FINISHING EDUCATION UNIVERSITY

CARLISLE FLUID TECHNOLOGIES

Knowledge is Power

The Brands You Trust

BGK™ products deliver precision-engineered curing capabilities for a full range of coatings including liquid, powder, wax, UV and adhesives.

Binks® products boast innovative spray gun and air cap design along with industry leading pumps and controls.

DeVilbiss® products include low pressure manual and automatic spray guns and related spraying accessories. *DeVilbiss* products are widely acclaimed for ergonomics and innovative spray gun design.

Hosco® products deliver smooth bore, “cavity free” stainless steel fittings and accessories designed for use in paint circulating and application finishing systems.

ms® products include powder coating systems and equipment. ms is recognized throughout the world for quality, efficiency and durability.

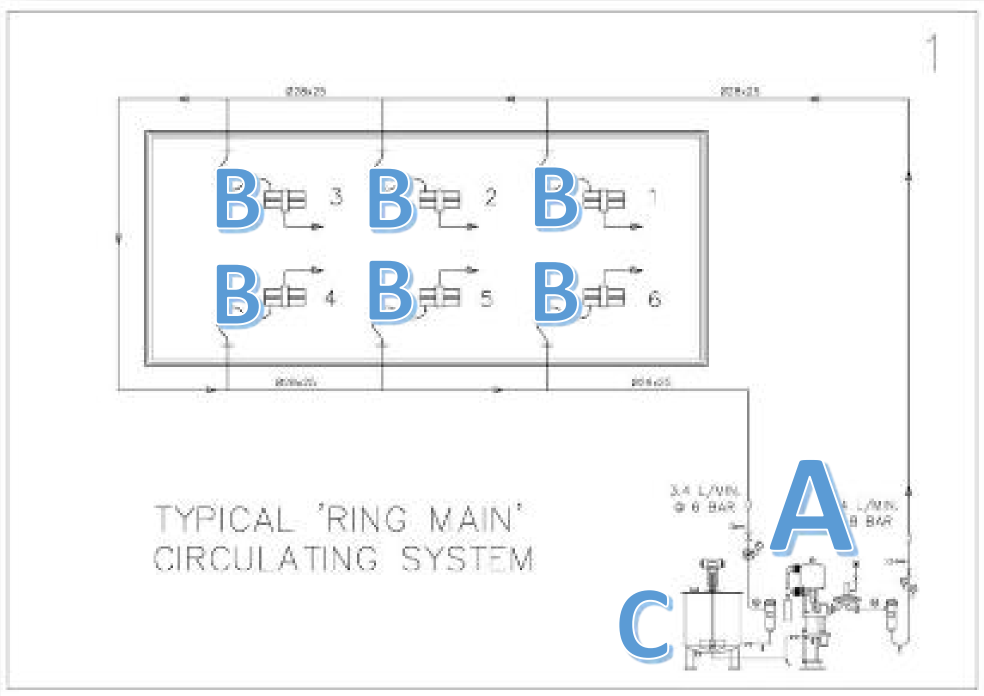
Ransburg® manual and automatic electrostatic finishing products offer spray finishing solutions to industrial and automobile manufacturing markets.

Paint Circulation Math

Understanding the math behind paint circulation systems to ensure correct material velocity

Paint Circulating System - Purpose/Function

- **MOVE** liquid material from point A to B and back to C
- Supply consistent **PRESSURE** at point B (when material is in demand)
- Supply consistent **FLOW** at point B (when material is in demand)
- Maintain **MATERIAL INTEGRITY** 24/7/365



Move

Circulation systems provide a more efficient method of moving material as opposed to manual transportation

“ IF ” :

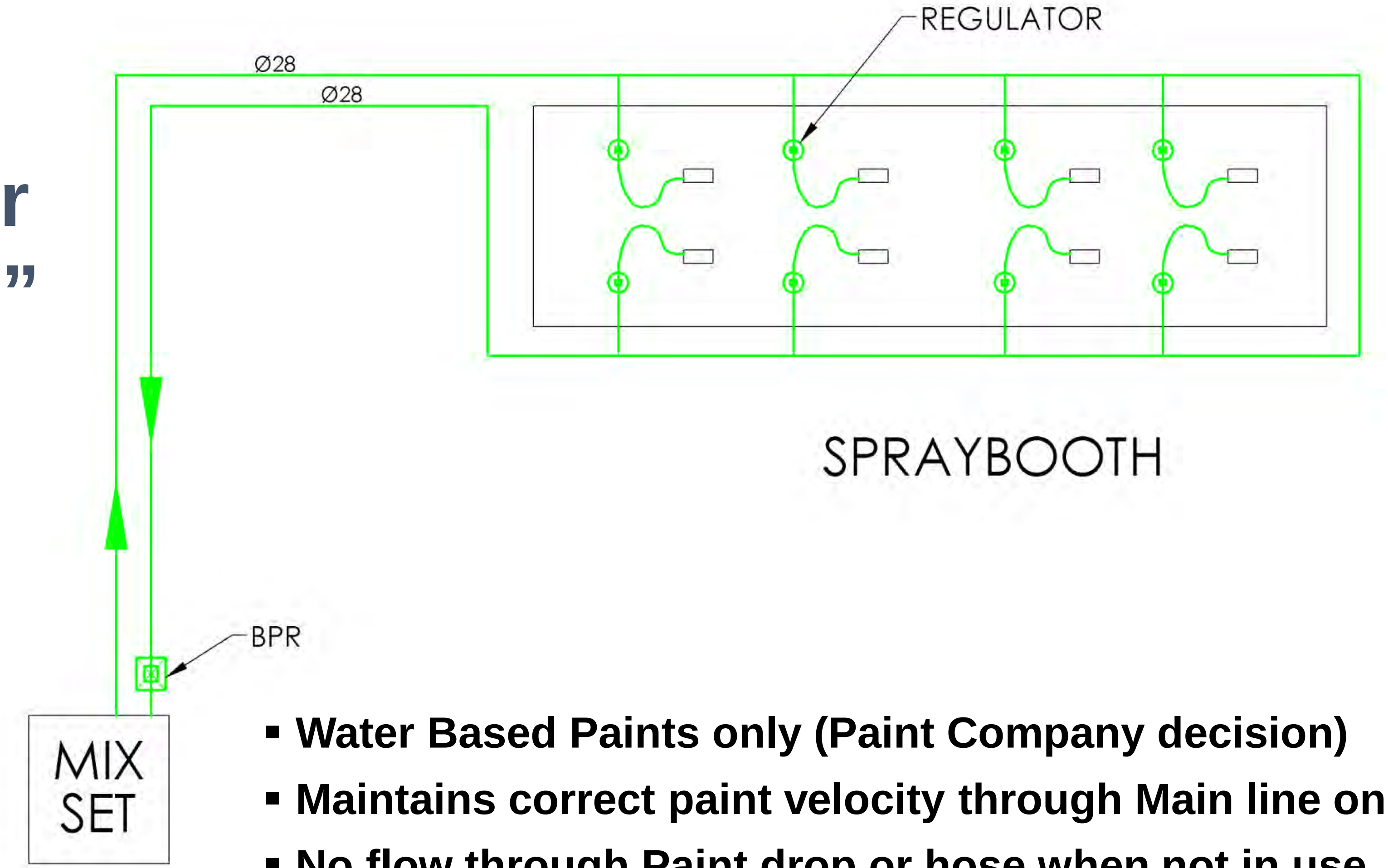
- Numerous colors are required

- Numerous application points exist

- Volume of material usage is high

Types of Paint Circulations Systems

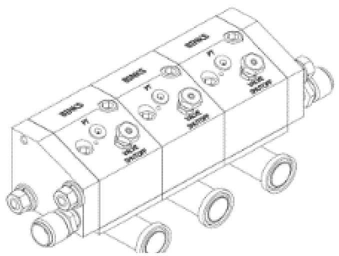
Typical "1-Pipe" or "Single Ring Main" with Dead-End Drops

