Welcome & Introduction

Martin Lamb
Chief Executive

Agenda

• Welcome & Introduction	Martin Lamb
• IMI’s core Fluid Technologies	Santhosh Kumar (Beverage Dispense) Richard Edwards (Fluid Power) Jean Christophe Carette (Indoor Climate) Jon Landes (Severe Service)
• Applications Showcase	4 Groups
• Questions and Answers	
• Closing comments	Martin Lamb
• Refreshments	

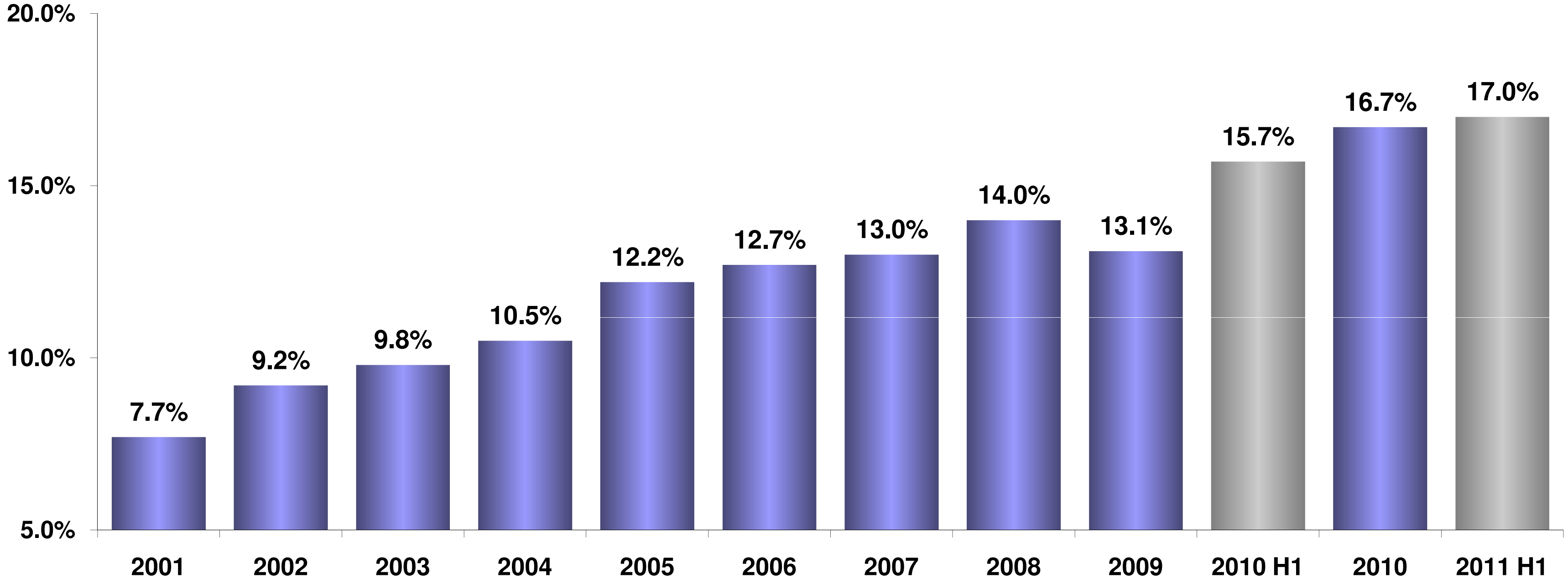
IMI Today

	2001	2011
% of revenue from customised or highly engineered products	20%	70%
% of revenue from new products	4%	15%
% of revenue from the aftermarket	<15%	>35%
% of low cost manufacturing	<5%	>40%

- Leading positions in global niche markets
- Strong long term growth drivers related to climate change, resource scarcity, urbanisation, and an aging population
- Key partner to over 100 global blue chip companies
- Highly differentiated and customised product and system offerings
- Strong and dependable aftermarket revenues
- Highly developed low cost manufacturing and low cost procurement capabilities

