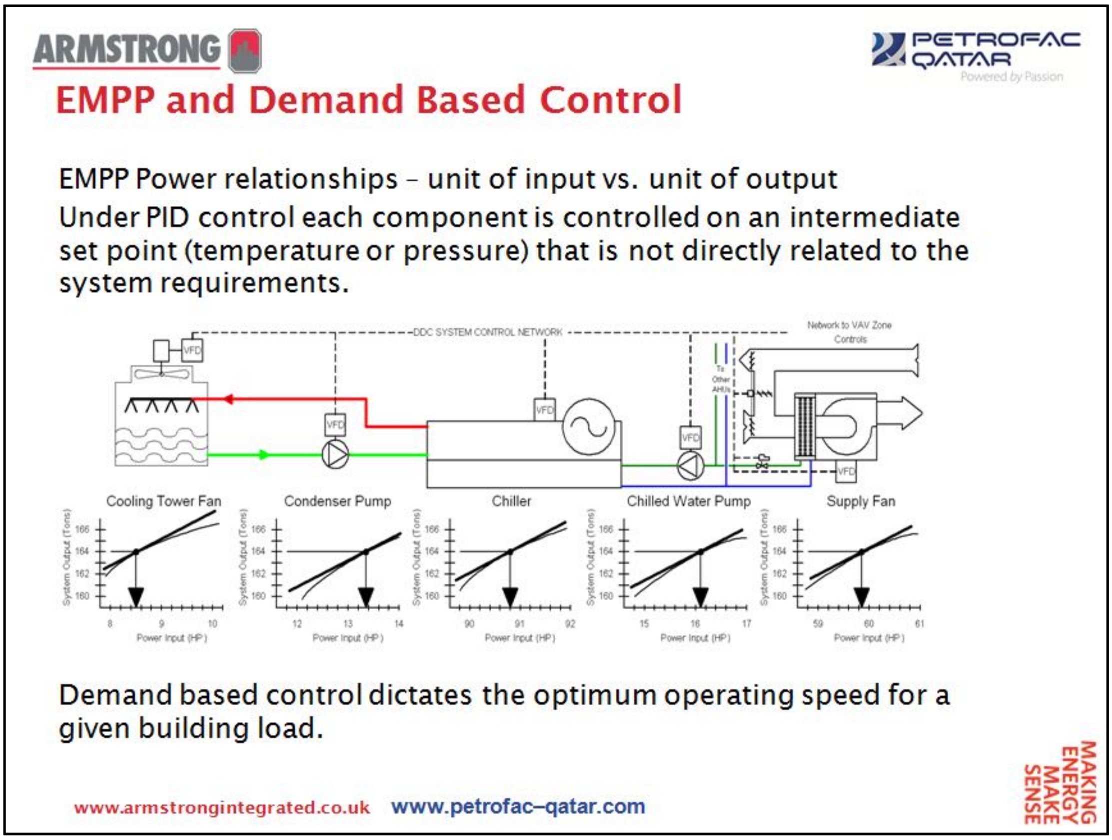
So now that we have sequenced our chillers and cooling towers so that they are always operating as close to and as far up the natural curve as possible how do we now start to ensure that every element of the chiller plant is operating at optimum efficiency for the given load?

This brings us to the second of our trio of new control methodologies... Imagine having a rheostat to control the speed of each of the 4 devices in the chiller plant that remove heat from the building, namely; the cooling tower fan, the condenser pump, the chiller, and the chilled water pumps. For a given scenario, and with enough time, you could vary the speed of the four devices and (to a point) the CHW supply temperature and eventually achieve the lowest input power for that particular load point.

In effect, what is happening here, is that power and efficiency are being traded off between the four devices to arrive at a net best system efficiency, or integrated result. For example, increase tower fan speed to reduce ECWT to improve chiller efficiency if it is more efficient to do so or indeed vice versa...

This operating concept is a patented control methodology referred to as the "equal marginal performance principle".

For a given load we can calculate the most efficient operating point for every device in the system using the EMPP algorithms.



To better visualize this consider the plot of kW electrical input, x-axis, with ton cooling output on the y-axis. When we have optimized the speed of each of the four devices to achieve the equal marginal performance principal, the point of operation of each of the devices on the power curve will have the same slope for all four devices, as shown in the illustration.

What has always made the all variable speed plant an enigma for control philosophy was how to control all 4 variable speed devices, as essentially, tradition has dictated that there are 3 control loops, but 4 variables, so as a result PID feedback loop control philosophies could not be applied. If we look at the plant as a mathematical model we are also stumped, because we end up with 4 variables to solve for with only 3 equations – can't be done.

Traditional control methodologies overcame this challenge by using large dead bands and long delay timers to prevent plant continually hunting. Certainly stable, efficient control of a chiller plant has long been a challenge. This is compounded by the lack of precision and accuracy of instrumentation devices (dp sensors, temp sensors, flow meters) on each of the control loops.

So how do we deploy the benefits of the EMPP in a dynamic environment, i.e. a variable building load.

This brings us to the third control element that we employ, Demand Based Control. Demand based control, is a relational control method that we use to deploy the "equal marginal performance principle".

Demand Based Control, is the third patented control method to the Hartman LOOP. With demand based control we are essentially looking at the demand of the system and instructing the equipment where to operate. More specifically, given that we know the performance curves from manufacturers data, we can use technology to pre-determine the

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Demand based Control

- Primary pumps / Distribution pumps, respond to building call for cooling
- Calculate Demand, by observing compressor kW, and building load. If Demand change greater than dead band, proceed to next step.
- Adjust cooling tower fan speed and tower pump speed according to EMPP Power relationships
- Adjust chiller supply temperature set-point and CHW flow rate for new load point
- Determine if a chiller, tower or pump is to be staged on or off to remain close to the Natural Curve.

Repeat above.