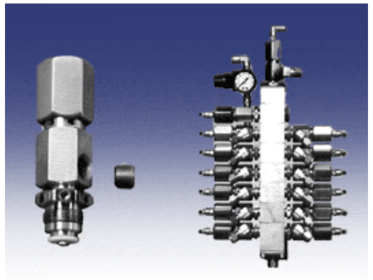


- Water Based Paints only (Paint Company decision)
- Maintains correct paint velocity through Main line only
- No flow through Paint drop or hose when not in use
- Lower Cost design

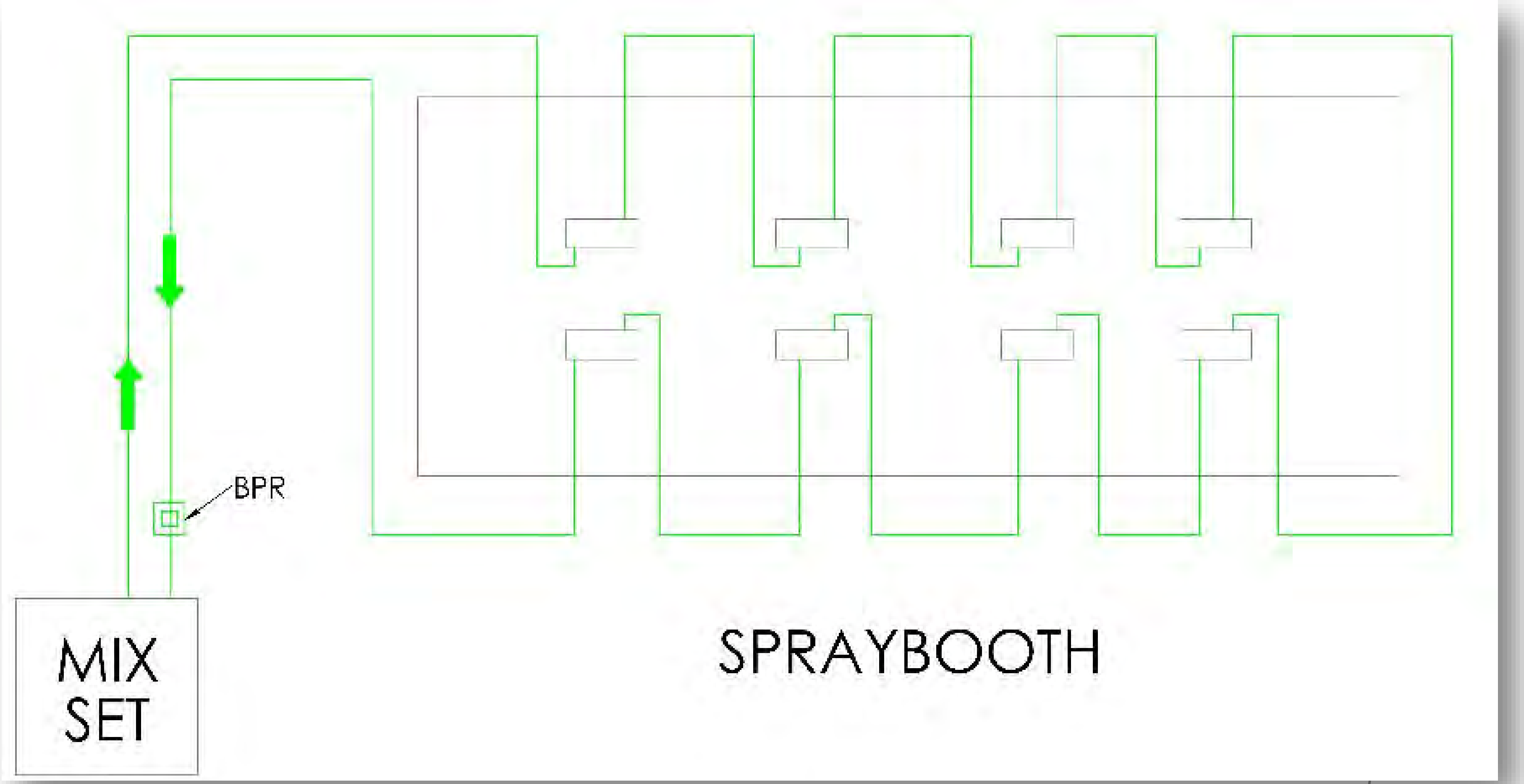
Types of Paint Circulations Systems

Typical “1-Pipe” Daisy Chained CCV



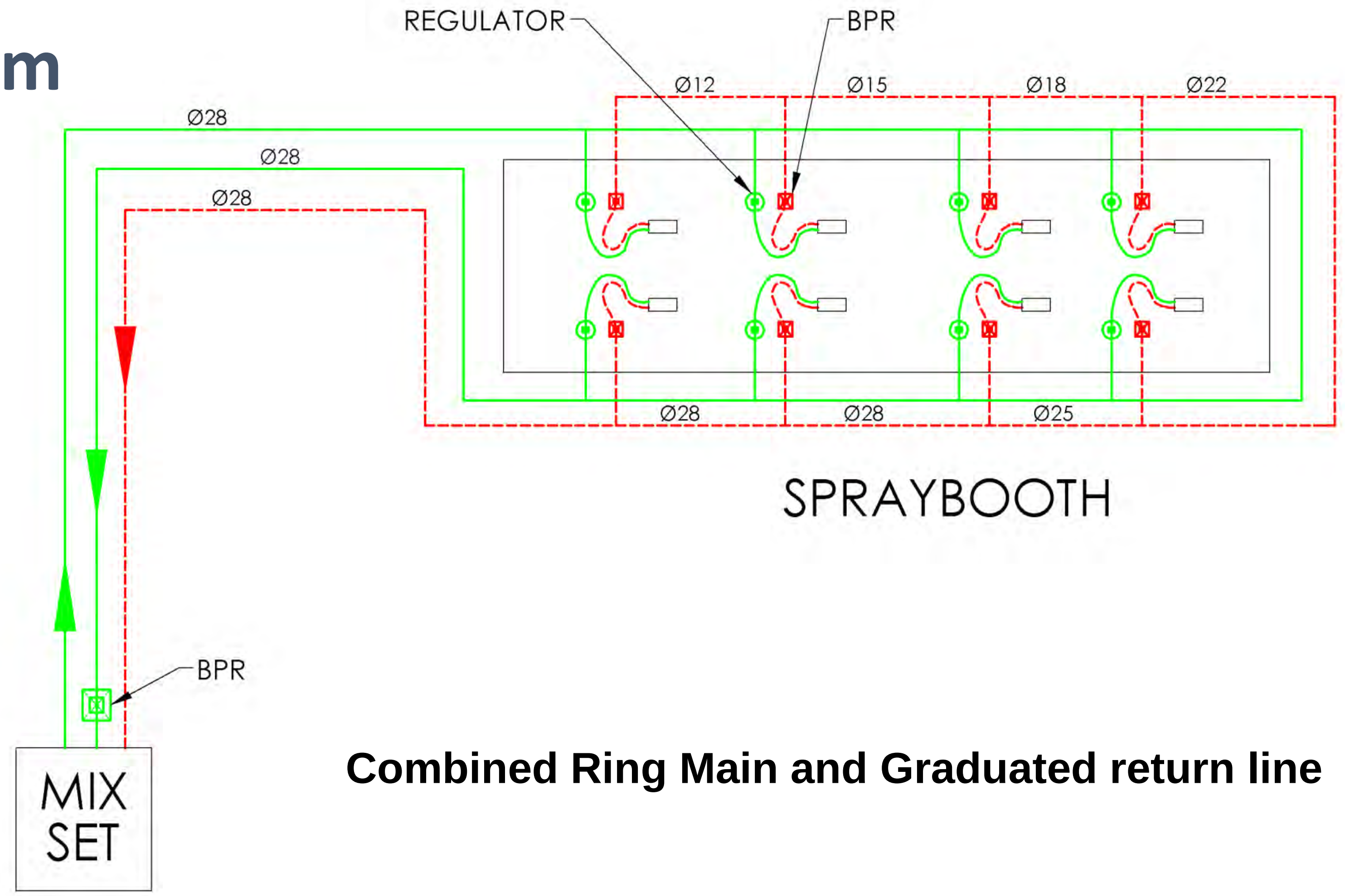


For systems using Pigging or are very small



Types of Paint Circulations Systems

Typical “3-Pipe” System



Combined Ring Main and Graduated return line

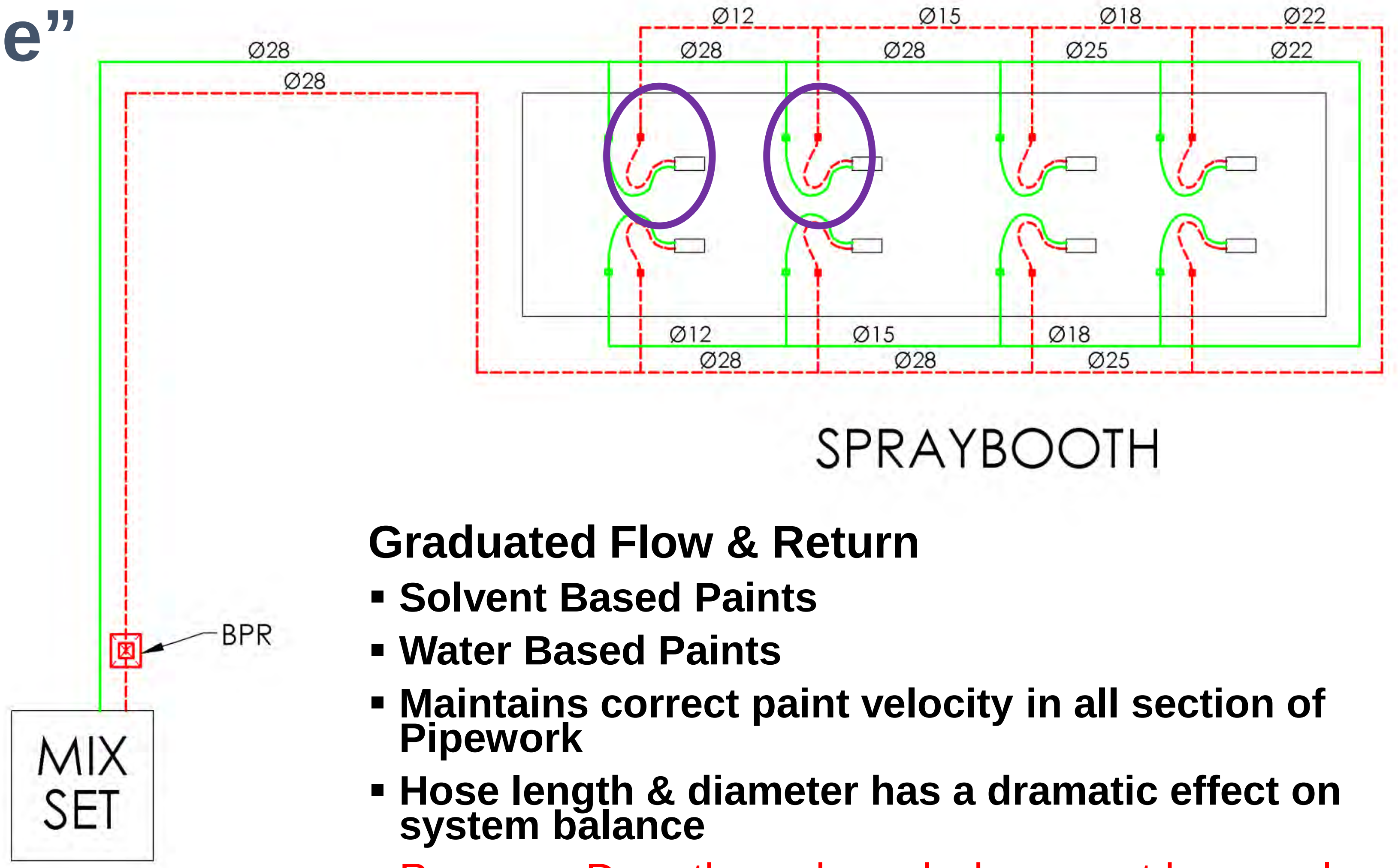
Types of Paint Circulations Systems

Typical “2-Pipe” System

This is probably by far the most common and accepted circ system method

Line diameters are regulators!

Hoses may be part of separate contract e.g. Robot Supplier