Margin improvement 2001 – 2011

Engineering Advantage

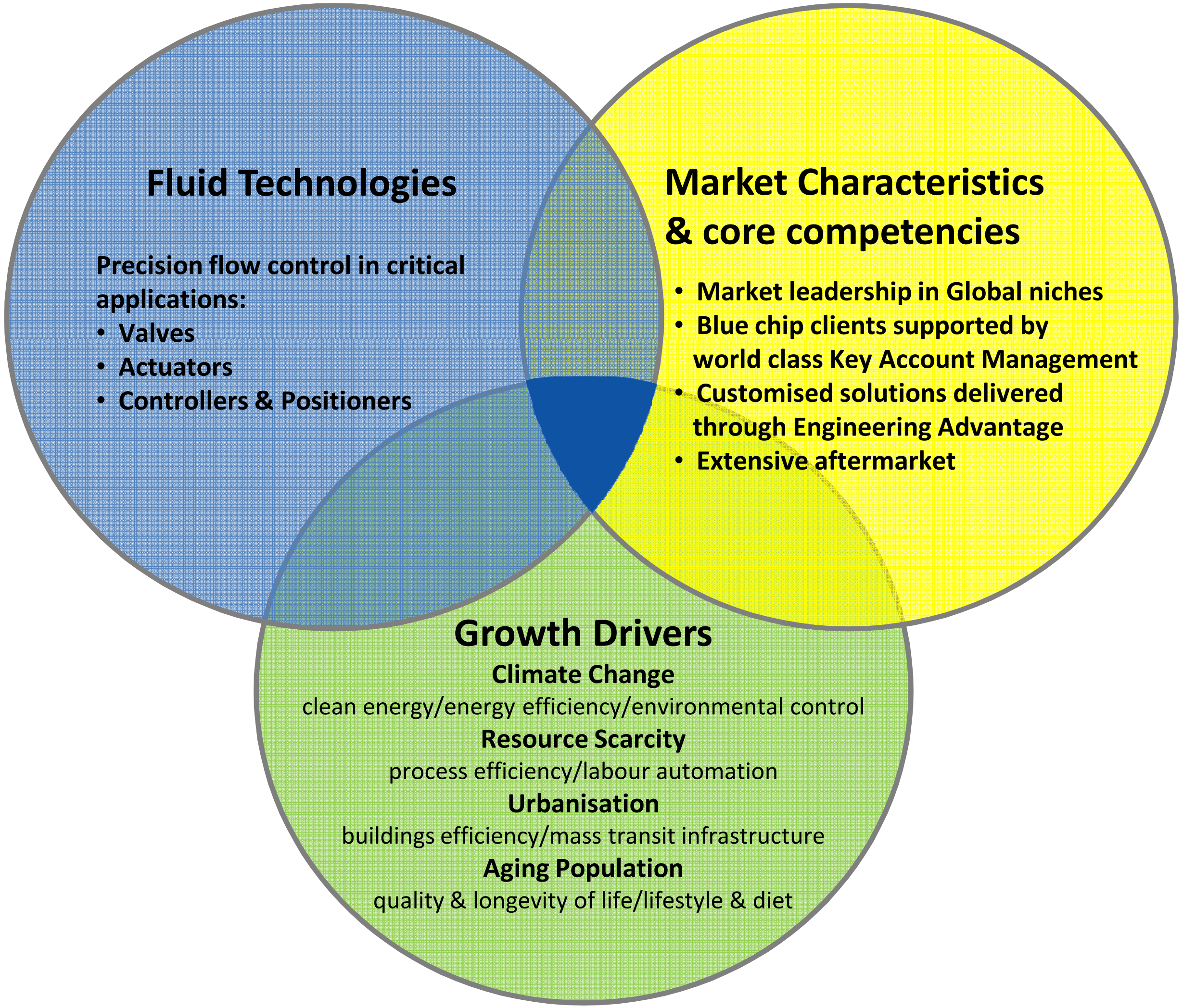


Long term objective for each of the three Fluid Controls businesses is 20% and for each of the Retail Dispense businesses is 15%

IMI Tomorrow

Strategic Convergence

Focusing on the “sweetspot”



Fluid Technologies

Precision flow control in critical applications:

- **Valves**
- **Actuators**
- **Controllers & Positioners**

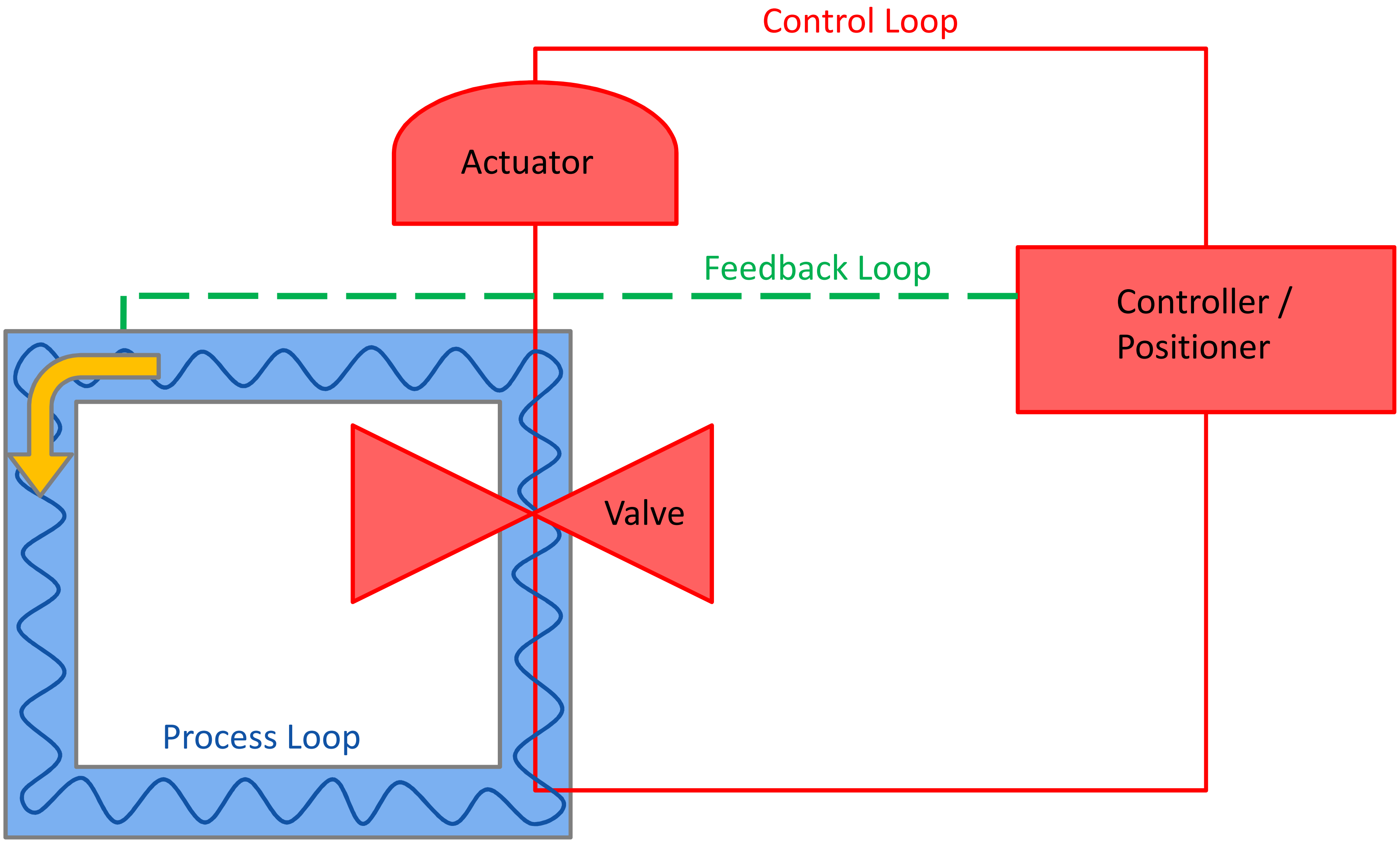
Market Characteristics & core competencies

