Brine Systems & Cavity Wrap Performance - Principles

Tom Mackerras
National Engineering Manager
A&G Engineering Pty Ltd, Griffith, NSW

WARNING
Theoretical
Content Ahead

Head Loss in a Pipe

- Friction loss in pipes is:

$$h = f \frac{L}{D} \frac{v^2}{2g}$$

- Where
  - h = friction loss in m head
  - f = friction factor due to pipe roughness and fluid viscosity
  - L = length of pipe (m)
  - D = pipe diameter (m)
  - v = velocity of the fluid in the pipe (m/s)
  - g = gravitational constant = 9.81m/s²

Head Loss in a Pipe

$$h = f \frac{L}{D} \frac{v^2}{2g}$$

- Head loss is :
  - Proportional to Length
  - Inversely proportional to Diameter
  - Proportional to the square of Velocity

Friction Factor

- Friction factor f

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left[\frac{k}{3.7D} + \frac{2.51\nu}{\nu D\sqrt{f}}\right]$$

Pipe roughness factor inversely proportional to diameter

Fluid viscosity factor proportional to viscosity (v)

Inversely proportional to diameter & velocity

Note that f appears twice in the equation and needs to be iterated

Example 1

- Change of Diameter - doubled
  - Velocity reduced 4 x, head reduced nearly 32 x
- Volume (velocity) - halved
  - Head reduced by nearly 4x
- Length - doubled
  - Head doubled

Volume l/hr	Volume l/s	Pipe Diameter mm	Pipe Length m	Velocity m/s	Head Loss m
90,000	25	100	50	3.2	3.7
90,000	25	200	50	0.8	0.13
45,000	12.5	100	50	1.6	1.1
90,000	25	100	100	3.2	7.5

PVC pipe

Example 2

Constant head (pressure, 3.7m), but different:

- Pipe lengths - doubled
  - Volume reduced by 1/3 ($P \approx v^2$)
- Diameters - doubled
  - Volume increased 6 x ($P \approx v^2$)

Volume l/hr	Volume l/s	Pipe Diameter mm	Pipe Length m	Velocity m/s	Head Loss m
90,000	25	100	50	3.2	3.7
61,550	17	100	100	2.2	3.7
564,450	156	200	50	5.0	3.7

PVC pipe

Example 3

Fluids of different viscosity:

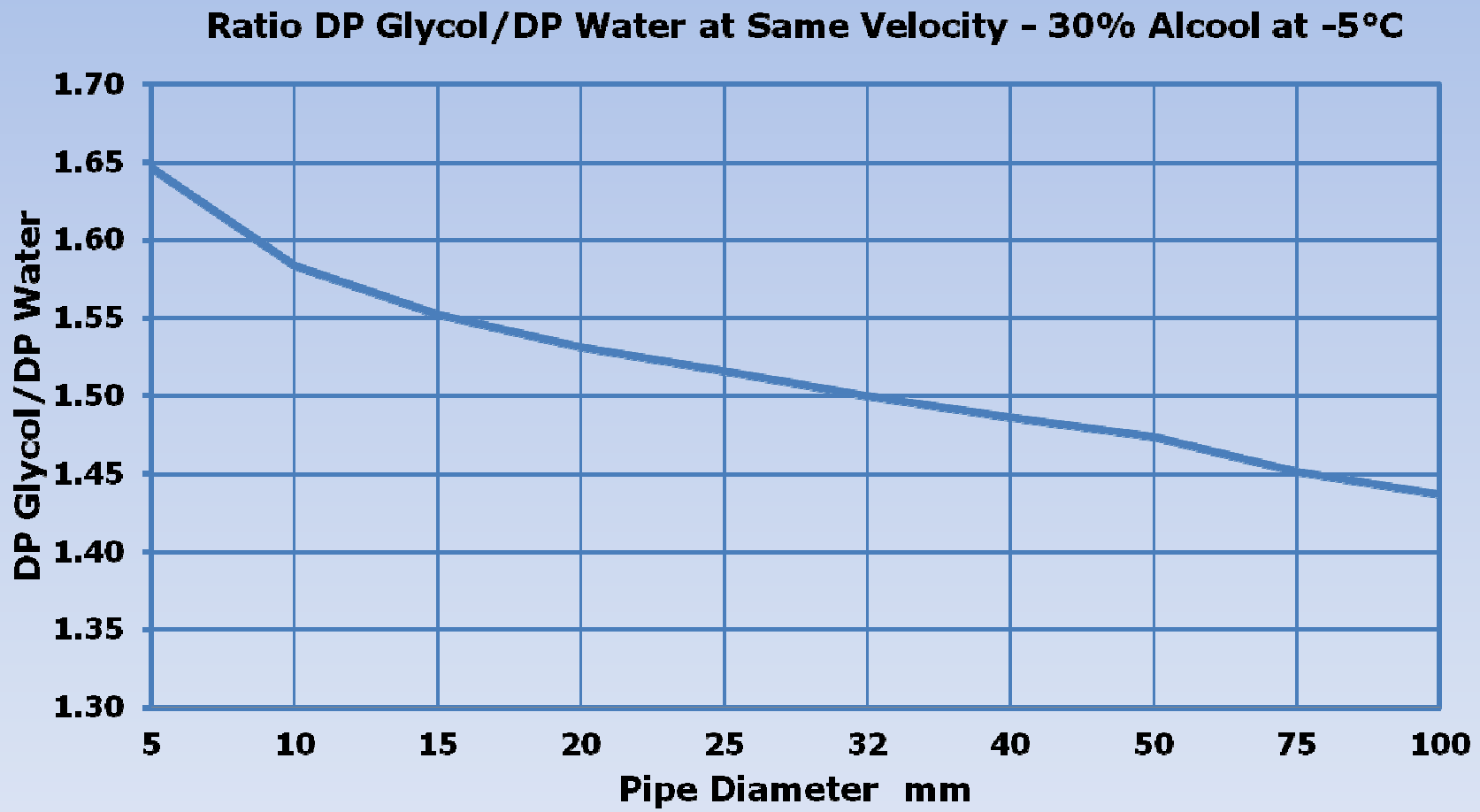
- Water at 15° C; viscosity = 1 cSt
- 30% Alcool LF solution at -5℃; viscosity = 6.2 cSt

Volume l/hr	Medium	Pipe Diameter mm	Pipe Length m	Velocity m/s	Head Loss m
90,000	Water	100	50	3.2	3.7
90,000	30% Glycol	100	50	3.2	5.4

50% increase in Head

PVC pipe

Change With Pipe Diameter



Types of Cavity Wrap

- **High Pressure Janda Wrap**
  - Automatically spot-welded to the strake sheet
  - Puffed under hydrostatic pressure to achieve a minimum cavity depth of 2.5mm
  - Maximum Pressure: 550kPa