Graduated Flow & Return

- **Solvent Based Paints**
- **Water Based Paints**
- **Maintains correct paint velocity in all section of Pipework**
- **Hose length & diameter has a dramatic effect on system balance**
- Pressure Drop through each drop must be equal.

Material Integrity

This is the #1 concern for paint circulating system design. Issues include:

- Material velocity
- Settling
- Shear

Material Integrity: Velocity

CARLISLE FLUID TECHNOLOGIES

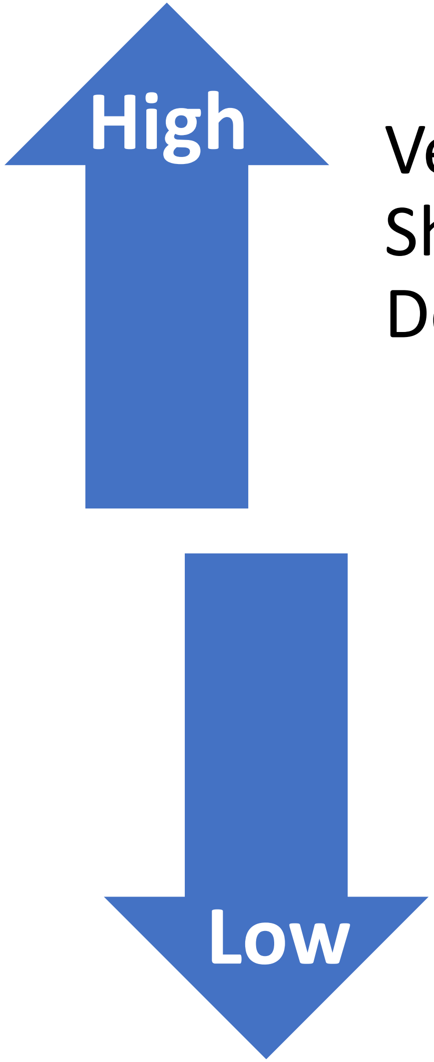
Material must maintain a certain velocity through all piping and drop hoses (think agitator).

“Velocity” is measured via ft/sec or m/sec of material flow through piping.

General rule is

- **WB** material must maintain 0.5'/sec or 0.15m/sec
- **SB** 1'/sec or 0.3m/sec.

Most users do not know their required velocity!