- **Market leadership in Global niches**
- **Blue chip clients supported by world class Key Account Management**
- **Customised solutions delivered through Engineering Advantage**
- **Extensive aftermarket**

Growth Drivers

Climate Change
clean energy/energy efficiency/environmental control
Resource Scarcity
process efficiency/labour automation
Urbanisation
buildings efficiency/mass transit infrastructure
Aging Population
quality & longevity of life/lifestyle & diet

Flow control fundamentals



Control Loop

Actuator

Feedback Loop

Controller / Positioner

Valve

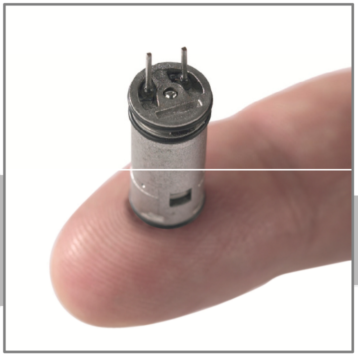
Process Loop

Applications spectrum

Steam,
Gas, Water

Water

Syrup, Water,
CO^2



Air, Oxygen,
Exhaust gas,
Reagent

3m Orifice size 0.2mm

600 bar Pressure 1 bar

Applications focus

- Challenging process environment
  - pressure / temperature / harsh environments
- Critical outcome
  - high consequences of failure
  - high commercial returns for optimised performance
  - regulatory requirements
  - unique competitive advantage

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• Applications Showcase (i) What is critical aspect of design? (ii) Why is it important to the customer? (iii) What are the key physical principles involved? (iv) What are the implications of getting it wrong or sub optimisation? (v) How have we solved the problem? (vi) Why does the solution give us a competitive advantage?	4 Groups
• Questions and Answers	
• Closing comments	Martin Lamb
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Common Fluid Technology

An introduction to the underlying design principles and techniques behind IMI’s engineering advantage approach

Presentation Overview

1. Design principles:
   Santhosh Kumar – VP Engineering (Cornelius)
   - The main system and performance parameters that must be considered and controlled during the design of a new product or technology

2. Design optimisation tools:
   Richard Edwards – Technical Director (Norgren Life Sciences)
   - The key tools and techniques used to achieve the optimum system solution

3. Benefits of optimised design (Engineering Advantage):
   Jean-Christophe Carette – Hydronic College Manager (TA Hydronics)
   - The benefits of delivering world class engineering advantage

4. Consequences of sub-optimal design:
   Jon Landes – VP (IMI Severe Service)
   - The consequences of relatively small deviations in performance

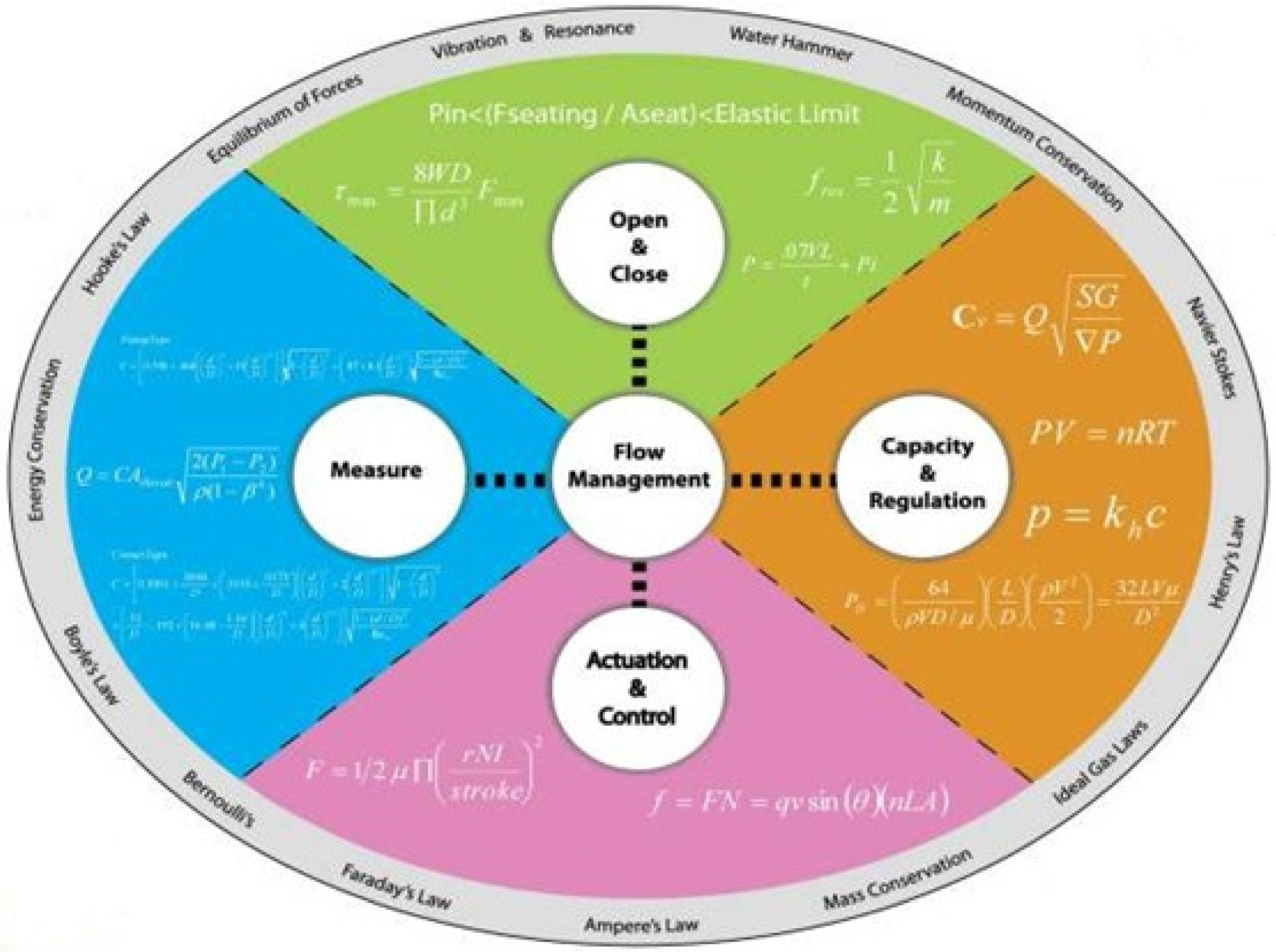
1: DESIGN PRINCIPLES

Focus on the physical principles that underpin the design of mechanical and fluidic systems.