Width (mm)	Flow at 1m/s velocity	Rated Pressure
1100mm	5500 l/hr	550kPa (80PSI)
900mm	4500 l/hr	550kPa (80PSI)
600mm	3000 l/hr	550kPa (80PSI)

Types of Cavity Wrap

A&G HIGH PRESSURE CAVITY WRAP – 550kPa

Types of Cavity Wrap

- **A&G Weld-On Wraps**
  - Pre-punched 1.6mm thick sheet
  - Cavity depth of 6mm
  - Can be fitted to the tank in varying widths and orientations
  - Available in two pressure ratings
    - Low Pressure
    - Medium Pressure

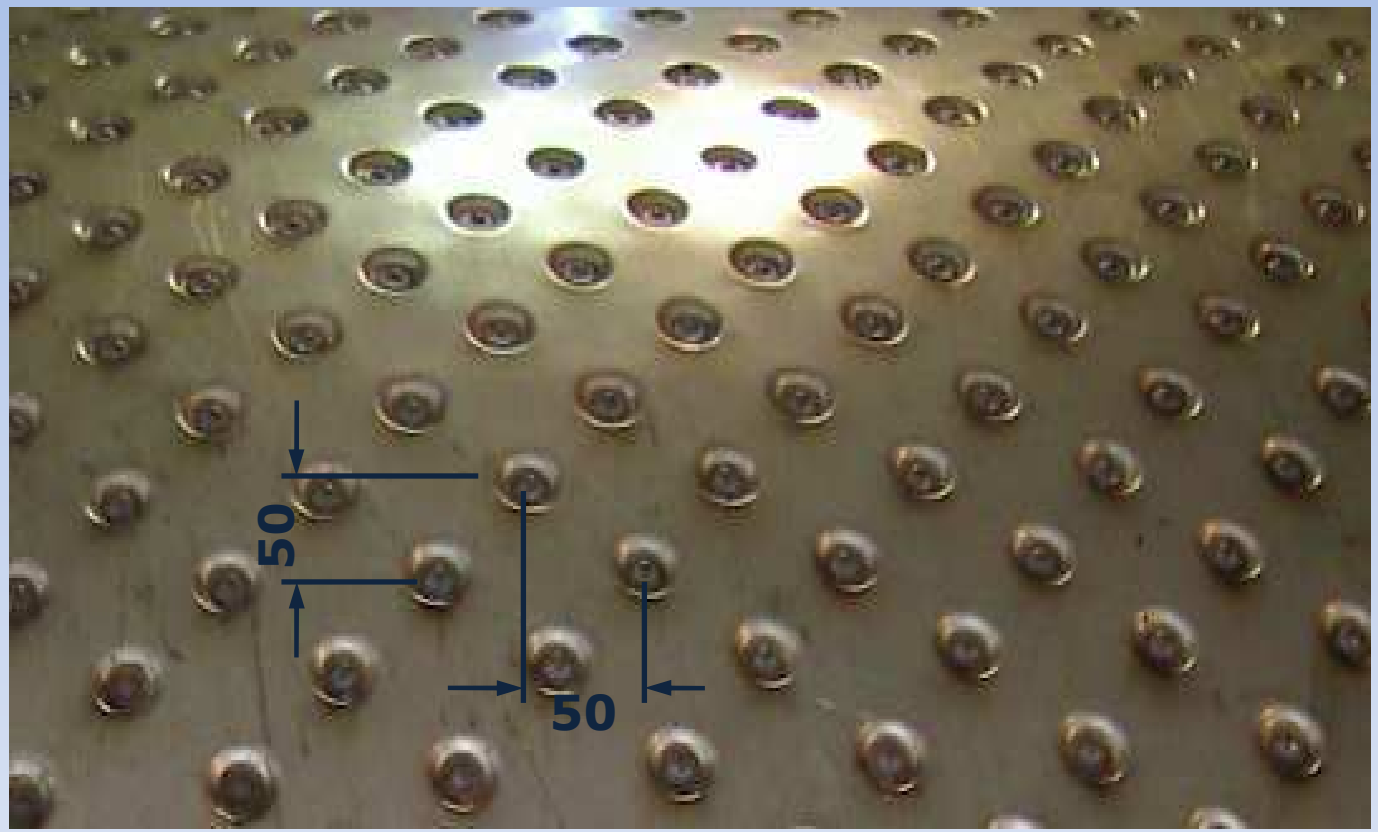
Types of Cavity Wrap

- **Medium Pressure Wrap**

Rated Pressure	Test Pressure	Dimple Spacing
300kPa	450kPa	50mm
43PSI	65PSI	

Width	Flow at 0.5m/s	Flow at 1m/s
1200mm	6,500 litres/hr	13,000 litres/hr
900mm	4,900 litres/hr	9,700 litres/hr
600mm	3,250 litres/hr	6,500 litres/hr