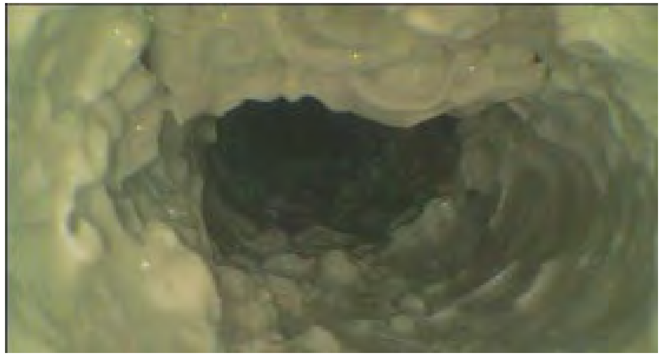


Velocity = Shear, Color Degradation

Material will settle – appearance of “dirt”

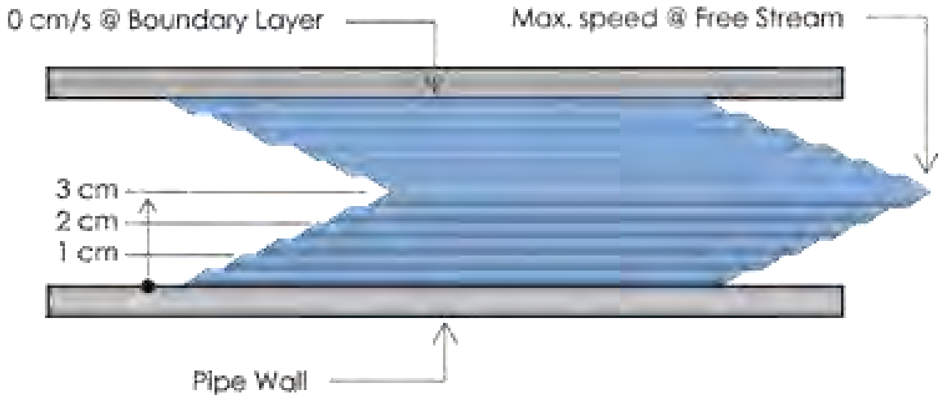
Material Integrity: Settling

- If velocity is too low, then material can settle.
- If material settles finished product can have the “appearance” of dirt when in fact it is a settling issue.
- Over time this can also lead to restricted or clogged lines (usually return lines).



Material Integrity: Shear

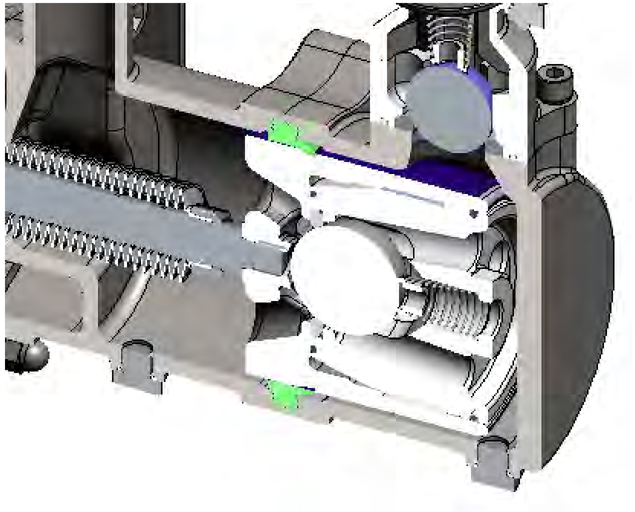
- Fluid is made up of multiple layers
- Applying force to some layers and not others (relative motion) cause layers to slide apart (Shear).
- Some fluids are more susceptible to Shear (sensitive) than others.
- Properties of the fluid is degraded.
- Some pumping technologies more likely to induce shear stress than others.
- Non-Newtonian liquids can change viscosity (thin or thicken) depending on shear rate



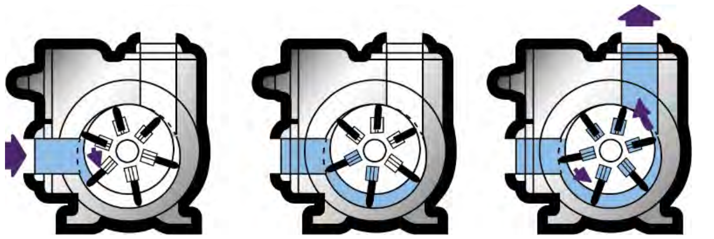
Material Integrity: Shear

Circulation Points That Attribute to Shear?

- Style of Pump.
  - Positive Displacement Piston pumps good
  - Plunger Pump medium
  - Rotary & Turbine Pumps bad

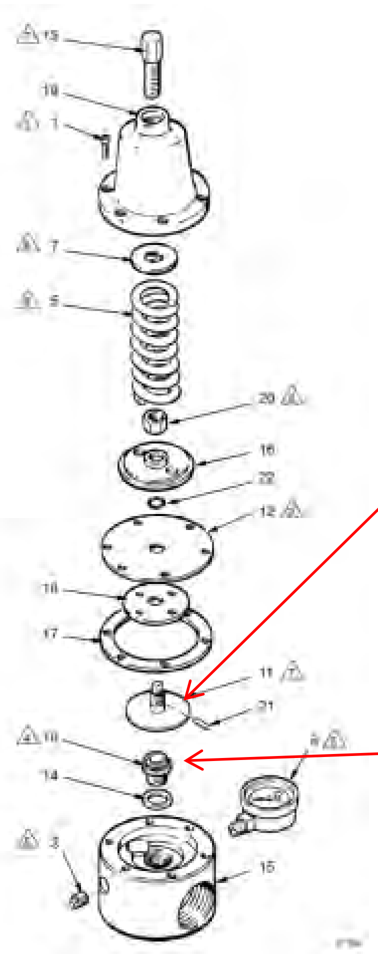


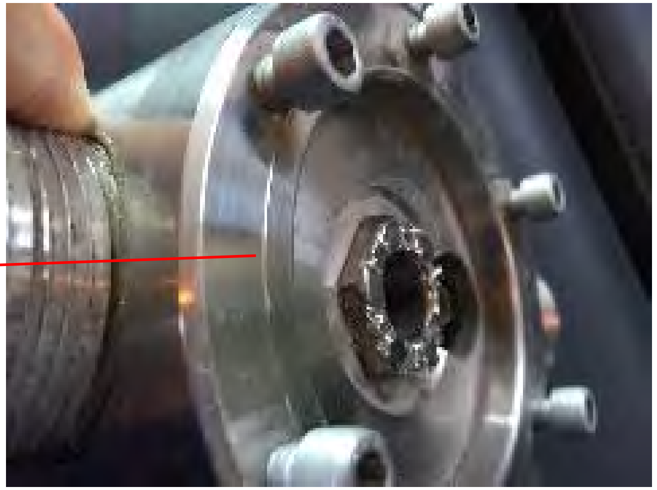
- BPR (Back Pressure Regulator)



Valve/Seat Style vs. Low Shear BPR

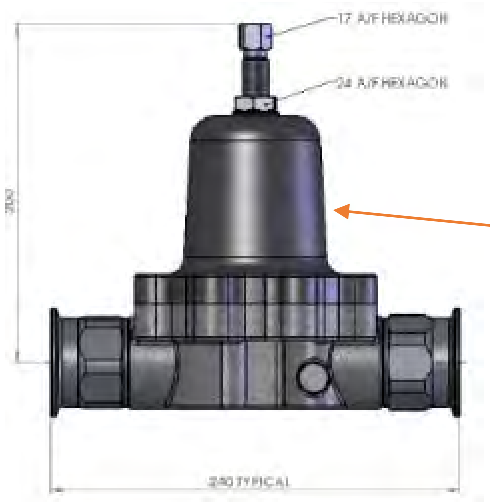
High Shear Valve Seat Style BPR

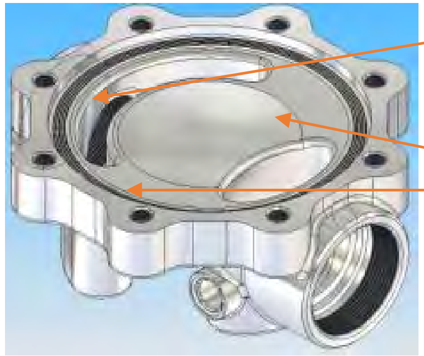




- Standard high shear valve/seat style BPRs have a small area where material flow is impinged.
- This small area increases material velocity thus increasing shear force.
- Wear on set area also reduces overall efficiency.

Valve/Seat Style vs. Low Shear BPR





- Diaphragm style BPRs have a large fluid area at the point of material impingement.
- By increasing fluid exit cavity dimension, a lower fluid velocity is also achieved.
- This larger area reduces material velocity thus lowering shear force.