IMI

Design Principles

Engineering Advantage



Designing a flow control system

<u>Fundamental steps in designing a valve:</u>

1. Establish the required <u>flow</u> performance
    - Single phase (liquid or gas) or 2-phase
    - Fluid Properties
    - Capacity & flow rate
    - Accuracy & repeatability

2. Identify the required <u>pressure</u> conditions
    - Pressure Drop & inlet pressure

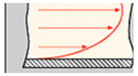
3. Decide the <u>method of control</u> & actuation
    - On-off or regulating/modulating
    - Response time
    - Mechanical or electrical actuation

4. <u>Optimise</u> the product & system performance

5. Design a stylish, robust & compact enclosure

Key Engineering Principles

Laminar Flow



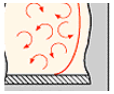
$$-\vec{\nabla} p + \mu\left(\vec{\nabla}^2 \mathbf{v}\right) + \frac{1}{3}\mu\left(\vec{\nabla}\left(\vec{\nabla}\cdot \mathbf{v}\right)\right) + \rho\mathbf{b} = \rho\dot{\mathbf{v}}$$

compressible fluid

$$-\vec{\nabla} p + \mu\left(\vec{\nabla}^2 \mathbf{v}\right) + \rho\mathbf{b} = \rho\dot{\mathbf{v}}$$

incompressible fluid

Turbulent Flow

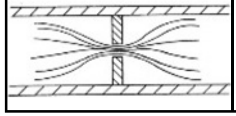


$$\mathrm{Re} = \frac{\rho \mathrm{v} D_H}{\mu} = \frac{\mathrm{v} D_H}{\nu} = \frac{Q D_H}{\nu A}$$

laminar when *Re < 2300*

turbulent when *4000 < Re*

Choked Flow

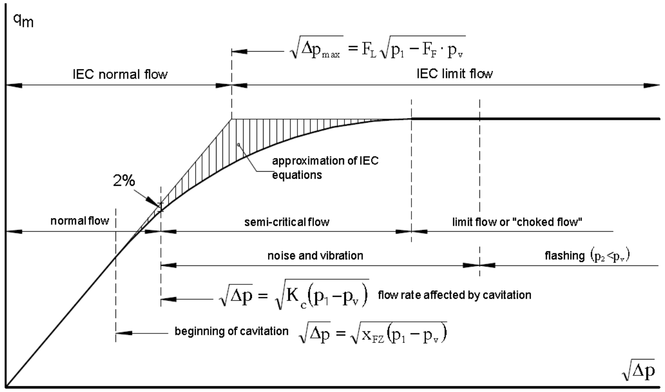


Turbulent - Incompressible

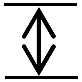
$$C_v = \frac{1.16\cdot q_{v(\max)}}{F_{LP}\cdot\sqrt{\frac{\left(p_1 - F_F p_v\right)}{\rho_r}}}$$

Turbulent - Compressible

$$C_v = \frac{q_{v(\max)}}{1414\cdot F_p\cdot p_1}\cdot\sqrt{\frac{M\cdot T_1\cdot Z}{F_\gamma\cdot x_{TP}}}$$



Pressure Drop



$$p_B = p_A - \rho g\left(\Delta z + f\frac{L}{D}\frac{V^2}{2g}\right)$$

$$f = \frac{64}{R}$$ *for laminar flow*

$$\frac{1}{\sqrt{f}} = -2\cdot\log\left(\frac{e/D}{3.7} + \frac{2.51}{R\sqrt{f}}\right)$$ *for turbulent flow*

Flow Coefficient

Cv

Turbulent - Incompressible	Turbulent - Compressible	Laminar - Incompressible	Laminar - Compressible
$C_v = F\sqrt{\frac{SG}{\Delta P}}$	$C_v = \frac{q_v}{2120\cdot F_p\cdot p_1\cdot Y}\cdot\sqrt{\frac{M\cdot T_1\cdot Z}{x}}$	$C_V = \frac{1.16\cdot q_V}{F_R\cdot\sqrt{\frac{\Delta p}{\rho_r}}}$	$C_V = \frac{q_V}{1500\cdot F_R}\cdot\sqrt{\frac{M\cdot T_1}{\Delta p\cdot(p_1+p_2)}}$

Flow control products

A wide range of flow management products are designed globally at IMI, following similar principles & techniques

OUR PORTFOLIO


Differential Pressure Controller


Pressure Independent Control Valve


TiO Cartridge Valve

Over 100 Flow Control Products & Active Patents


Closed Loop Ratio Control Valve


Balancing Valve


Multi function diesel engine control module


Turbine Bypass Valve with CoolMist Nozzle Desuperheater


Proportional Ratio Control Valve

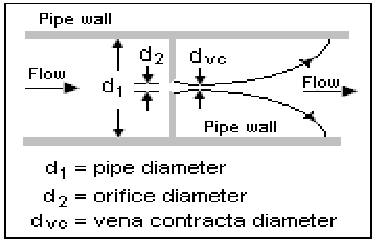

Fast-Acting QuickTrak Controls And Drag Anti-Surge Valve

2: DESIGN OPTIMISATION

Application of design tools to optimise the solution for any application

Design Optimisation Tools

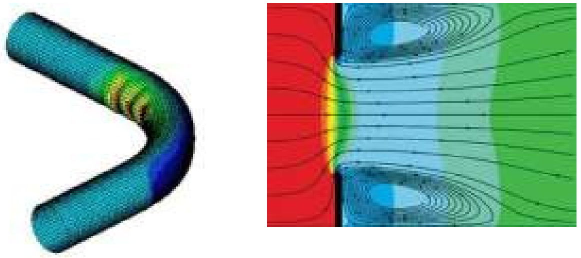
Engineering design is fundamentally about a deep understanding of the underlying physics.