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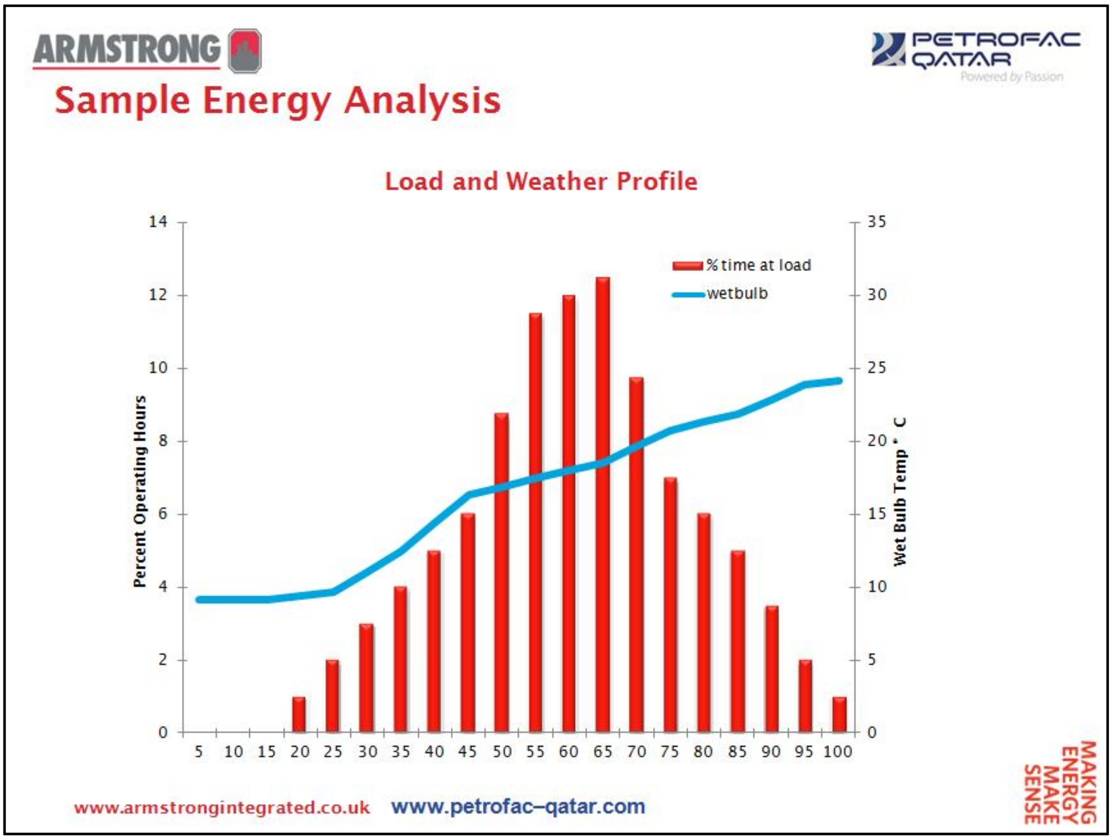
Here we see the simple sequence of events that the IPC goes through in each “Loop Calculation”, typically performed every 60 secs.

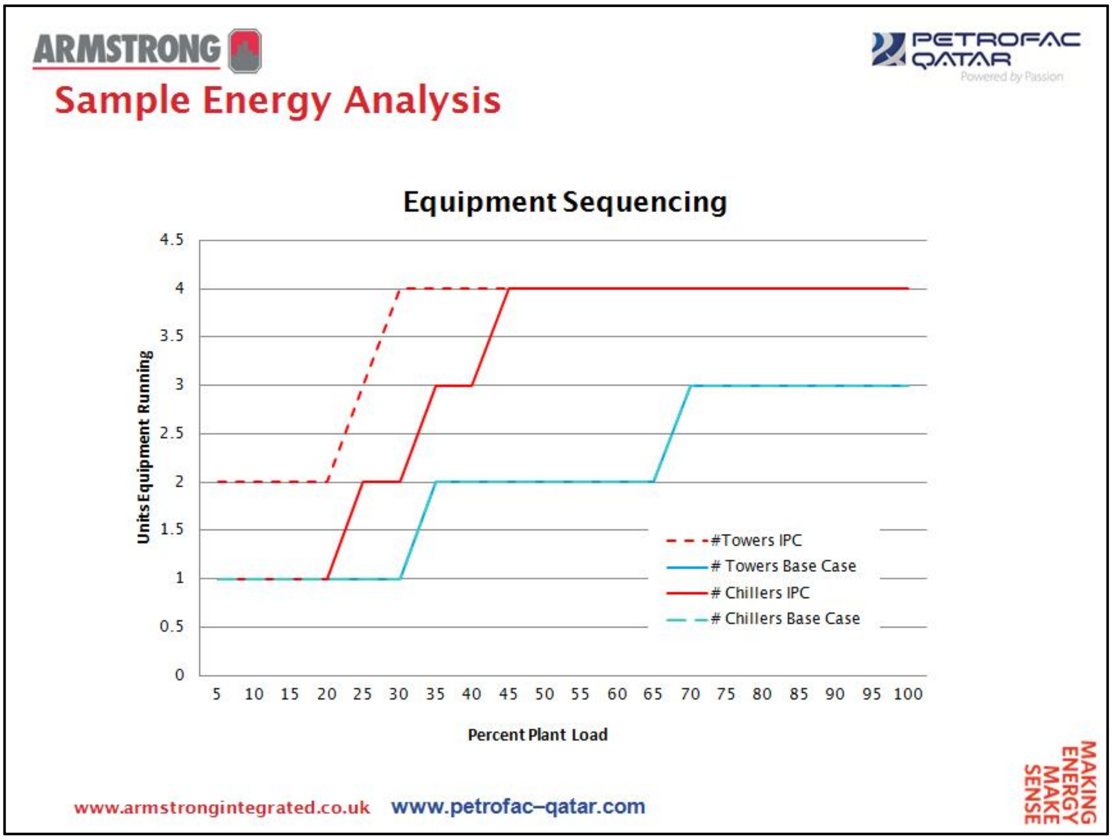
Example Energy Analysis

Typical mixed use commercial building

- Location: Dubai
- 24 / 7 operation (8760 hours)
- Design Day cooling Load – 4.5MW
- Configuration:
  4No 1.5MW High Performance VS chillers D / D / D / S
  4No VF Cooling Towers
  AVP CHW Pumping
- Energy Cost: $0.10 / kW