Types of Cavity Wrap



MEDIUM PRESSURE CAVITY WRAP – 300kPa

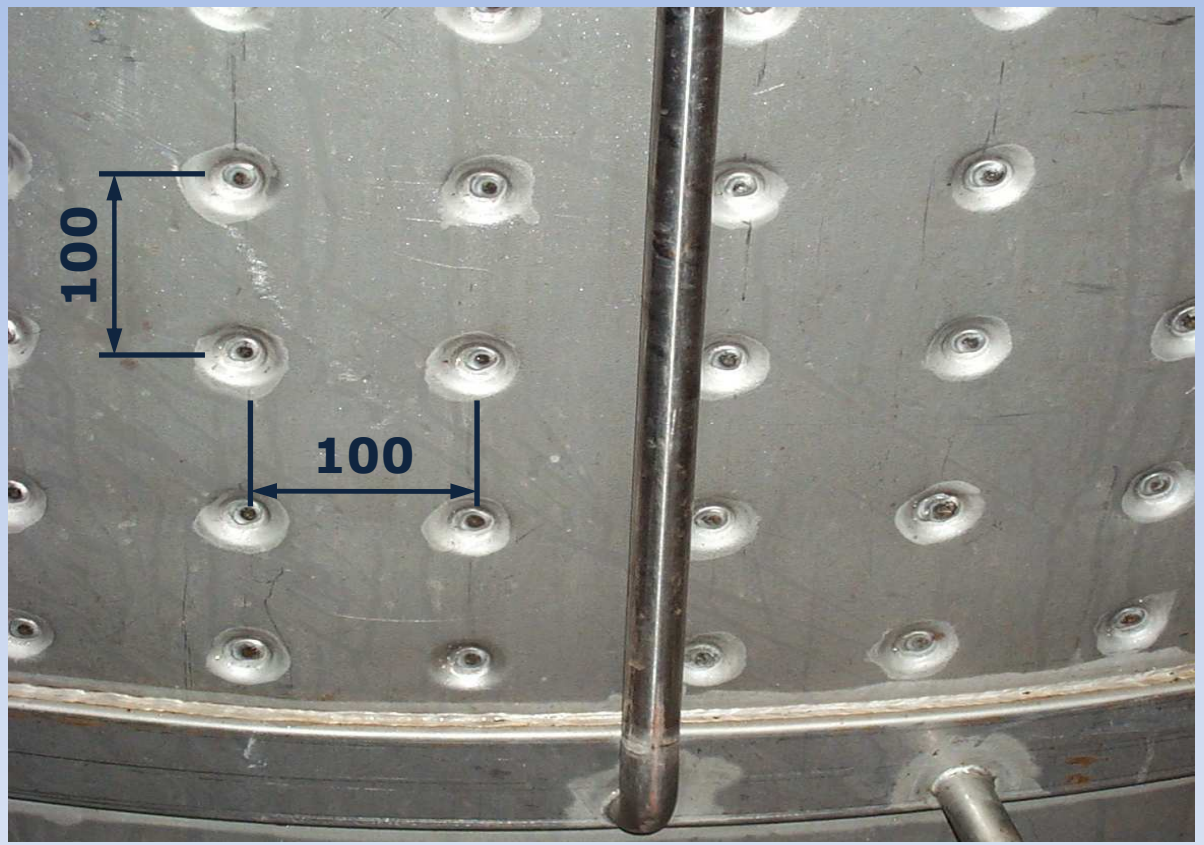
Types of Cavity Wrap

- **Low Pressure Wrap**

Rated Pressure	Test Pressure	Dimple Spacing
140kPa	210kPa	1000mm
20PSI	30PSI	

Width	Flow at 0.5m/s	Flow at 1m/s
1200mm	6,500 litres/hr	13,000 litres/hr
900mm	4,900 litres/hr	9,700 litres/hr
600mm	3,250 litres/hr	6,500 litres/hr