- Mechanical Stress Calculations
- Navier-Stokes Equations
- Statistical Tolerance Analysis

However, the expansion of high powered computers has enabled the automation of these complex calculations.

- Finite Element Analysis (FEA)
- Computational Fluid Dynamics (CFD)
- Mechanical & Electronic Simulation Tools (CAE)



These increasingly sophisticated tools are still based upon the same physical principles and the requirement to understand and accurately model the system boundary conditions remains critical (GI-GO)…

Cleanliness and Cross Contamination

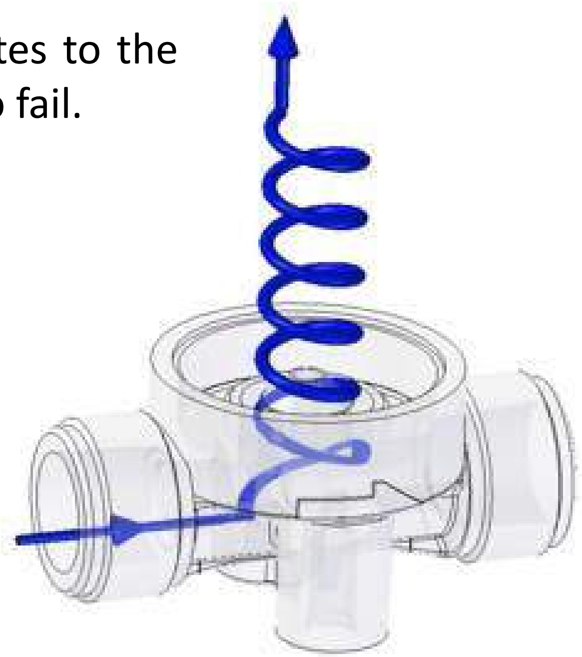
Engineering Advantage

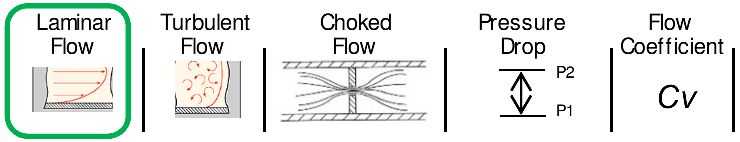
We recently launched a fluid control valve designed for professional coffee machines.

Any unswept volume in the valve would restrict adequate cleaning of the valve and risk contamination of subsequent drinks.

More significantly, unswept volume within the valve contributes to the build up of limescale deposits that ultimately cause the valve to fail.

- Competitor valve life = 6 months
- IMI valve life = 2 years





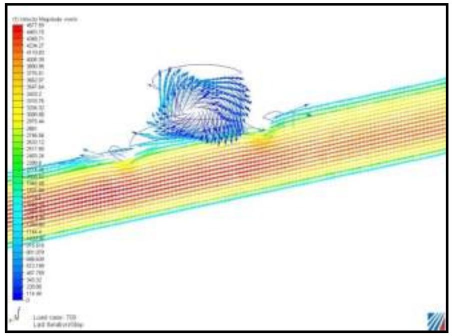
IMI Cleanliness and Cross Contamination

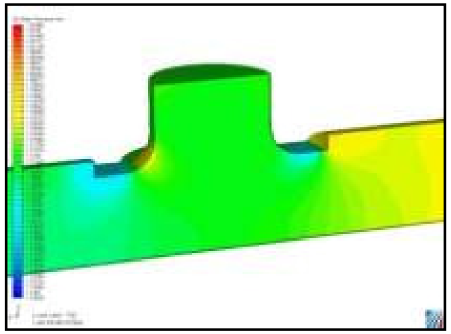
We worked intimately with a customer to develop an integrated solution for an endoscope decontamination system.

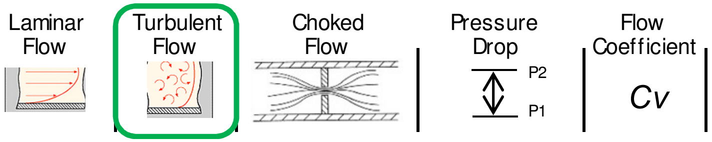
Legislation now requires empirical verification that endoscopes have been effectively decontaminated between patients.

We used CFD at a very early stage in the design to ensure that the fluid flow paths eliminated any potential “dead spots” in the system.

More importantly, we did this without inducing turbulent pressure spikes that would affect the sensor readings.







Flow Sensing and Control

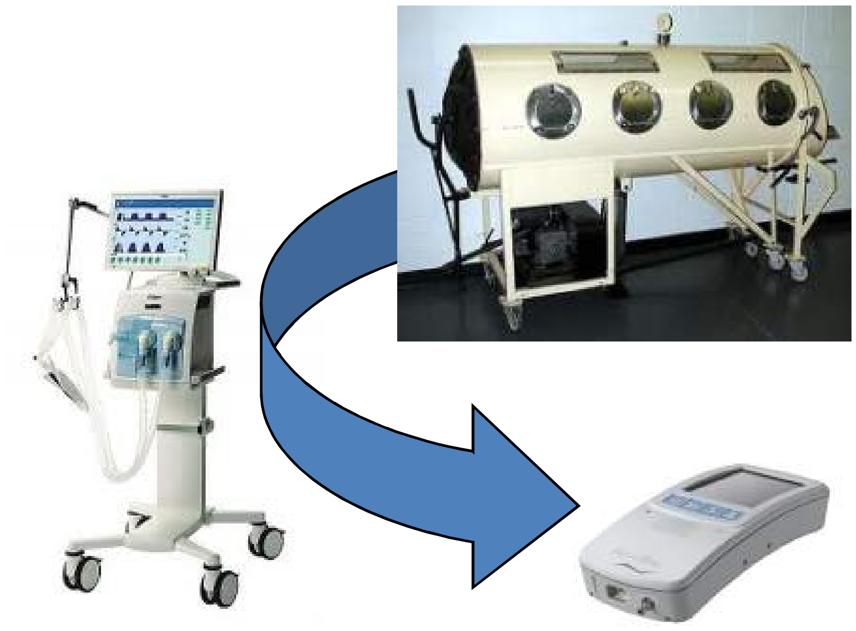
For a portable ventilator application, we needed to minimise the size of an integrated manifold.