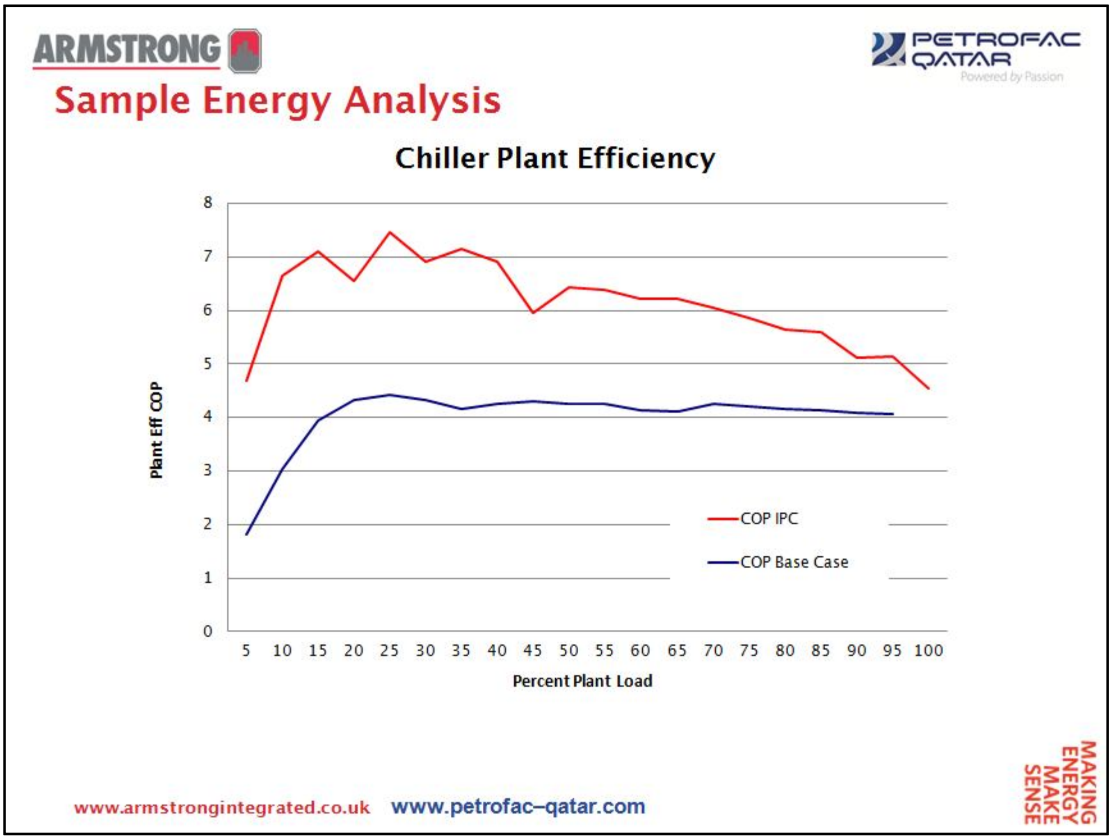


Dubai load and weather profile from ASHREA



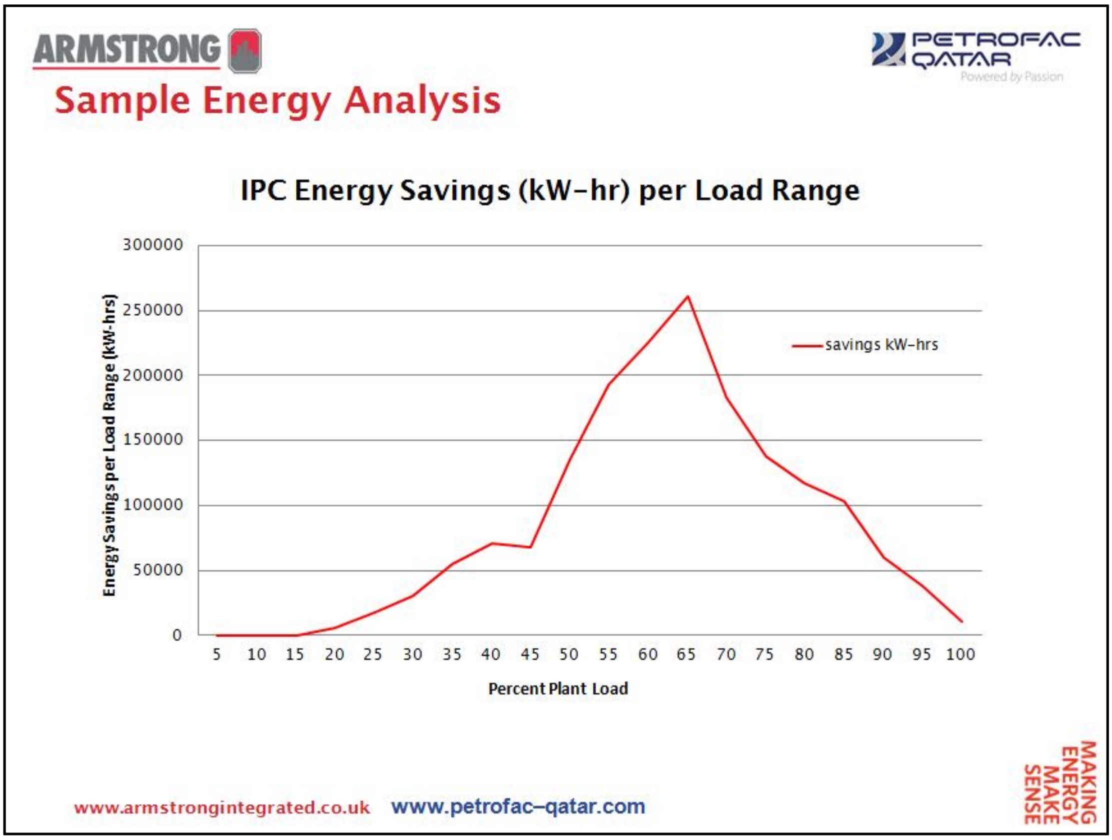
Red lines show staging points as IPC

Blue lines show traditional capacity-based sequencing



Total chiller plant COP

Massive improvements



Distribution of energy savings across load profile

Similar curve to load profile

Largest savings are derived where plant spends most of its time

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Sample Energy Analysis

RESULTS:

- PLANT COP INCREASED FROM 4.21 TO 6.06
- 30% ENERGY SAVINGS P.A.
- $171,000 SAVED IN ENERGY COST P.A.
- INCREASED OCCUPANT COMFORT
- STABLE OPERATION, EXTENDING PLANT LIFE
- REDUCED COST OF SUPPORTING INFRASTRUCTURE

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Implementation

FAQ:

- DOES IPC REPLACE THE BUILDING MANAGEMENT SYSTEM (BMS OR BAS)?

  NO – IPC sits between the devices and the BMS, takes a global enable signal from BMS and reports out to BMS.

- WHAT GUARANTEES ARE GIVEN ON PLANT PERFORMANCE?

  Performance contracts with guarantees of COP at certain load points.