Types of Cavity Wrap



LOW PRESSURE CAVITY WRAP – 140kPa

Flow Testing Cavity Wraps

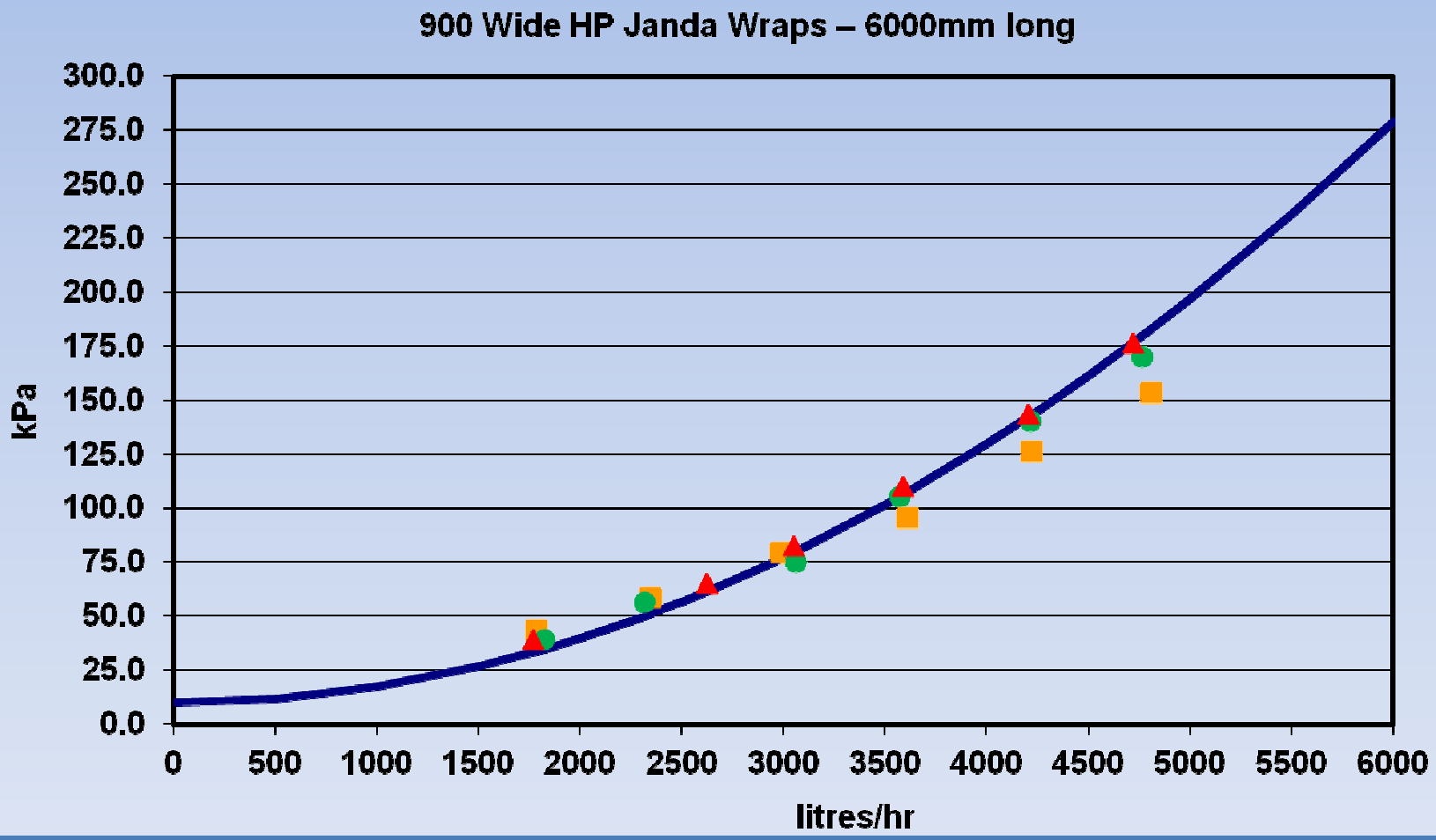
INLET TO CAVITY

FLOW METER L/MIN

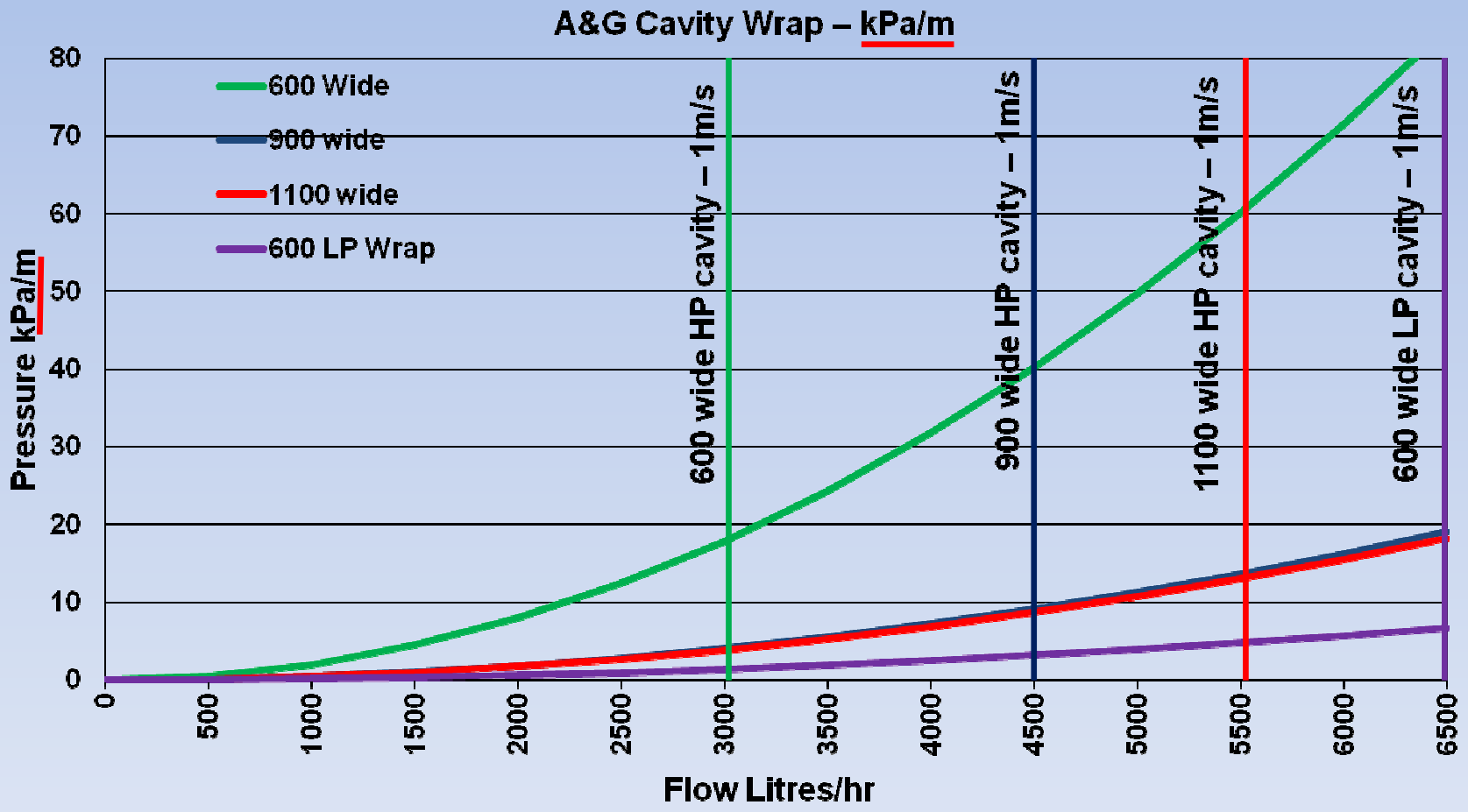
RECIRCULATING PUMP SET

RETURN TO TANK

Flow Testing Cavity Wraps



Flow Charts


A&G Cavity Wrap – kPa/m
600 Wide
900 wide
1100 wide
600 LP Wrap
600 wide HP cavity – 1m/s
900 wide HP cavity – 1m/s
1100 wide HP cavity – 1m/s
600 wide LP cavity – 1m/s
Pressure kPa/m
Flow Litres/hr
0
10
20
30
40
50
60
70
80
0
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500

Notes to Performance Curves

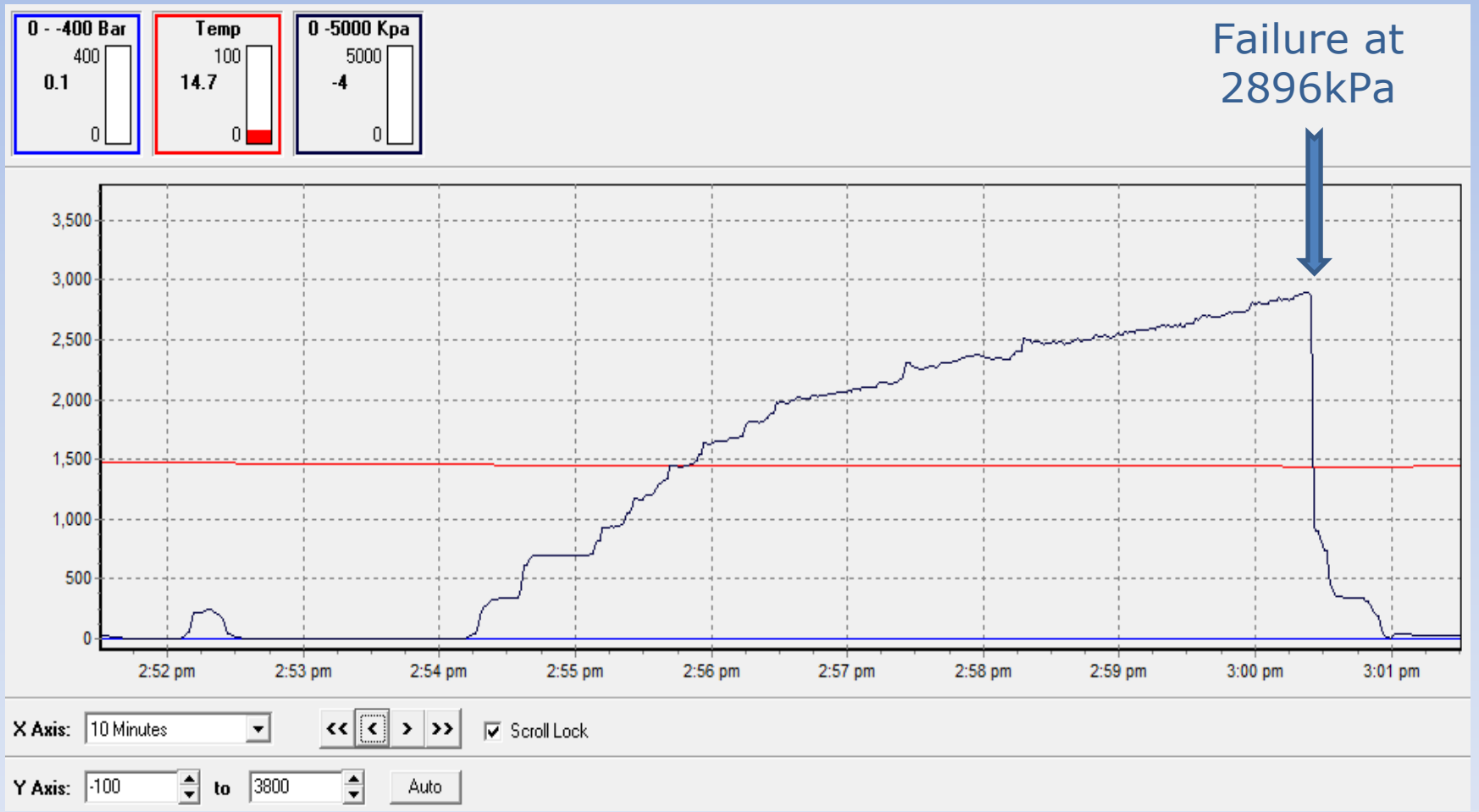
- Test medium is water
  - SG = 1.0
  - Kinematic viscosity =1 cSt
- Do not include the head difference between the inlet & outlet positions
- Only very limited data available for MP & LP wrap to date.