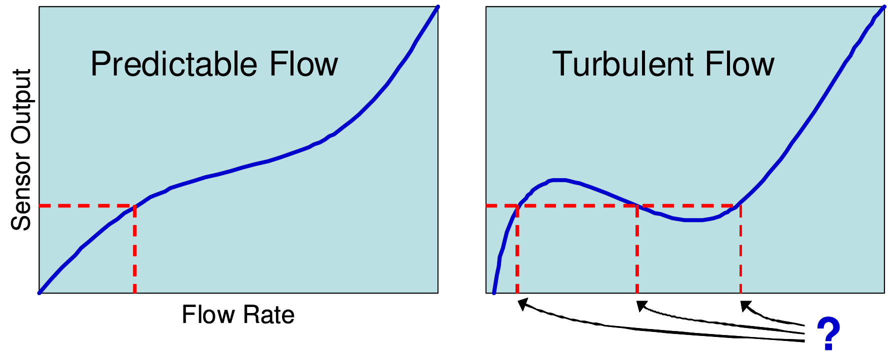
Reducing the size can lead to turbulent flow conditions.

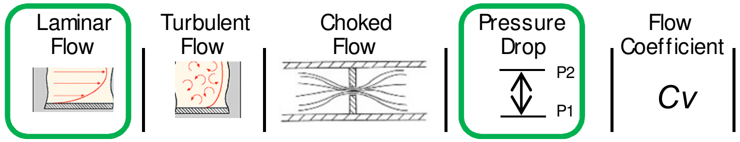
In a closed loop system, turbulence can cause significant issues in sensing and thus controlling the flow.

We minimised the size, whilst optimising:

- Flow
- Pressure Drop
- Control





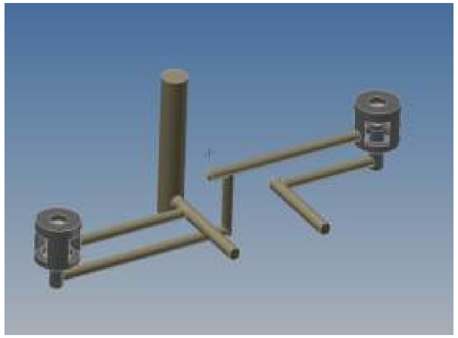


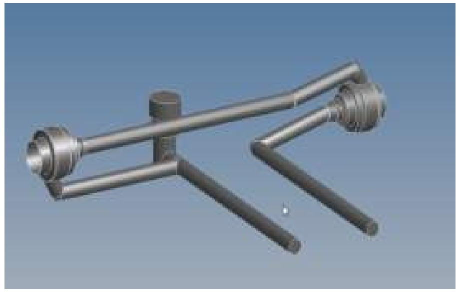
Fuel Delivery Manifold

We used CFD to characterise the flow of natural gas to a hydrogen fuel cell and were able to conduct a series of iterative design improvements prior to producing a physical prototype.

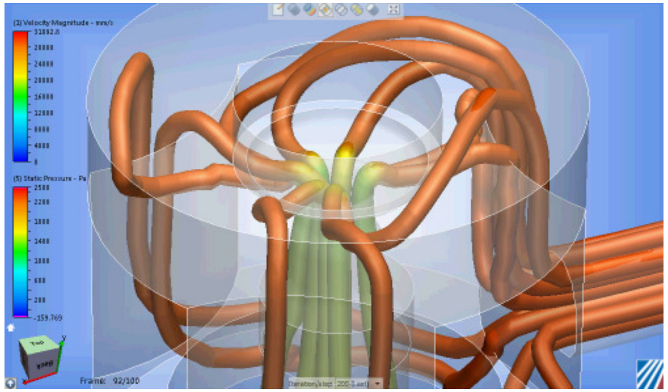
Each iteration was reduced from several weeks to just a few days and the simulation allowed us to complete most of the physical testing with compressed air rather than gas.

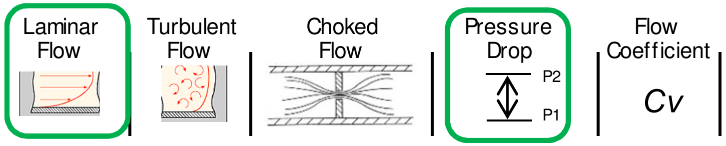
The CFD simulation was accurate to within ± 4% of the validation results and delivered a 100% improvement in flow compared to the competitor solution.





- Reduced manifold size and weight
- Reduced power consumption (smaller pump needed)





Finite Element Analysis

The optimum mechanical design is one that is sufficiently strong, but no more.

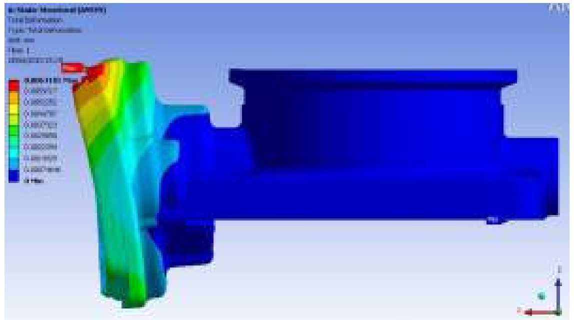
- Avoid excess weight
- Avoid excess cost

For a recent inlet throttle application, this principle was fundamental to the way in which we developed a new motorised proportional valve.

The intense engine vibration loads become even more severe with increasing mass.

We optimised the design to ensure the valve was strong enough, without over-engineering the design which would actually have been counter-productive.