Pressure

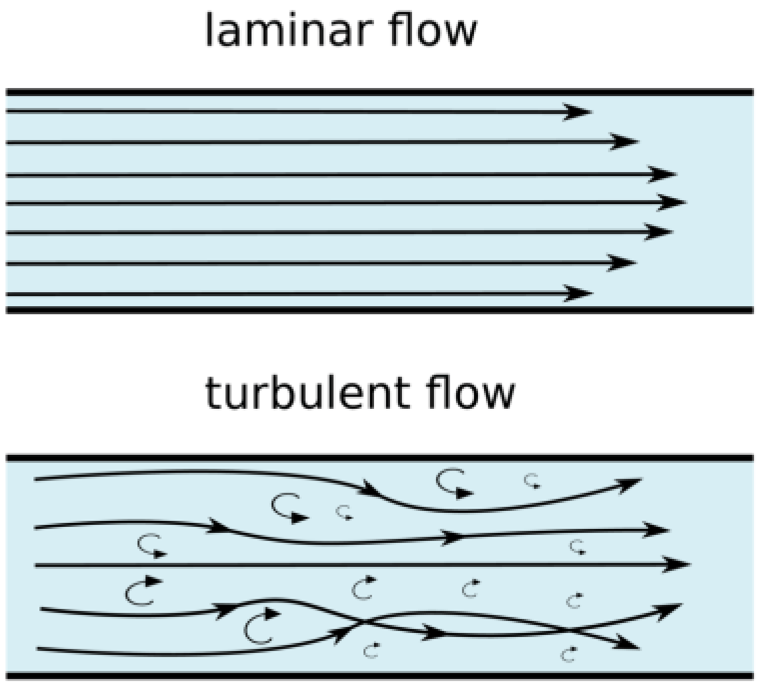
Pressure Drop: As material flows through piping there is a pressure loss caused by friction.

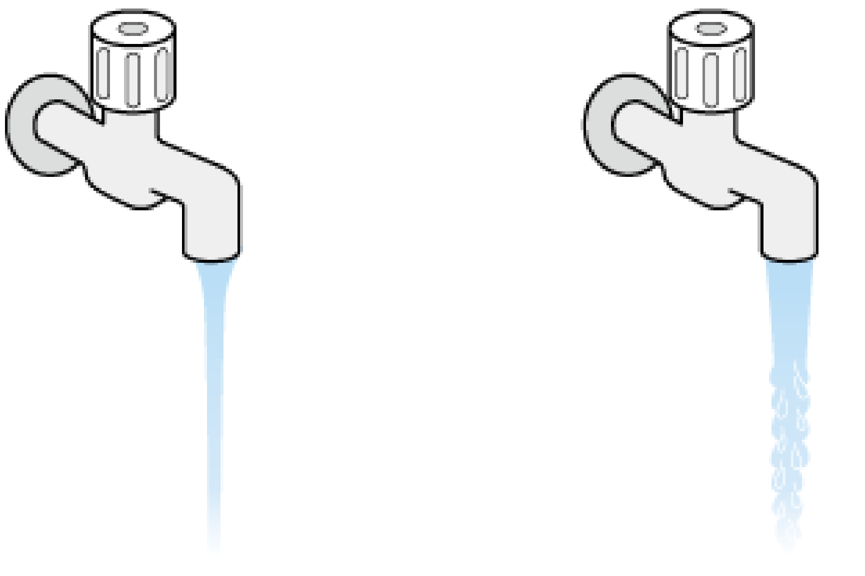
- You can provide value by calculating pressure drop and line sizes for customer.
- This could be an additional revenue stream!
- Be careful as this increase's liability and responsibility.
- Full systems are best done with modelling software, e.g PIPES, Pipe Flow, Fluidflow, etc

Laminar vs Turbulent Flow

Cold Drawn Seamless (CDS) Steel Pipe

- Extrusion process where tube is drawn at <u>room temperature</u> from a solid stainless steel billet into a hollow form
- No welded seams





(a) Laminar flow

(b) Turbulent flow

- Pressure drop calculations assume a laminar (smooth) flow through a pipe
- Flow is <u>laminar</u> **if** ***Reynolds*** number <u><2300</u>. Unpredictable >2300, <4000 Turbulent if >4000
- $Reynolds\ \# = Diameter\ of\ Pipe \times Average\ Speed\ x/min \div Kinematic\ viscosity\ x/min$

$\begin{pmatrix} ft/min \\ m/s \end{pmatrix}$ $\begin{pmatrix} ft^2/min \\ m^2/s \end{pmatrix}$

Viscosity – Poise Converter

- Material viscosity can be affected by many factors.
  - Temperature
  - Shear stress
  - Pressure
  - Time
  - Humidity / Moisture Sensitivity
- **Solvent Based Paint** viscosity is mainly affected by temperature, the static viscosity is similar to the dynamic viscosity constant.
- **Water Based Paints** are affected mainly by both temperature and shear so the static viscosity is much higher than the dynamic viscosity.
- Convert viscosity cup measurements to Poise or Centipoise for calculations

Poise	0.10	0.15	0.20	0.25	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00	1.20	1.40	1.60	1.80	2.00
Centipoise	10	15	20	25	30	40	50	60	70	80	90	100	120	140	160	180	200
Ford #3			12	15	19	25	29	33	36	41	45	50	58	66			
Ford #4	5	8	10	12	14	18	22	25	28	31	32	34	41	45	50	54	58
Zahn #1	30	34	37	41	44	52	60	68									
Zahn #2	16	17	18	19	20	22	24	27	30	34	37	41	49	58	66	74	82
Zahn #3											10	12	14	16	18	20	23
Zahn #4												10	11	13	14	16	17
DIN #4	11	21	14	16	20	23	25	26	28	30	34	38	42	45	49	52	
ISO #4		17	23	34	51	60	68	74	82	93							

Pressure Drop *Delta P* Formula

$$\Delta \text{ Pressure loss} = \frac{\text{Friction Factor x Flow/min x Pipe Length x Dynamic Viscosity}}{\text{Internal Pipe Diameter}^4 \text{ (dxdxdxd)}}$$

OR

$$\Delta P = \frac{FQVL}{ID^4}$$

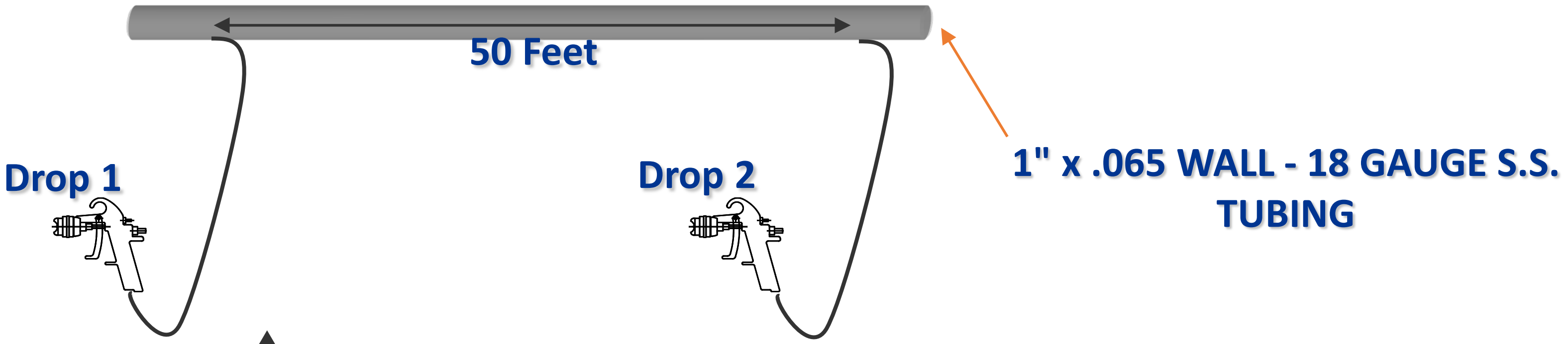
- Friction Factor based on the mass flow characteristics for typical pipe / hose used for installation
  - o Imperial – 0.0273
  - o Metric – 679
- Flow
  - o Gallons per minute
  - o Litres per minute
- Length
  - o Feet
  - o Metres
- Viscosity must be Dynamic Viscosity
  - o Poise
- Pipe Diameter
  - o Inches
  - o Millimetres