Pressure Rating Cavity Wraps

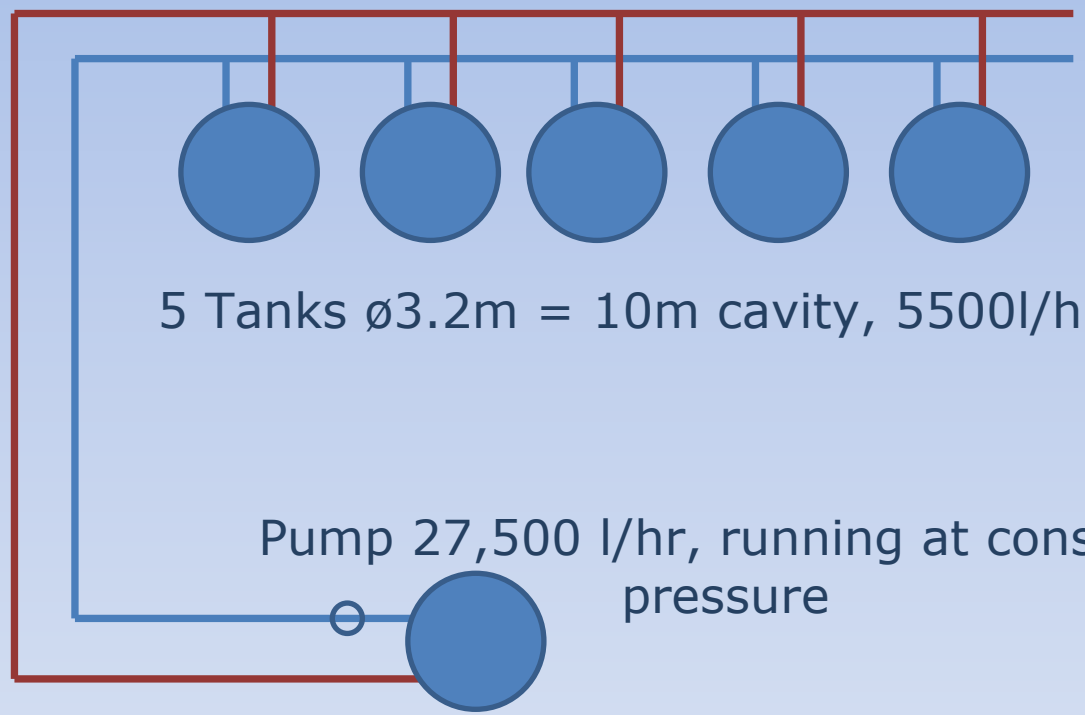
- Test plate is produced and sent to NATA certified laboratory
- Plate is hydrostatically tested until it bursts
- Pressure recorded at failure
- Capacity is determined in accordance with formula in AS1210 – Pressure Vessels

Pressure Rating Cavity Wraps

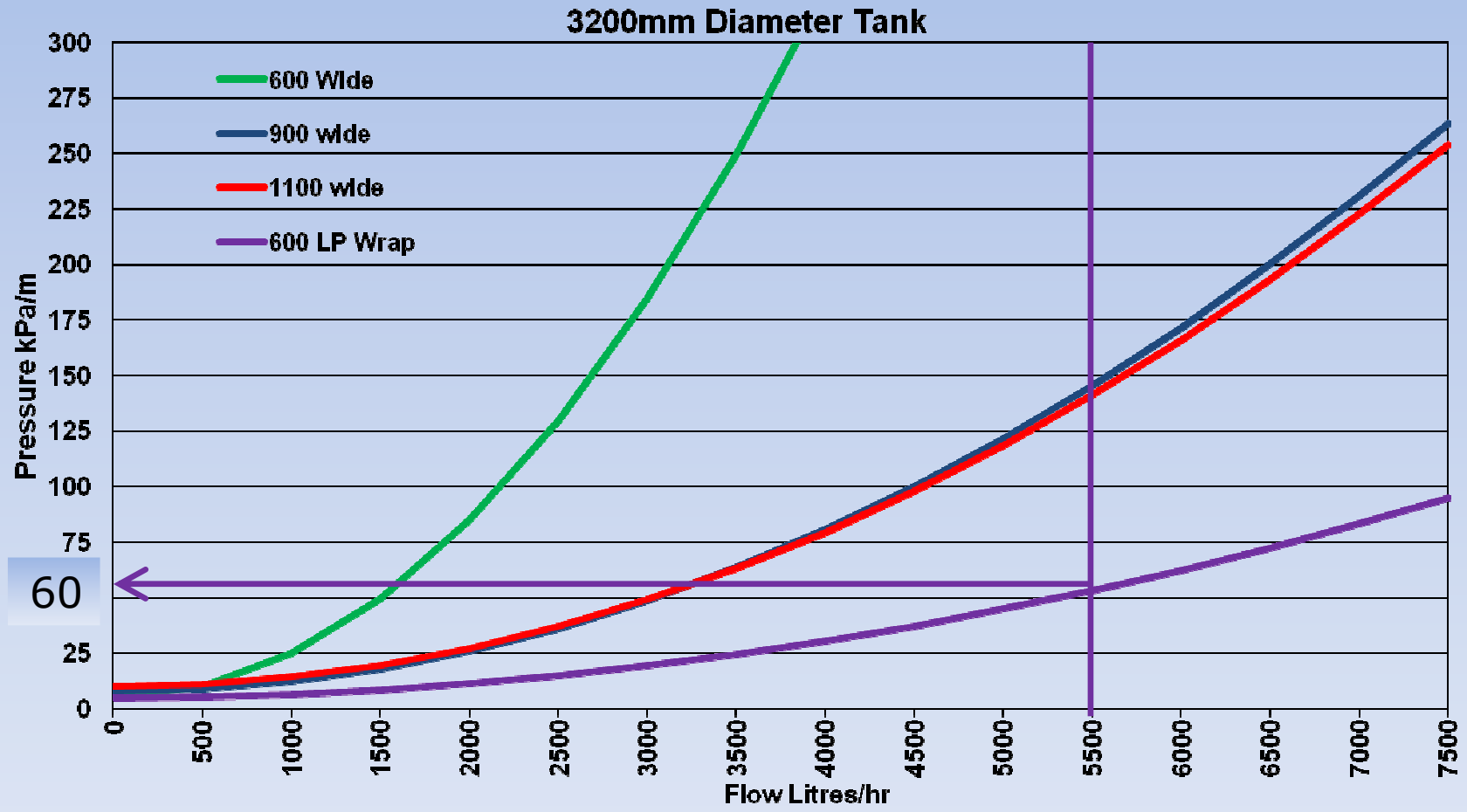
Pressure Testing Cavity Wraps



Sample System



Flow Charts for ø3200 Tank



System Head Losses

Item	Volume l/hr	Size mm	Velocity m/s	Head Loss kPa	Pressure in Pipe kPa
Delivery Line	27,500	65	2.3	100	275
Hose & valve	5,500	40	1.22	10	175
Cavity 600 LP	5,500	600	0.8	60	165
Hose	5,500	40	1.22	5	105
Return Line	27,500	65	2.3	100	100
Calculations based on water			Total	275	