We also adjusted the resonant frequency of the valve to avoid catastrophic vibration feedback.



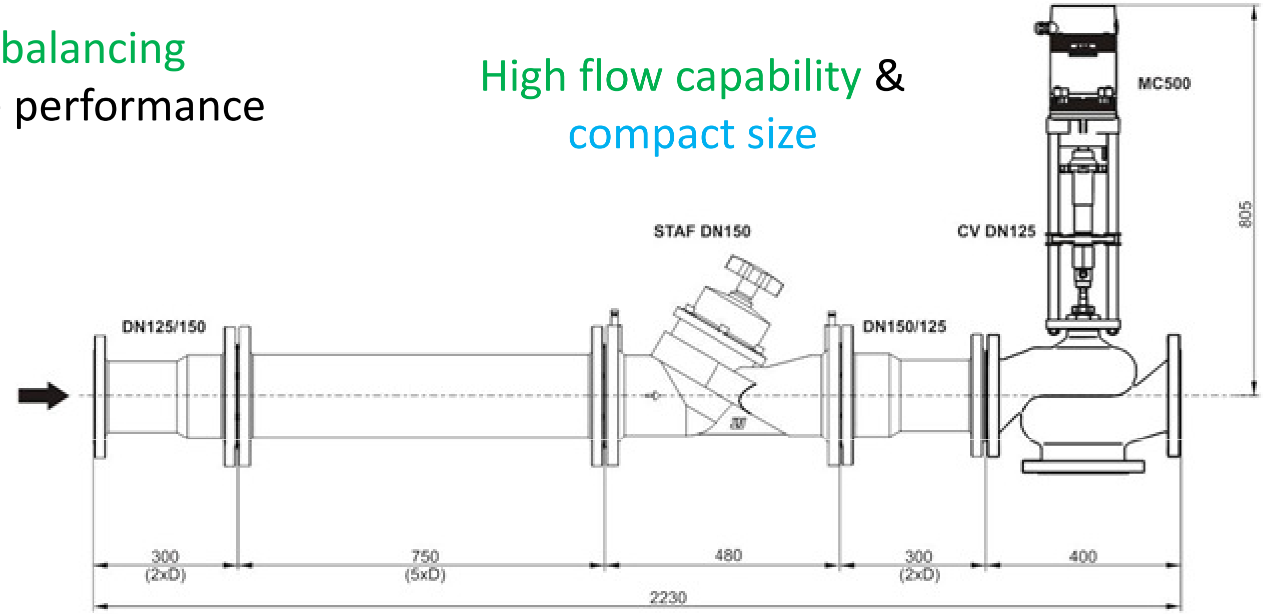
3: OPTIMISATION BENEFITS

Benefits that design optimisation delivers to both customers and IMI

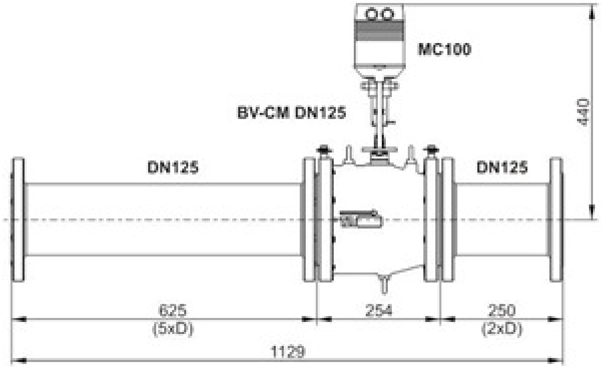
Combined balancing and control valve

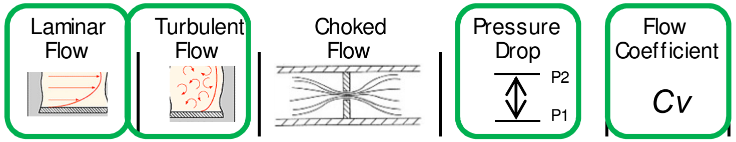
Combined balancing
& control valve performance

High flow capability &
compact size



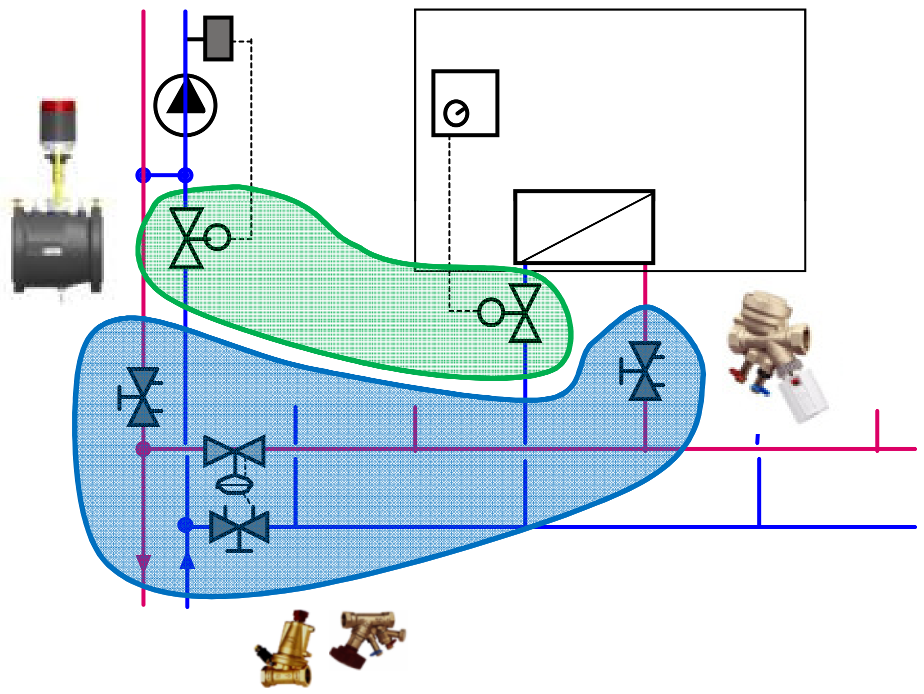
Excellent controllability at
low flows
with leak tight close off