Calculating Delta P

Substitute numbers into formula

FORMULA ~ $$\Delta P = .0273 \frac{Q\ V\ L}{ID^{4}}$$

FORMULA ~ $$\Delta P = .0273 \frac{1.84 * 1 * 50}{.87x.87x.87x.87}$$



$$\Delta P = 4.384 \text{ psi}$$

Pressure Drop Quick Table

Pressure Line Drop Calculations

$$\Delta P = \frac{0.0273\ QVL}{ID^4}$$

Flow Rate (GPM)	Viscosity (poise)	Pipe/Hose Length (feet)	Pipe/Hose ID (inches)	Pressure Drop (psi)
1.84	1	50	0.87	4.4
1.84	1	**100**	0.87	**8.8**
1.84	1	100	**0.62**	**34.0**
1.1	1	100	**0.62**	**20.3**

Take Off Hoses – are often not considered in the overall design!
Diameter and Length of the hose has a dramatic effect on System Balance

Paint Flow Short Circuit will result in Higher Pump Flow and Pressure requirement

- Wasting energy
- Potentially damaging paint
- Causing pigment settlement issues
- Increasing wear and tear on the pump and system

Flow Balancing

If a paint system is not balanced correctly then the Pump needs to run at a higher pressure, the flow is also greater than needed, wasting energy and decreasing pump life.

Example for 8 Robot & 8 Hand Stations

8 x Robot hose 15m flow & return, flow needed 0.8L, hose Ø6

8 x Manual hose 6m flow & return, flow needed 0.6L, hose Ø6

Description	Flow Rate *L/min*	Viscosity *Poise*	Pipe Length *Metres*	Pipe Diameter *mm*	Pressure Drop *bar*	Flow Speed *M/Sec*
Hand Station	0.60	1.00	12.00	6.00	3.77	0.352
Robot Station	0.80	1.00	30.00	6.00	12.57	0.470
Hand Station Flow due to increased Pump Pressure	2.00	1.00	12.00	6.00	12.57	1.174
Robot Station Flow if Pump Pressure is not increased	0.24	1.00	30.00	6.00	3.77	0.141

The Higher Pump Pressure needed to achieve the desired flow rate of 0.8L/min at the Robot will increase the flow at the manual station to 2L/min. (2L x 8) – (0.6L x 8) = 11.2 L extra paint flow rate, plus increase in pump pressure.

If the Pump Pressure is set to achieve the manual station flow rate then the robot station will have reduced flow rate of 0.24L/min.

Flow Balancing

Comment – to correct system imbalance and maintain required flow rate

- Change Robot Hose to Ø8

Description	Flow Rate *L/min*	Viscosity *Poise*	Pipe Length *Metres*	Pipe Diameter *mm*	Pressure Drop *bar*	Flow Speed *M/Sec*	Remarks
Hand Station	0.60	1.00	12.00	6.00	3.77	0.352	Pressure drop is now virtually the same so Flow Balance is achieved
Robot Station	0.80	1.00	30.00	8.00	3.98	0.264	

The pressure drop through the robot hoses has now reduced. Both manual and robot hoses have virtually the same pressure drop. **This example shows that the hoses connected to the paint take offs have a major impact on system balance.**

This can be a problem when different companies are responsible for the supply of Circulating System and Painting Robots.

Comments - Even when the main line and droppers are sized correctly for the total flow and pressure requirements, incorrect hose selection causes:-

- Unexpected high flow and pressure demands
- Paint velocity is Too High or Too Low causing paint damage and colour match problems.

Circ System Design Review

What Do We Need To Know?

- Viscosity
- Booth and Paint Kitchen Location (dimensions)
- Required Material Velocity
- Special Material Concerns (i.e. shear sensitive)
- Max Required Flow at Applicators
- Pressure Required at Drop

Answer These Questions and We Are Good To Go!

A Better Way?

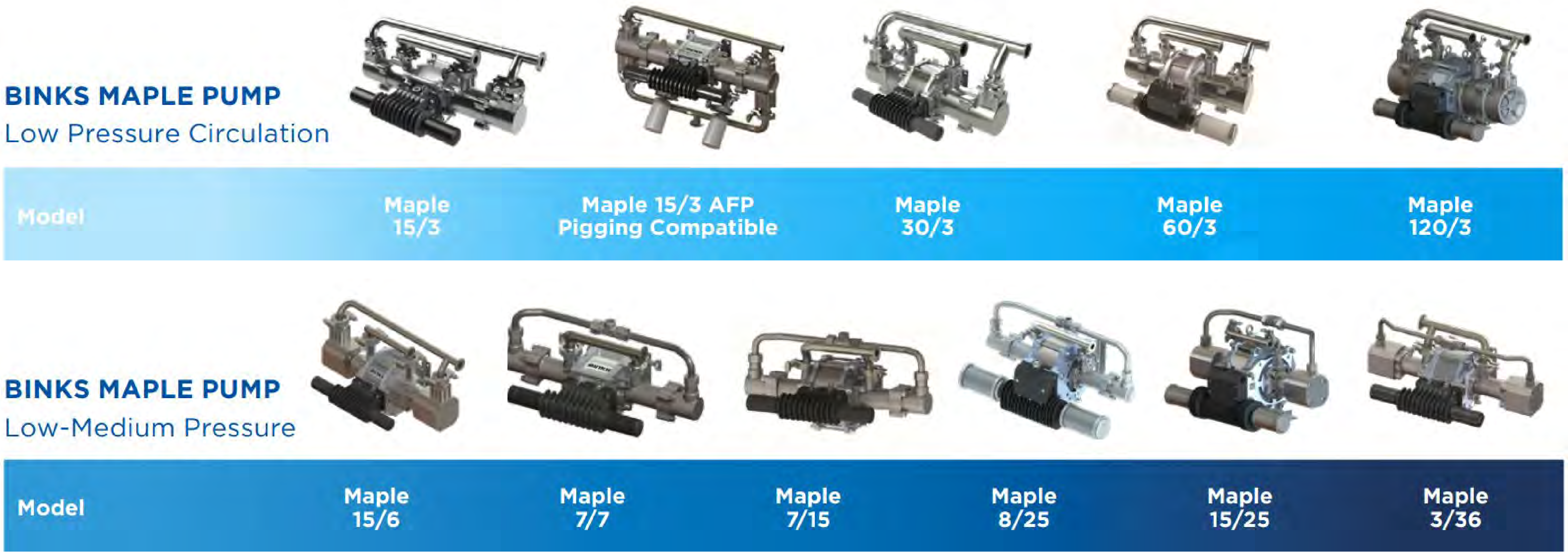
Conventional Circulating Systems - need pipework diameters sizing for maximum flow demand as this is the circulating flow for the majority of the time.