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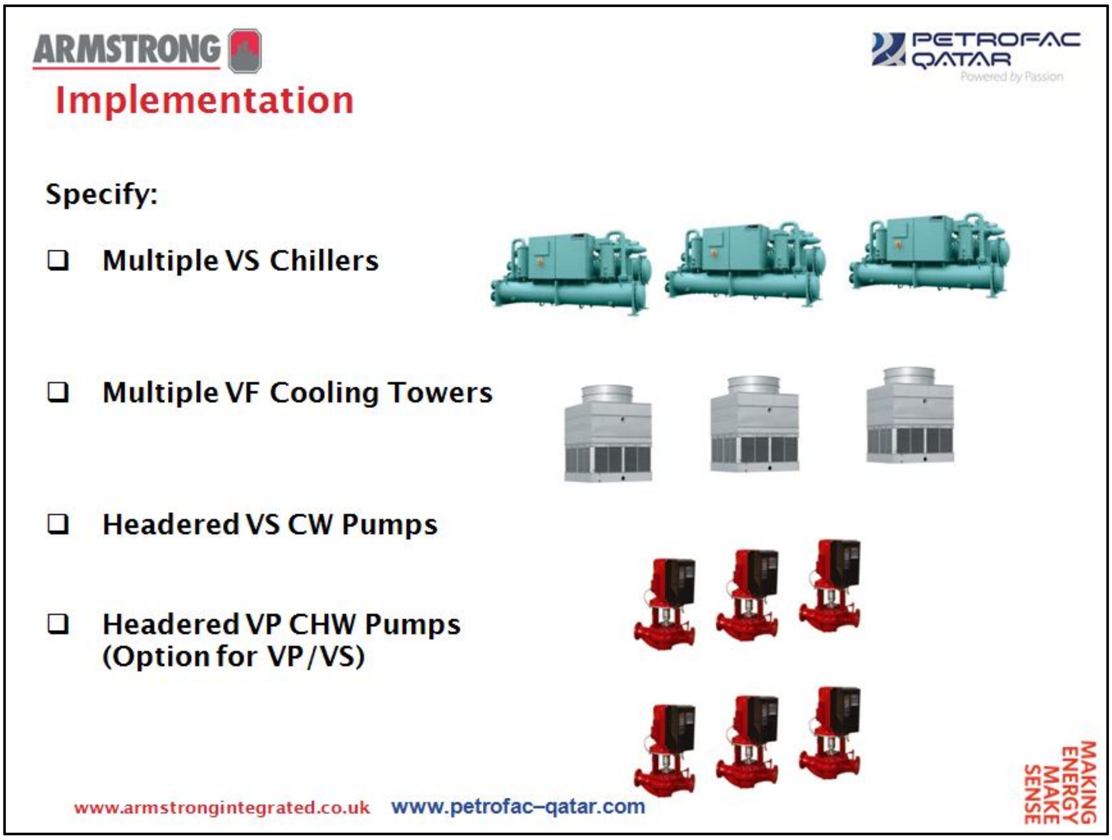

SPECIFY
Multiple Variable speed chillers
Multiple VS cooling towers/DACs/ACUs
Headered (not dedicated) VS CW pumps
Headered All Variable Primary only CHW pumps (VP/VS can be employed where close control of multiple CHW circuits is required)

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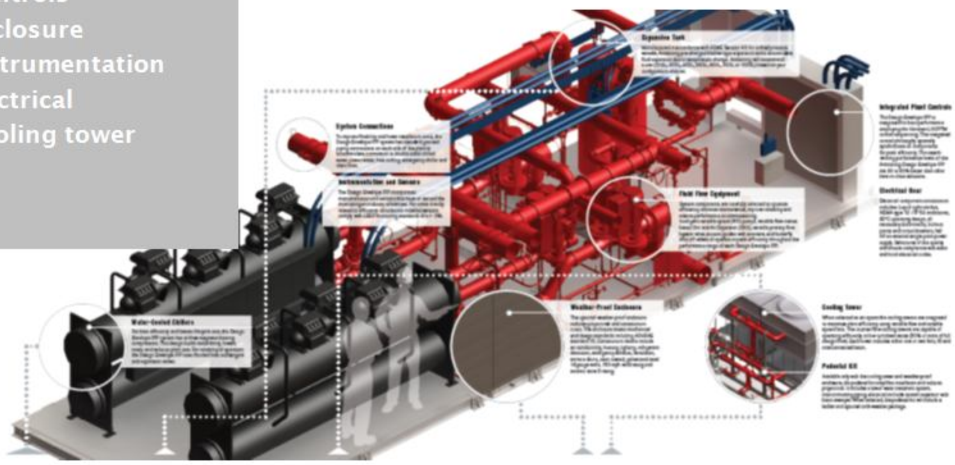
Implementation

OR SPECIFY AN INTEGRATED PLANT PACKAGE (IPP)

- Chillers
- Controls
- Enclosure
- Instrumentation
- Electrical
- Cooling tower



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MAKING ENERGY MAKE SENSE

MITIGATE RISK OF CONTRACTOR BREAK UP

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Implementation

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OR SPECIFY AN INTEGRATED PLANT PACKAGE (IPP)

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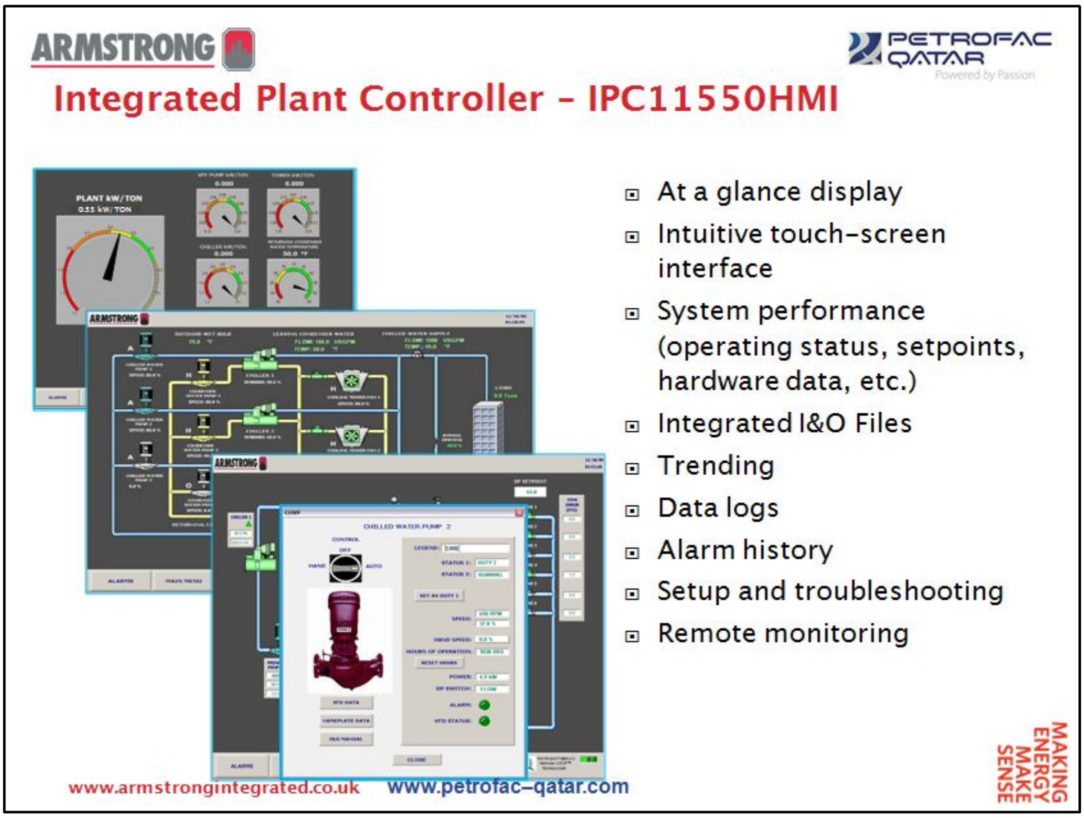
MAKING ENERGY MAKE SENSE