IMI Benefits

Market potential increase: 20 to 50%



Customer Benefits

- Reduction of space, installation time & costs
- Pumping power: 10% saving
- Chiller efficiency: up to 8% saving
- Room temperature set-point: up to 18% saving / °C

Green building values:
New buildings: +10.9%
Retrofits: +6.8%
(Mc Graw Hill Construction Report 2010)

Total energy saving
20-30%

4: SUB-OPTIMAL DESIGN

Consequence of even a small deviation away from the optimum solution

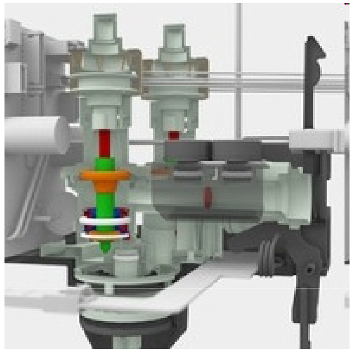
Sub-Optimal Design – Beverage Dispense

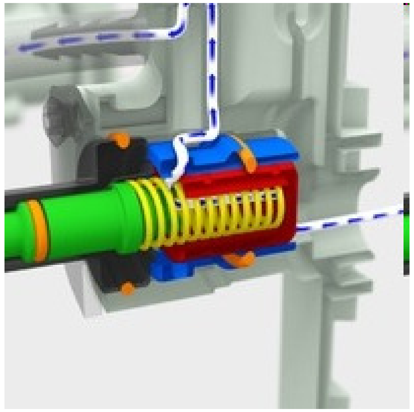
Objective: Optimize valve design to control ratio within +/- 2.5% between various syrups and water across wide range of inlet conditions such as pressure and fluid properties over 1.5M cycles.

Key parameters optimized: Pressure drop across the valve and Cv (flow capacity) in the laminar flow regime.

Impact on Fountain Beverages:

- Drink Quality & Brand Integrity: Taste Impact due to incorrect ratio & drink temperature leading to dissatisfied customer
- Increased service calls for valve adjustment ($150/call/store)

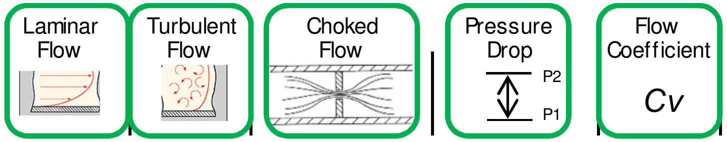




Impact on Frozen Beverages:

- Drink Quality & Brand Integrity: Freezing point shift alters ice content, drink temperature & impacts drink presentation (runny, hard to drink from straw, voids/gas pockets) leading to a dissatisfied customer
- Increased energy consumption (10% or higher)
- Increased refrigeration system cycling (25% or higher) = 1 to 3 year reduction in system reliability/life

1% decrease in beverage sales can impact a large retailer over $5M/year.



Power Plant Lesson

Customer Challenge:

Customer selected new competitor based on *lower price* and upon plant startup, customer experienced:

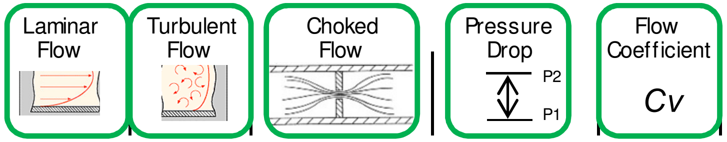
- Valves *sticking* and not opening upon demand to protect turbine
- *Jammed* plug in seat from over-pressurization of the actuator and *slamming* the plug into seat
- Competitor attempted numerous costly fixes during the *4.5 years* of operation of the plant and lost revenues in *excess of $10M*

CCI Delivered Customer Value:

- Eliminated magnetite issue
- Eliminated sticking, jamming, and slamming issues
- Improved plant availability resulting in over *$2.2M per year in revenues*

Lessons Learned for Plant Owner:

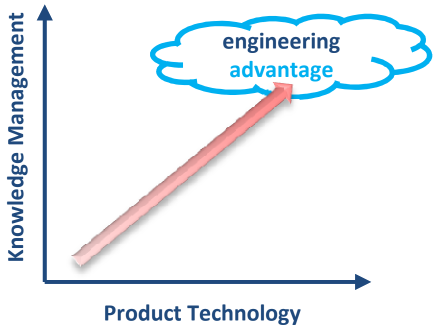
- Modest installed cost savings overshadowed by operational losses
- Accepting unproven technology comes with great risk

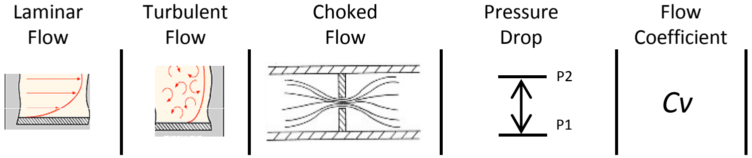


Common Fluid Technologies Summary

Engineering Advantage

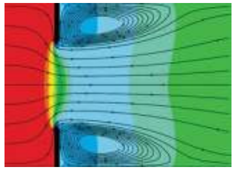
- Design principles
- Design optimisation tools
- Benefits of optimised design
- Consequences of sub-optimal design



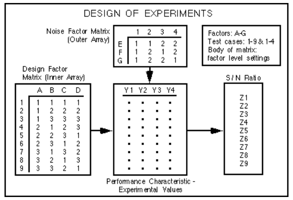


Laminar Flow | Turbulent Flow | Choked Flow | Pressure Drop | Flow Coefficient

Computational



Statistical



DESIGN OF EXPERIMENTS

Noise Factor Matrix (Outer Array)

	1	2	3	4
E	1	1	2	2
F	1	2	1	2
G	1	2	2	1

Factors: A-G
Test cases: 1-9 & 1-4
Body of matrix: factor level settings

Design Factor Matrix (Inner Array)

	A	B	C	D
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3
4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

Performance Characteristic - Experimental Values

Experimental