System pressure is maintained by dynamically controlling paint flow with the BPR

Smart Circulating Systems - can use smaller diameter pipework (but within pump pressure capability) as the pump is reactive to the fluctuating flow demand and for the majority of the time, paint flow is set to a lower volumetric rate, increasing energy efficiency and reducing running costs

Maple – Pneumatic Pumps

- Pneumatic pumps are always working at max system pressure for spraying
  - High energy consumption from compressed air usage
  - BPR always at set back pressure; increases paint shear effect long term



Pump Selection - Conventional System

Determine Correct Pump Size
Consider Maximum Fluid Output v Maximum Dynamic Paint Flow requirement

Design Recommendations should follow continuous operation:-
Maple Pump 24/7 Operation - 20 cycles/min continuous operation
Maple 15 i.e. 20 x 0.375L = 7.5L/min
Maple 30 i.e. 20 x 0.750L = 15L/min

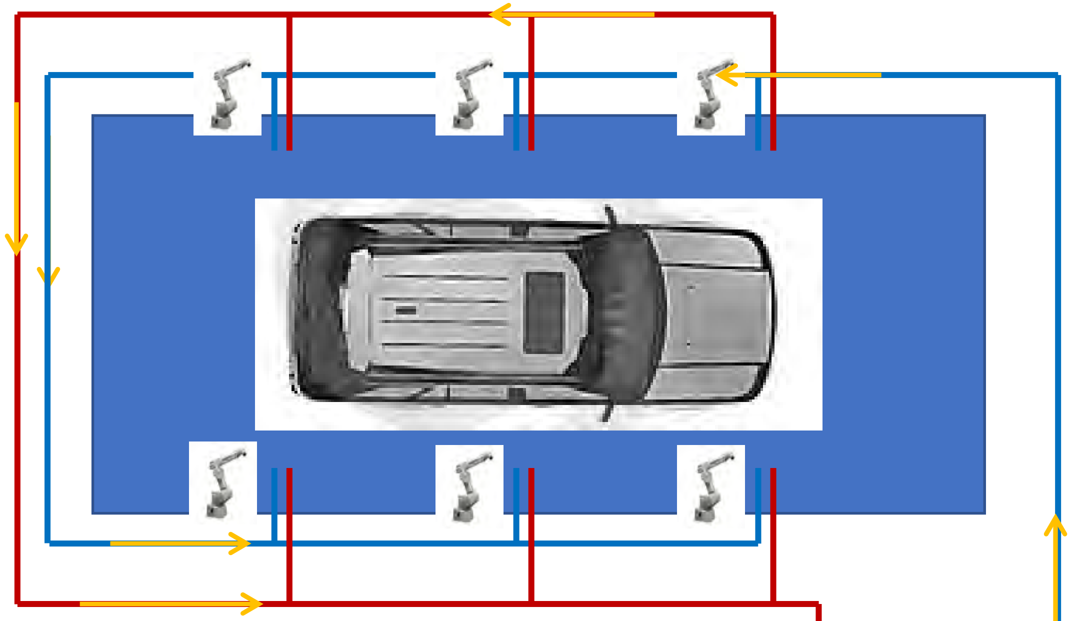
E2-15 24/7 Operation we should consider up to 75% of Pump Maximum capability
i.e. E2-15 → 15L/min x 0.75 = 11.25/min (max design)

Note: Conventional Long stroke Vertical Pumps are usually limited to 12 cycles/min due to air motor freezing issues

e.g. Maximum Flow demand:-
Basecoat System Specification - 8 x Robot 800c/min and 8 x Manual 600cc/min = **11.2 L/min**
Actual requirement based on Utilisation of 80% Robot & 50% Manual = **7.52 L/min**
Real World Requirement would be less as Robot and manual flow rate is less than specified.

Recommend Pump Maple 30 or E2-15

Pump Selection - Conventional System



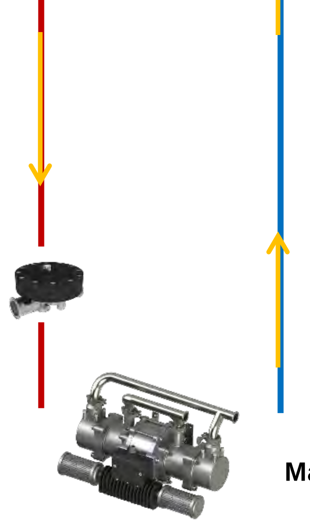
Flow 11.2L/min
@ 12 bar pressure

Set up for
Pneumatic Pump
or
Electric Pump used in
Flow mode

System is Set up to achieve:-
- Maximum Needed Dynamic Flow
- Minimum Pressure needed at last ‘take off’

Pump has Flow Set up for:-
25 mm bore main pipe

Flow 11.2L/min
Flow Velocity 0.379m/s



Back Pressure Regulator

BPR is set up to:-
Maintain 8 bar at last take off
Reactive to flow demand changes

Maple 30 Pump

29

Smart Pump Family

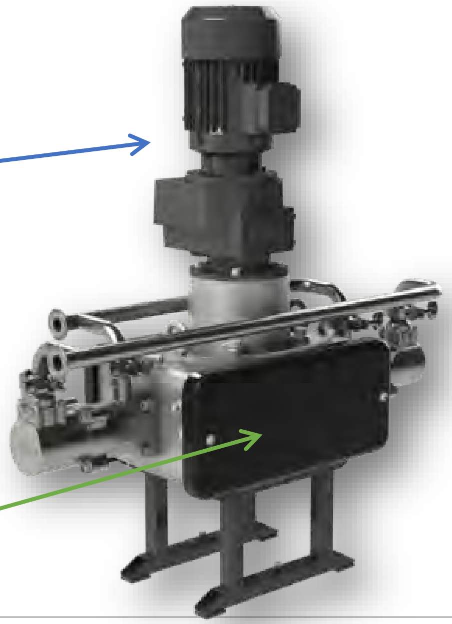
BINKS
SMART PUMP

Model	E2-7	E2-15	EV2-15	E2-15 AFP 'Easi-Flush'	E2-30	EV2-30	E2-40	E2-60	E4-60	E4-100