MITIGATE RISK OF CONTRACTOR BREAK UP



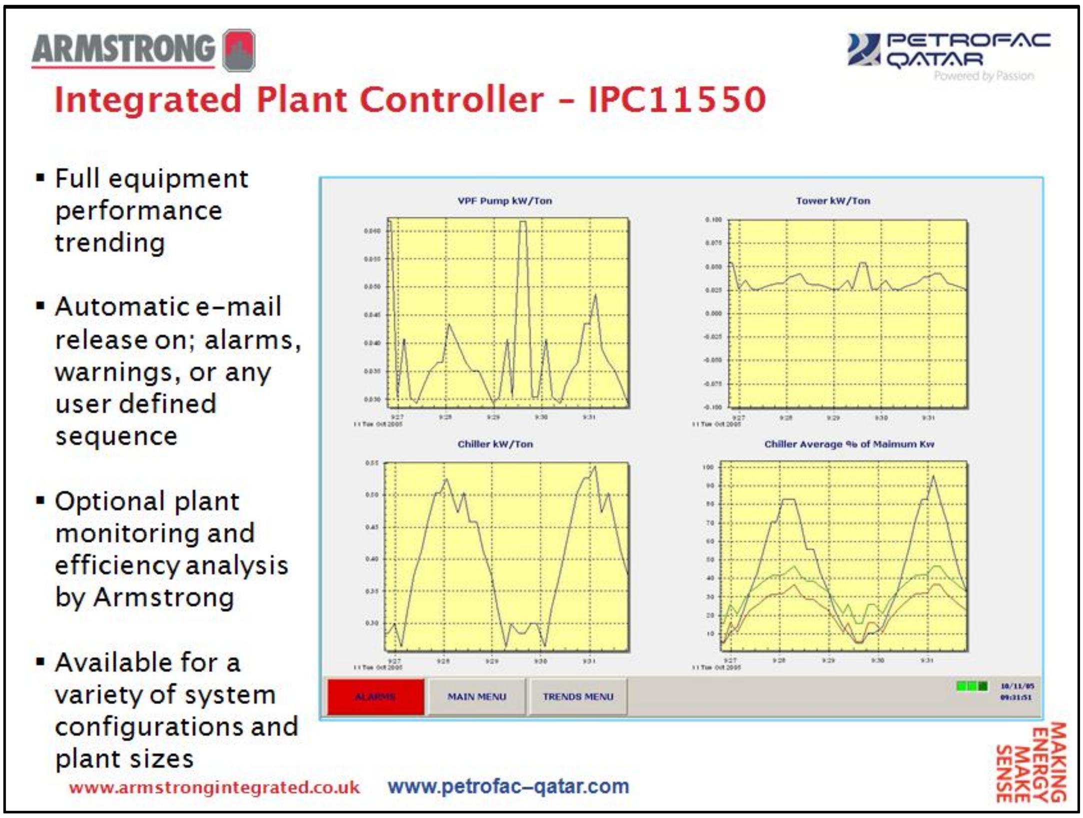
The default screen, or screen saver is a performance screen for the complete plant, and ea

This screen serves as a terrific training tool for the operator to observe the efficiency gains
mode.

The IPC 11550 ushers in a new era of user friendliness with a number of firsts.

Like many other system schematic displays, the IPC has icon driven control that enables tl
gather operating data and limits for that device. IN addition, the operator can change the c
duty status 1,2,3 …, or as the standby piece of equipment. The equipment may also be se

More interestingly, the IPC equipment screen has two additional screen buttons titled "nam
to get the information. The I&O button brings up the operating manual in PDF format. All c
ability to receive a warning by email from our controller, log in and take the suspect equipm
have a single operator, this technology enables them to be in two places at once.



Each system comes with 20 standard trends, and a simple one button "data log" function that downloads all data by email in excel format. Automatic emails are released on high and low level warnings.

When an alarm is received the operator can go to the alarm screen and touch the recent alarm description to receive a list of possible causes of the alarm to aid him in taking corrective action in what might be a highly stressed emotional state.

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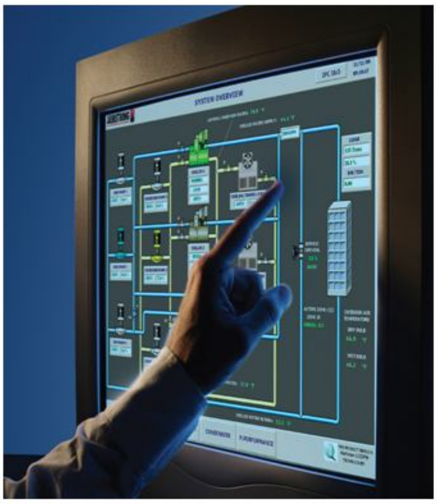
Design Envelope
Integrated Plant Control System

Sequences for:

- All variable flow (VPF & VPVS)
- Water Side Economisers
- Thermal Energy Storage
- Ground Source (Geothermal)
- Dry Air Coolers (Evaporative mist)
- Compressor Sequencing (large 11 kV dual compressor CS)
- Demand Limiting for Demand Response
- Emergency Power Transfer Switch



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Design Envelope
Integrated Plant Control System

Quarterly Reports (1st year)

- Performance Review
  - Plant efficiency
  - Equipment behaviour
  - Plant Maintenance
  - Calibration to "worked-in" equipment

Site Services

- ✓ Coordination Meeting & Project Mgr
- ✓ Commissioning & Training
- ✓ First Cooling Season Tuning
- ✓ Project Energy Analysis (load / WBT)

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Powered by Passion

Design Envelope
IPC 11550

At Frito Lay Delivers:

On an annual basis **55%** energy cost savings

Confirmed by an Independent
Power Utility

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Powered by Passion

Design Envelope
IPC 11550

At **Humber College** Delivers:

On an annual basis **53%** energy cost savings

Confirmed by an Independent **Power Utility**

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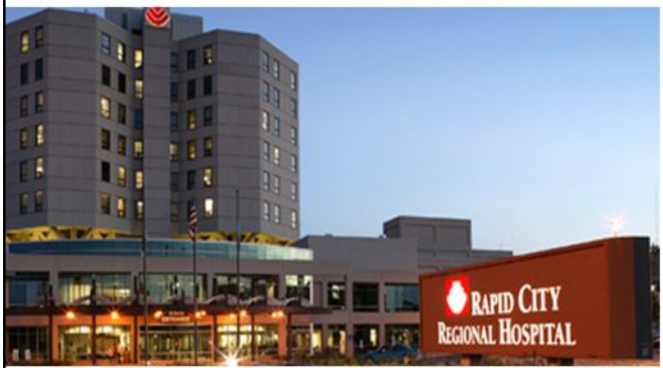
IPC 11550



At **Rapid City Hospital**

Integrated plant controls deliver:

On an annual basis
35%
energy cost savings

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Design Envelope OPTI-VISOR

PETROFAC QATAR
Powered by Passion

At Data Centre (6000 TR)

On an annual basis
28%
energy cost savings

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PETROFAC QATAR
Powered by Passion

Design Envelope IPC 11550

At Headquarters TN Integrated Plant Controls

Deliver:

On an annual basis **33%** energy cost savings

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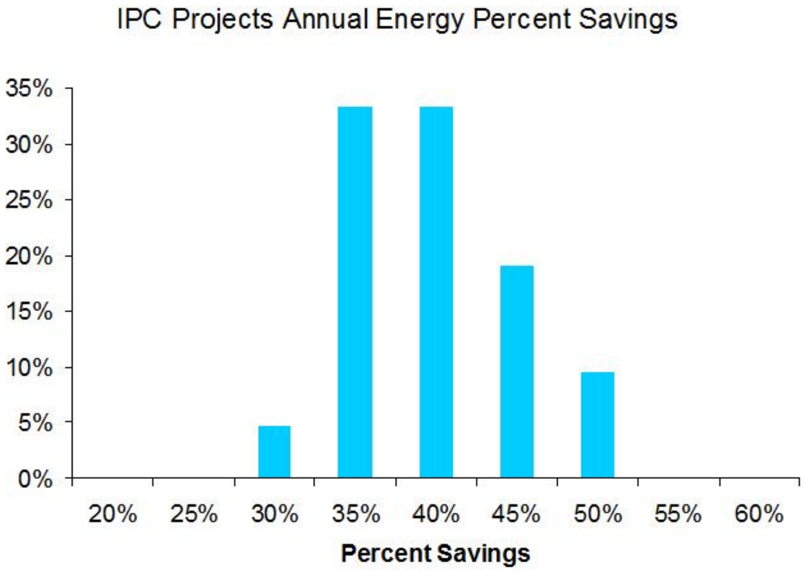
Design Envelope Integrated Plant Control Installed Population Distribution of Savings



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Take the Load Off

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DESIGN ENVELOPE

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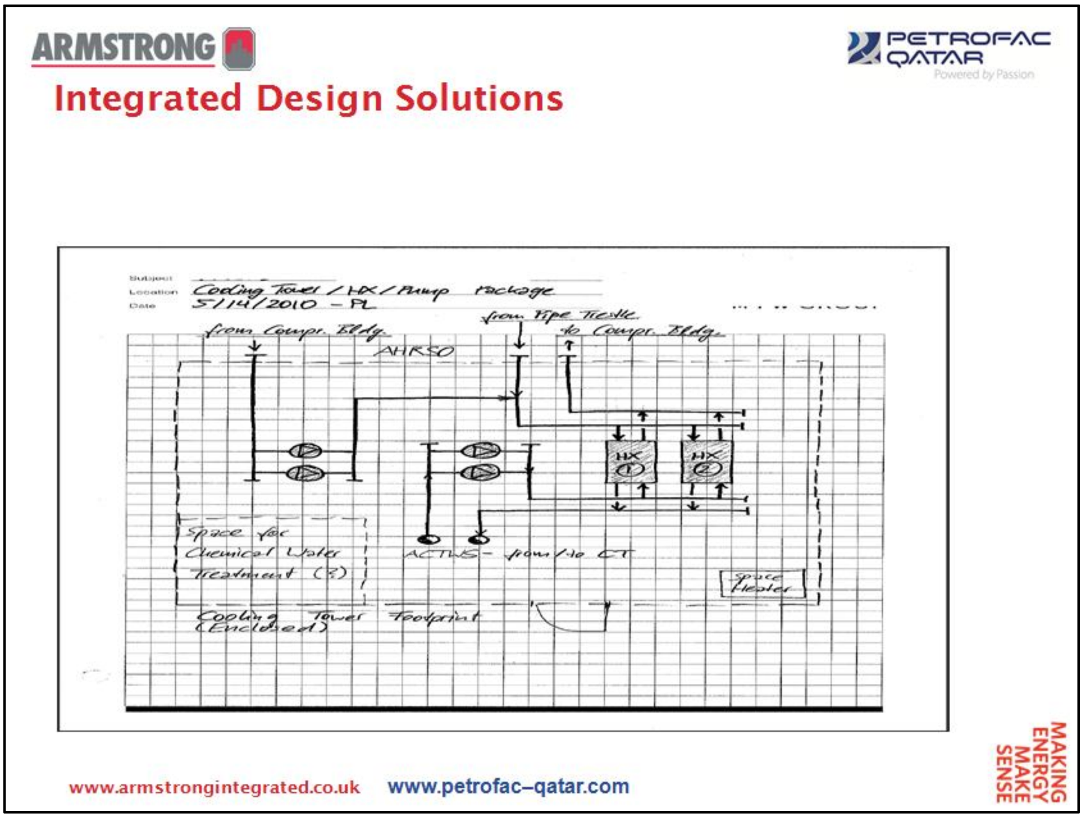
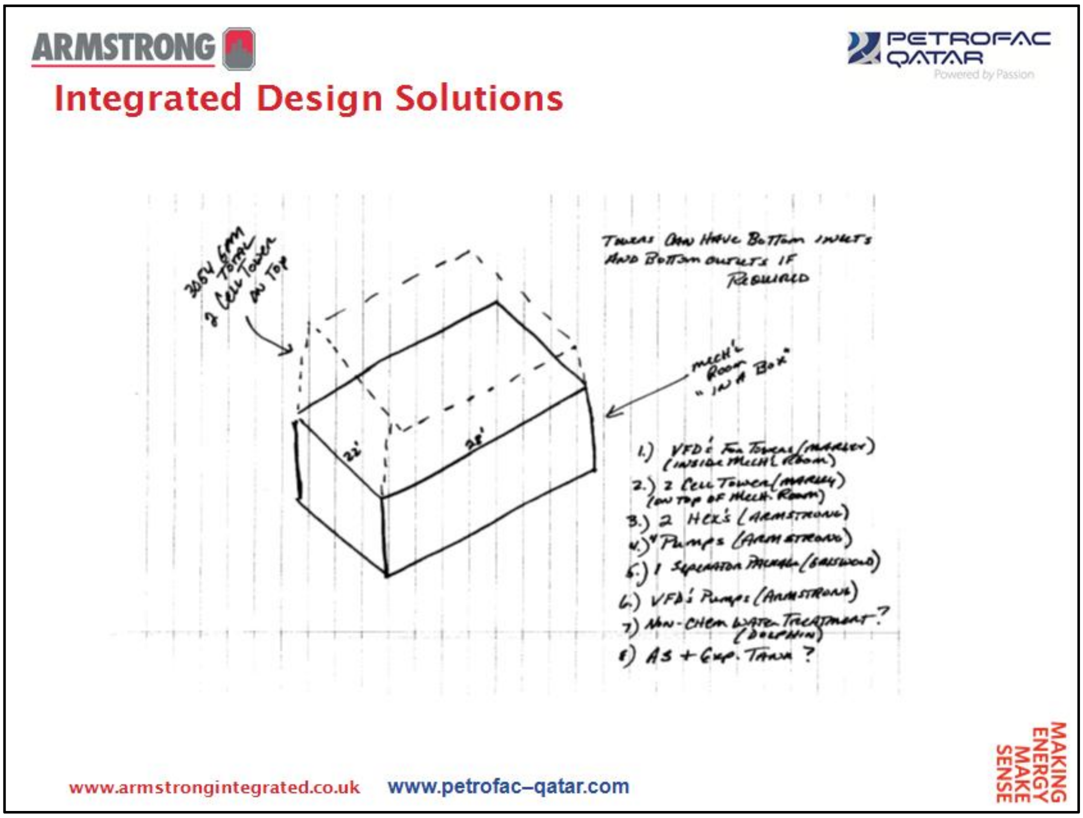
- Single source responsibility
- Shortened delivery and installation time
- Reduced work on site
- Reduced logistical coordination on site
- Performance tested at the factory
- Performance specification (not component driven)