- Inlet pressure exceeds rated capacity of 140kPa!
- 200kPa used just in the mains lines at full system flow
- When one cavity is operated
  - The pump will maintain the pressure by increasing the flow
  - All flow and pressure (275kPa) will go through the one wrap

Revised System Head Losses 1

Item	Volume l/hr	Size mm	Velocity m/s	Head Loss kPa	Pressure in Pipe kPa
Delivery Line	27,500	**75**	2.3	50	175
Hose & valve	5,500	40	1.22	10	125
Cavity 600 LP	5,500	600	0.8	60	115
Hose	5,500	40	1.22	5	55
Return Line	27,500	**75**	2.3	50	50
Calculations based on water			Total	175	

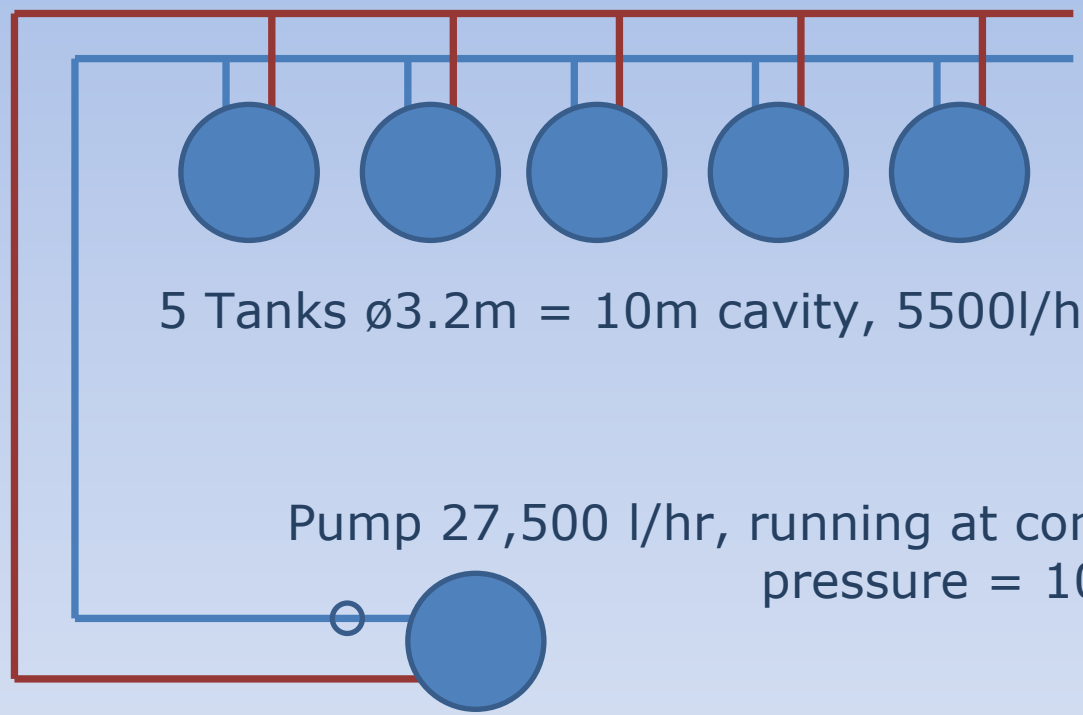
- Reduced pressure & power requirement 175kPa
- Mains loss (100kPa total) still dominates the system
- Single cavity operation still likely to exceed LP wrap rated capacity

Revised System Head Losses 2

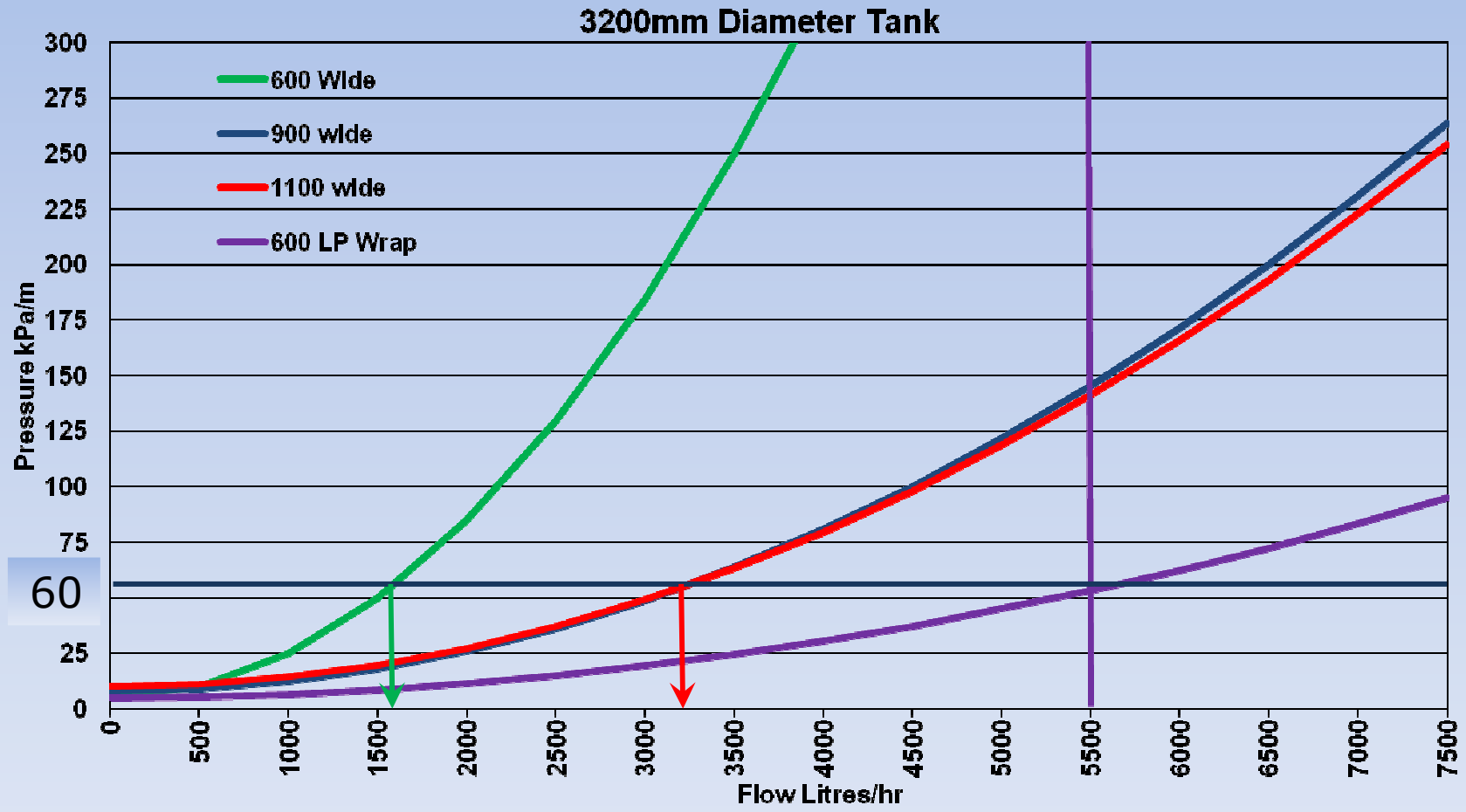
Item	Volume l/hr	Size mm	Velocity m/s	Head Loss kPa	Pressure in Pipe kPa
Delivery Line	27,500	**100**	2.3	12.5	100
Hose & valve	5,500	40	1.22	10	87.5
Cavity 600 LP	5,500	600	0.8	60	77.5
Hose	5,500	40	1.22	5	17.5
Return Line	27,500	**100**	2.3	12.5	12.5
Calculations based on water			Total	100	