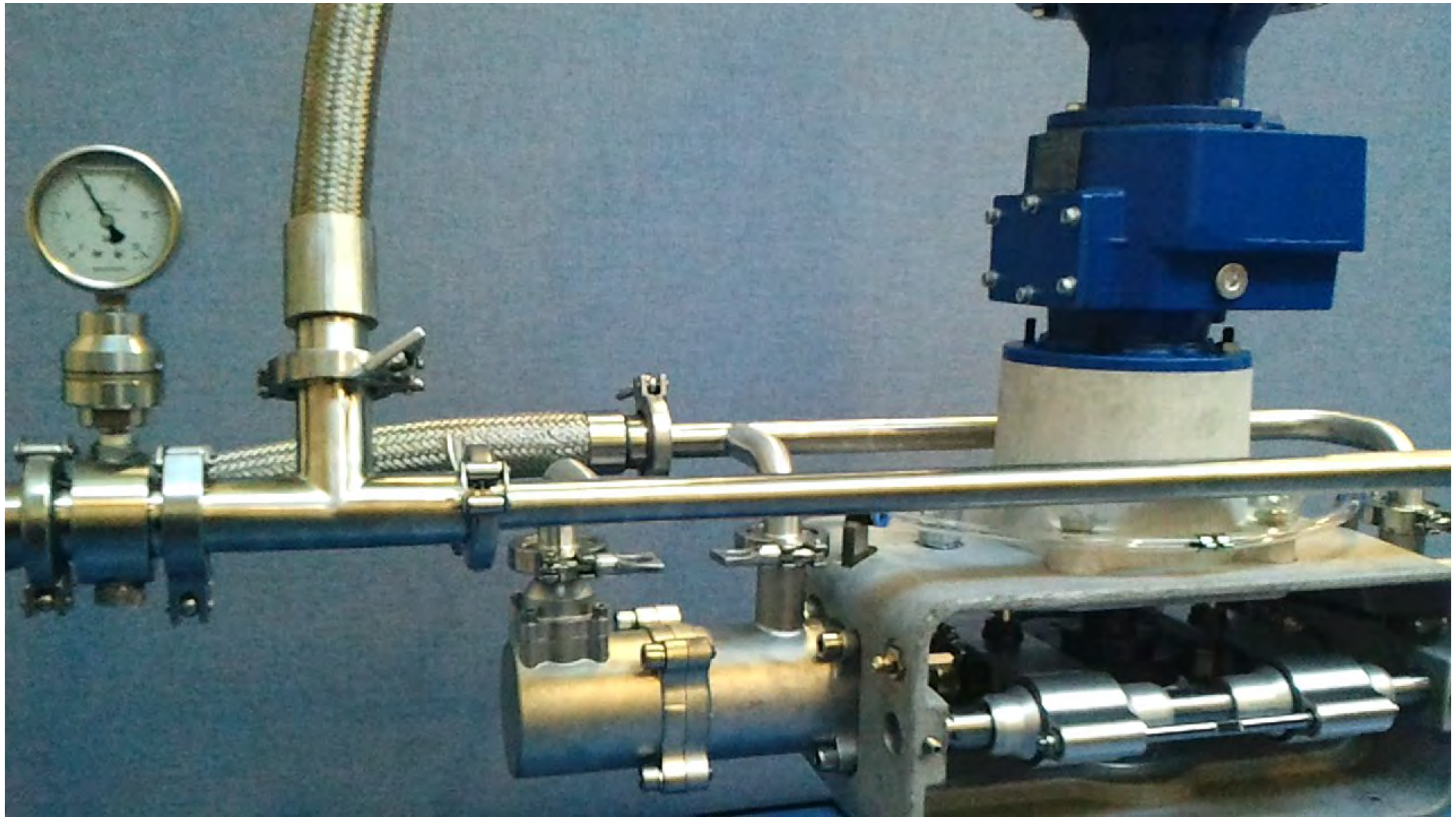
Electric Positive Displacement Pumps

Consists of:

- Ex-Proof Motor
- Standard Gearbox
- Positive Displacement Fluid Sections
- CV "constant velocity" cam drive area



Smart Pump CV Cam Drive



Pressure Drop on Pump Change Over
NO SURGE CHAMBER

Smart Pump Process

- Smart Pump can operate in open or closed loop process.
- Open loop is Flow Control.
- Closed loop is pressure control.
- Smart Pump controls can switch between open and closed loop controls in real time thus can adapt to applicator requirements as production flow demands change.
- During nonproduction times Smart Pump can switch to **automated sleep mode** thus lowering energy, material wear, pump and system component wear.
- Ability to control flow rate via Hz input to motor provides more process control.
- Any brand VFD or PLC, or Binks Smart Card can be used to control Smart Pump.

Motor Speed Fluid Output Table

Motor Speed HZ	Pump Speed Cycles/min	Fluid Flow Rate Litres/min	Fluid Flow Rate US Gall/min
20	10.0	15.00	4
25	12.5	18.75	5
30	15.0	22.50	5
35	17.5	26.25	7
40	20.0	30.00	8
45	22.5	33.75	9
50	25.0	37.50	10
55	27.5	41.25	11
60	30.0	45.00	12
65	32.5	48.75	13
70	35.0	56.25	14
75	37.5	56.25	15
80	40.0	60.00	16

Pump Selection - Smart System

Determine Correct Pump Size

Consider Maximum Fluid Output v Maximum Dynamic Paint Flow requirement

Design Recommendations

In Closed Loop Smart Mode we should aim for up to 80% of Pump Maximum capability.

i.e. E2-15 → 15L/min x 0.8 = 12L/min (max design)

e.g. Maximum Flow demand:-

Basecoat System Specification - 8 x Robot 800c/min and 8 x Manual 600cc/min = **11.2 L/min**

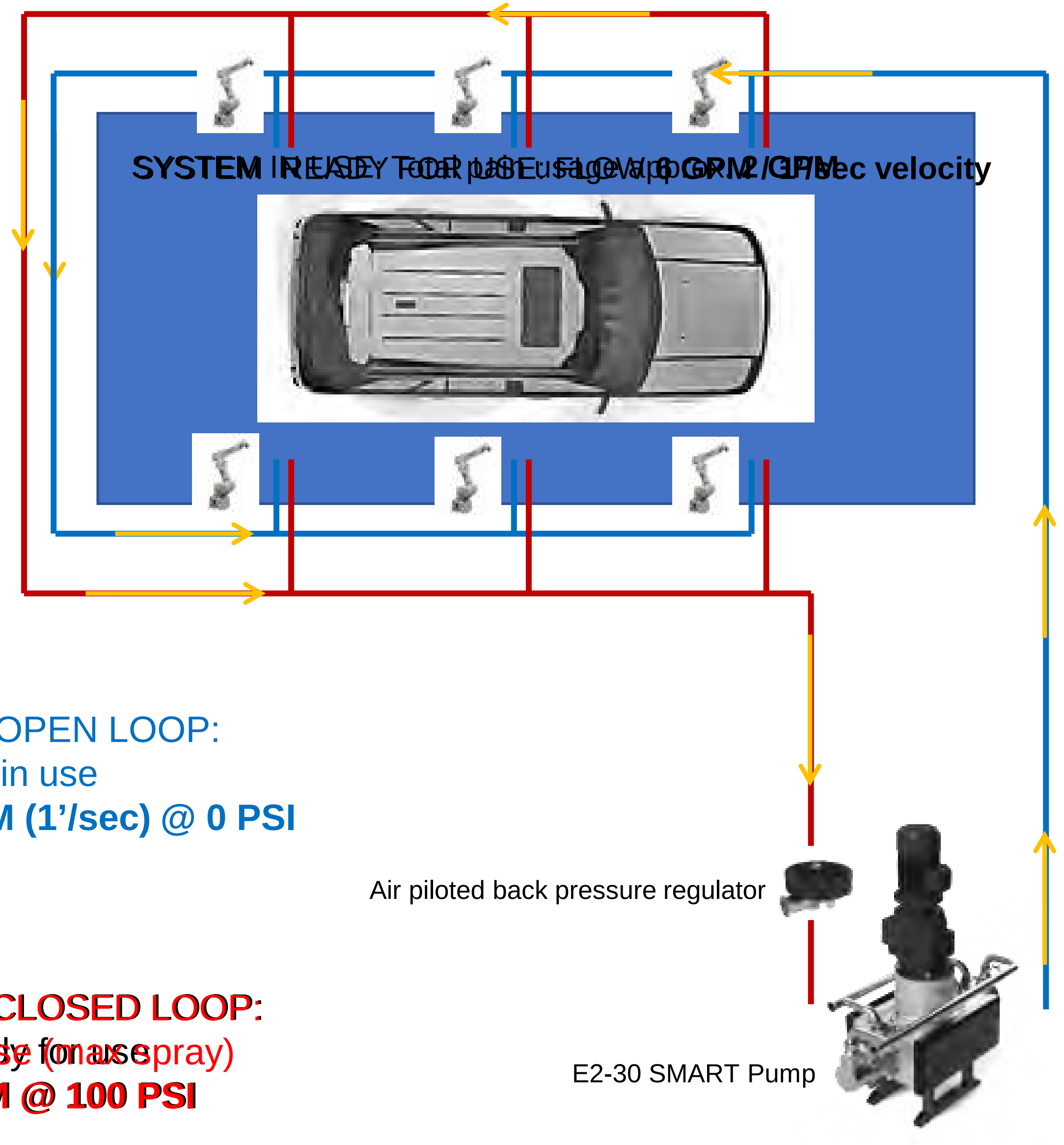
Actual requirement based on Utilisation of 80% Robot & 50% Manual = **7.52 L/min**

Real World Requirement would be less as Robot and manual flow rate is less than specified.

Recommend Pump E2-15

Smart Pump Process

“Smart Circ” Process



Return line OPEN LOOP:
System not in use
Flow 6 GPM (1’/sec) @ 0 PSI

Pump OPEN LOOP:
System not in use
Flow 6 GPM (1’/sec) @ 90 PSI

Return line CLOSED LOOP:
System ready for use
System in use (max spray)
Flow 4 GPM @ 100 PSI
Flow 6 GPM @ 100 PSI

Pump CLOSED LOOP:
System READY for use
System IN use (max spray)
GPM @ 100 PSI
Flow 6 GPM @ 190 PSI

Thank you!

If you'd like of a copy of today's presentation, email marketing@carlisleft.com