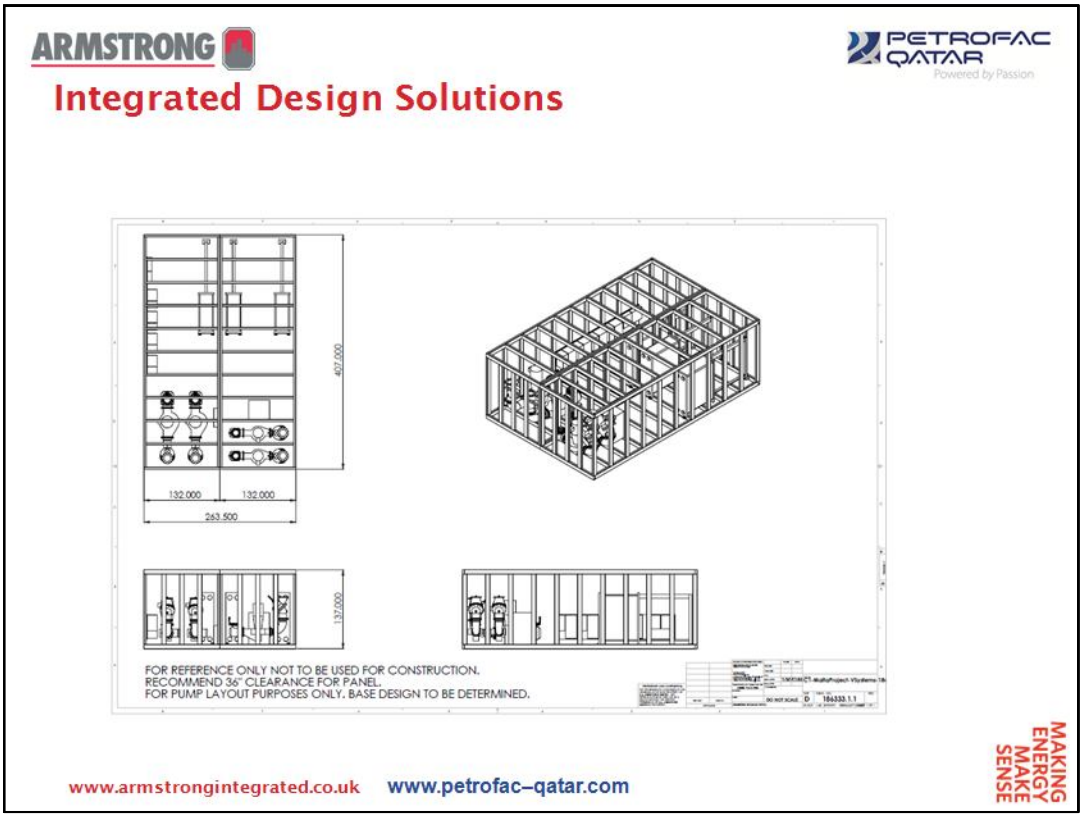


We started having the conversation with the engineer close to the end of May for an Energy Heat Transfer Station.

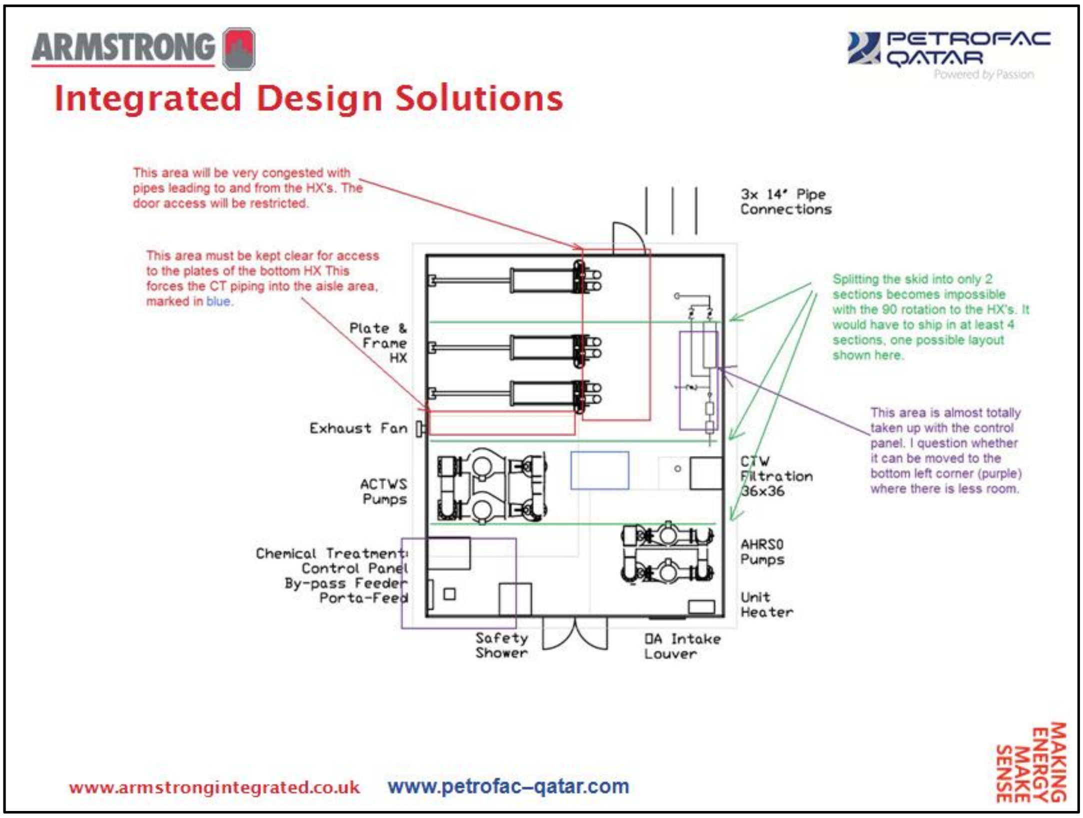
The Heat Transfer Package station is a dual circuit pumping package that will be installed as a component of an HVAC system. The Pumping and heat transfer system contains 4 x Vertical Inline pumps, 3 x Plate and frame heat exchangers, VFD, piping, valves and various accessories all mounted on fully enclosed insulated weather proof housing.