- Even lower system pressure & power requirement
- Tank/cavity loss (75kPa) now dominates the system
- Total system pressure (100kPa) below LP wrap rated capacity

Revised System



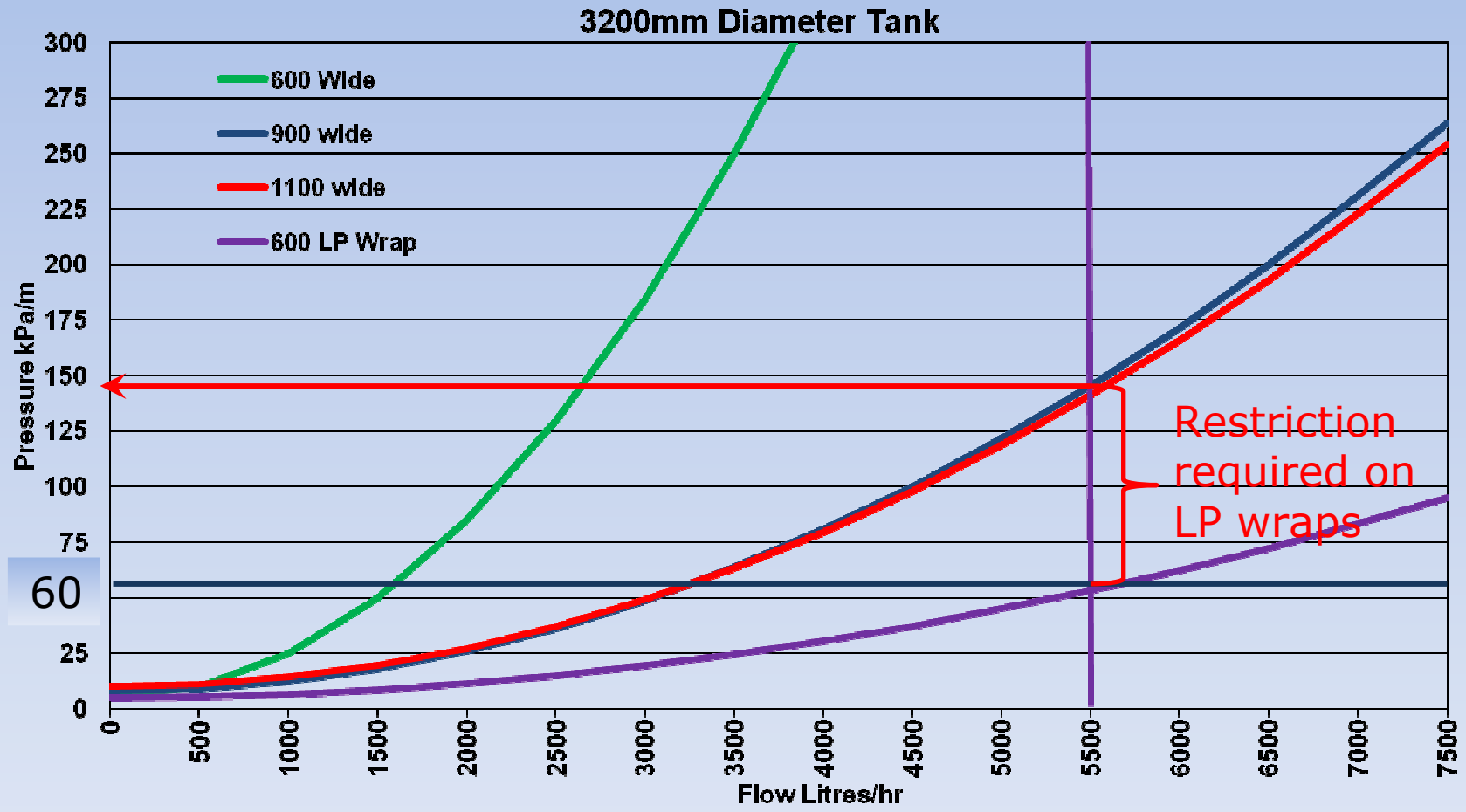
High Pressure and LP Wraps on the Same System



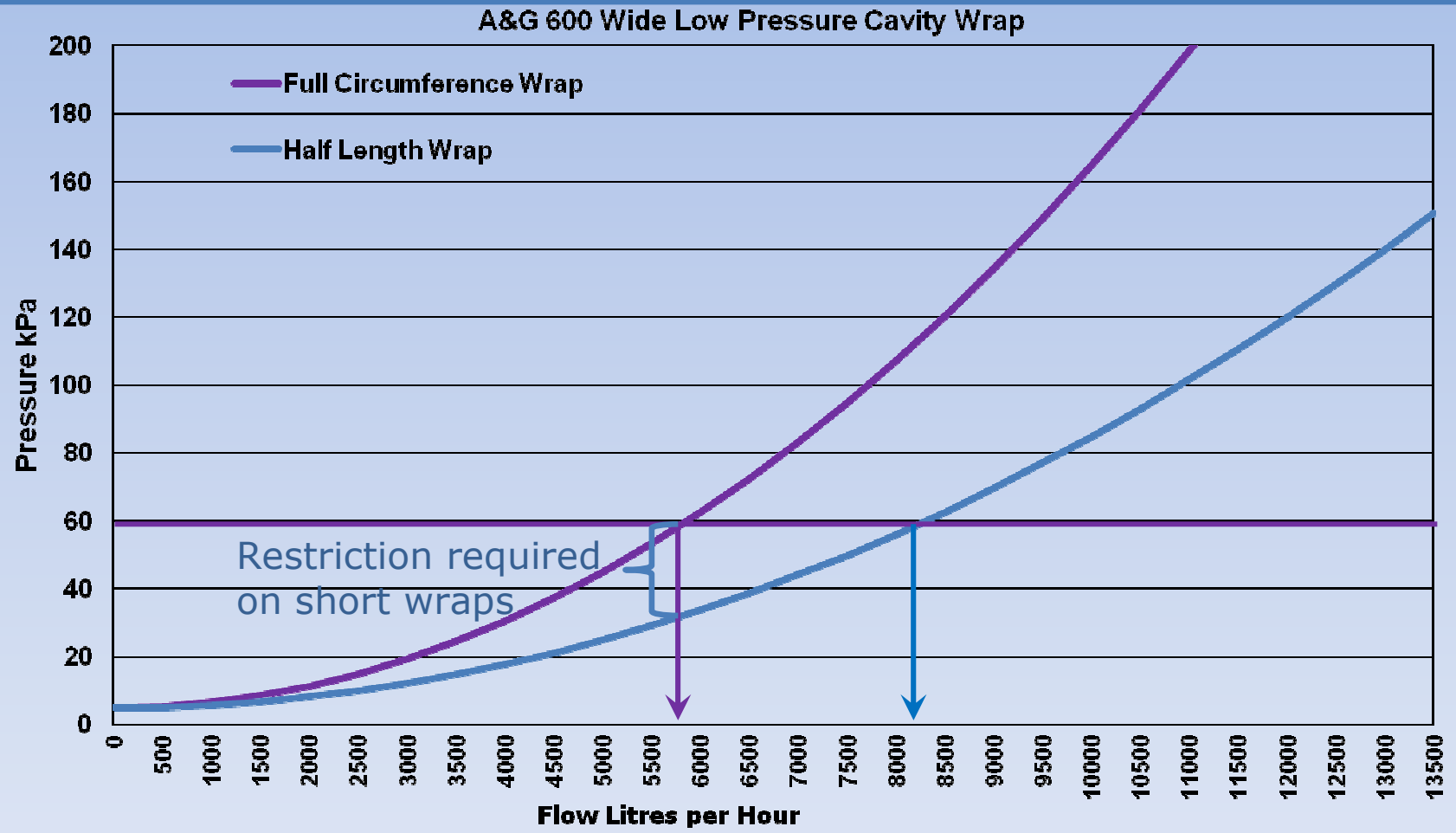
Mixed Wraps in the system

- Different flows at same dp (60kPa):
  - 600 wide LP 5500 l/hr
  - 900 wide HP 3200 l/hr
  - 600 wide HP 1600 l/hr
- Or to obtain the same flow of 5500l/hr
  - Increase system pressure by 150 – 60 = 90kPa and
  - Restriction on the LP cavity inlet to:
    - Balance the total pressure between the 2 cavity wraps
    - Ensure the pressure in the wrap does not exceed 140kPa

High Pressure and LP Wraps on the Same System



Tanks With Different Wrap Length

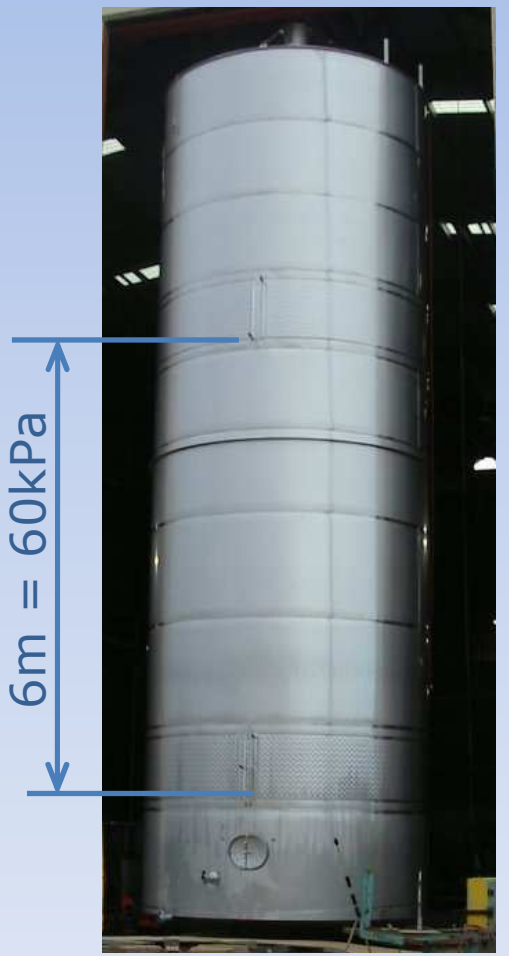


Tanks With Different Wrap Length

- Shorter wrap will have higher flow (8250l/hr) at same pressure.
- Or to obtain the same flow of 5500l/hr
  - Restriction on the shorter cavity to:
    - Make the performance curve the same as the longer wrap and
    - Balance the total pressure between the 2 cavity wraps

Other Things to Consider

- Tall Tanks:
  - Head between cavity wraps
    - 1m = 10kPa (sg=1.0)
    - Top wrap will have less flow
    - Bottom wrap will see the full head pressure
- Mains pressure will vary with volume flow
  - What effect will this have on the system?
  - Will this result in higher flows in cavities when only one or 2 tanks are being cooled?
  - Increase the mains size so that the loss through the cavity is the biggest factor in the system.
- Cooling Demand:
  - How many tanks do you want to cool at a time?
  - Fermentation or maintenance requirement?



A&G Engineering

Do's and Don'ts

- Don't:
  - Mix HP and LP/MP wraps on the same system/branch
    - Will result in uneven/unpredictable performance
  - Run excessive pressure in the system
    - Higher pressure = higher power cost
  - Mix Demands
    - Fermentation cooling & maintenance cooling
    - Services

Do's and Don'ts

- Do:
  - Consider the total system pressure when selecting the type of wrap
    - Operate cavity wrap within the rated pressure
    - Consider height implications
  - Use wider cavity wrap for
    - Lower pressure loss at
    - Higher flow rates

Do's and Don'ts

- Do:
  - Consider the impact of your brine on system performance
  - Have separate lines for
    - Different wrap types
    - Different cooling demands – fermentation or maintenance
    - Other services, e.g. air-conditioning services

Do's and Don'ts

- Do:
  - Oversize your mains
    - Allows expansion at marginal initial cost
    - Ensures that cavity pressure loss controls the system flow/operation
    - Reduces total system pressure & cost
  - Have your system designed for optimum performance
    - Tune the system to optimise its performance