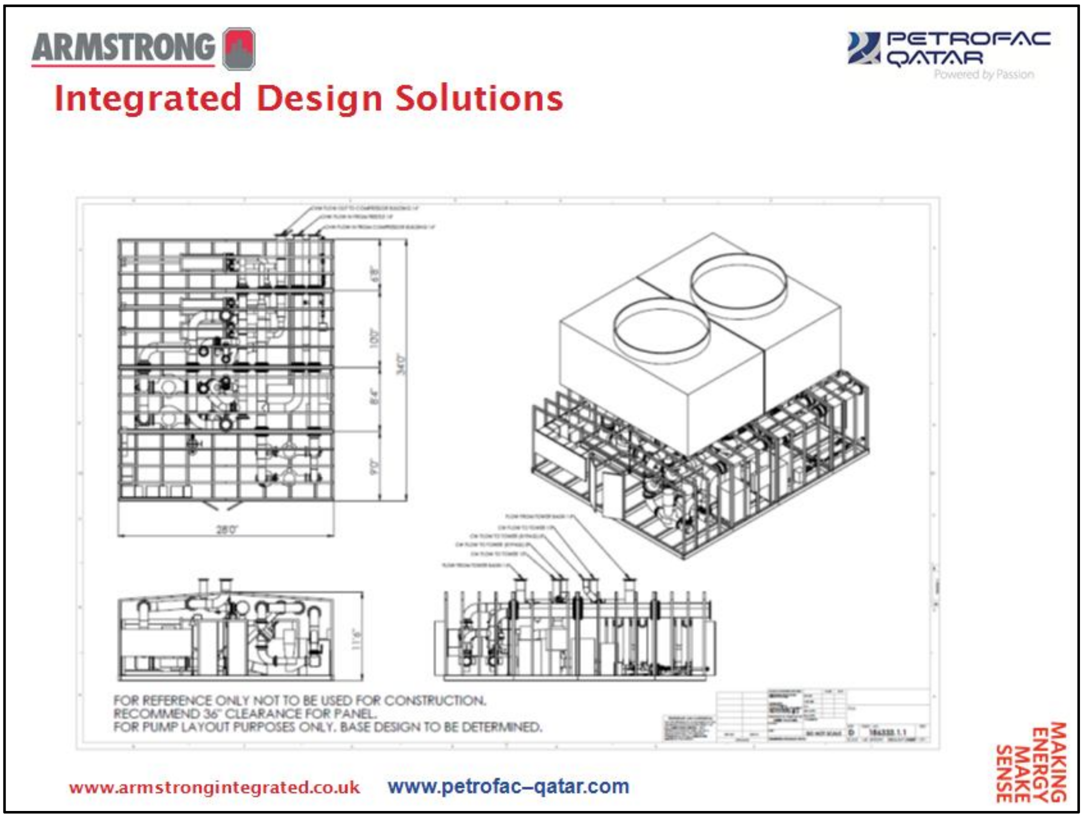
Before June we got our equipment specified, just equipments!



And at the same time, we started working out on our first layout.



Several discussions



After 6th revision on June 21st and numerous discussion, we finally have something that the engineer wishes to pursue for bid and as a basis of design

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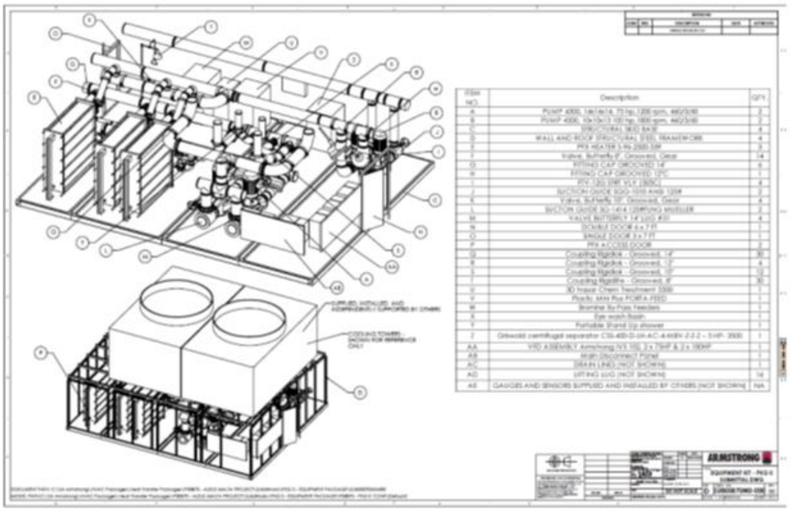

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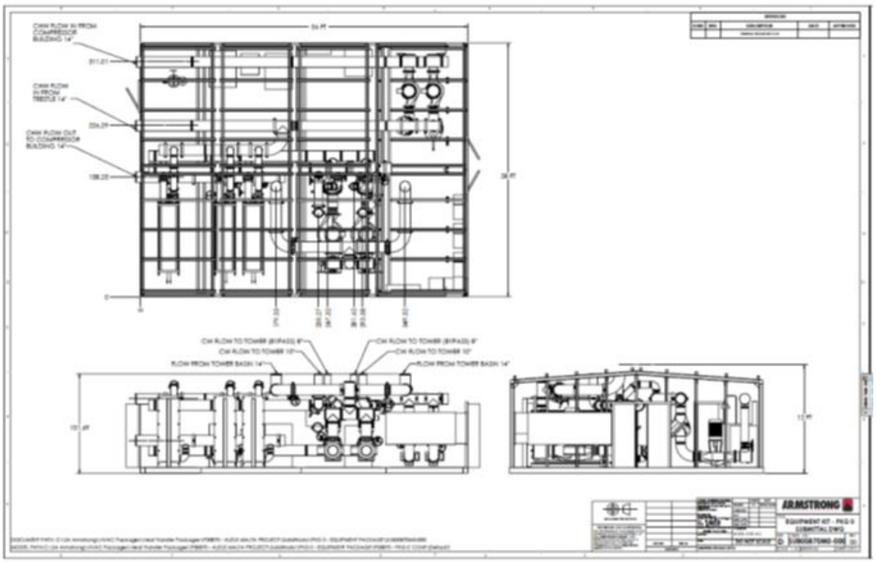

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March we have shipped the whole packaged system

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