2010 IAOM Technical Conference

Pneumatic Systems in the Mill

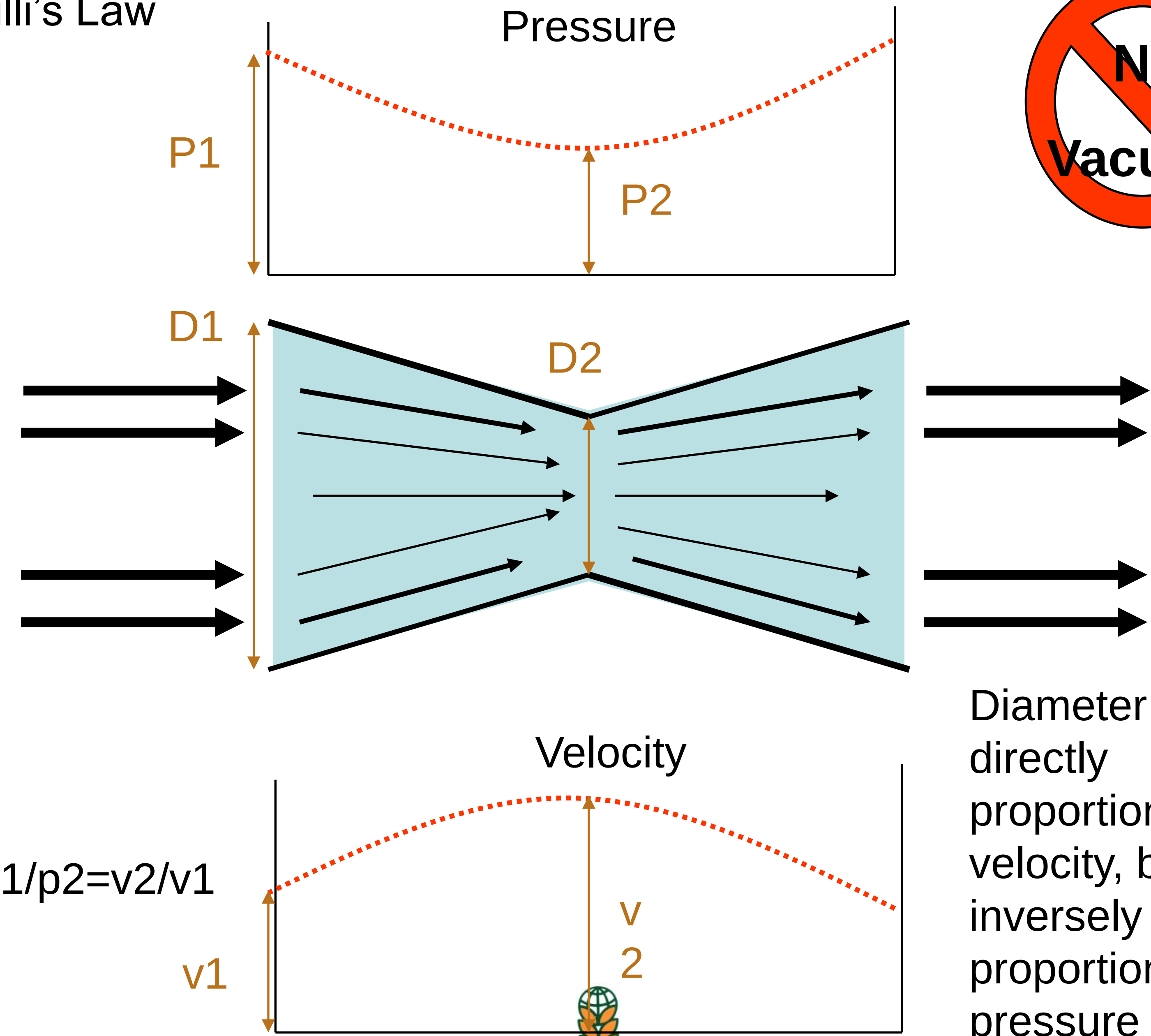
Peter Lloyd – US Wheat Associates Inc, Casablanca

A pastime nobody enjoys!

In summary

- **Pneumatic conveying is quite simple – pneumatic systems are NOT.**
- This presentation is not designed to teach you how to design a system, but to understand how one works.
- **PLEASE REFER TO YOUR EQUIPMENT SUPPLIERS FOR GUIDANCE!! – they are the only ones who know everything about how YOUR system was designed.**

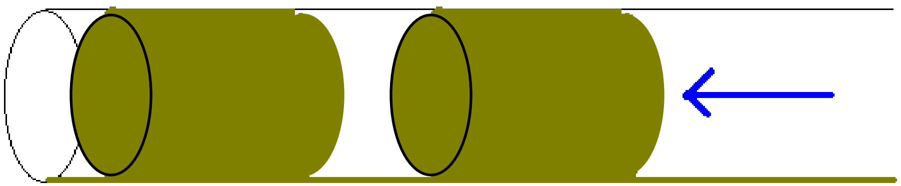
Bernoulli’s Law



D1/d2=p1/p2=v2/v1

Diameter is directly proportional to velocity, but inversely proportional to pressure

Pneumatic Conveying phases;

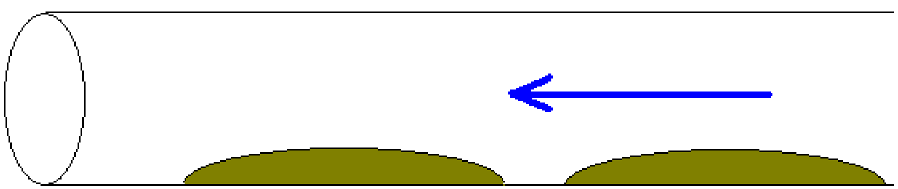


Dense phase, solid plugs

Unused in milling today

>200m. 10+ bar pressure

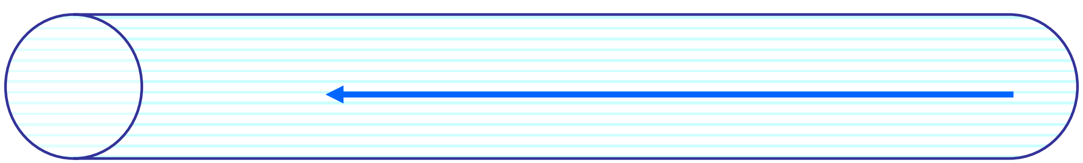
Both at less than Vterm for wheat



Medium phase, pulsing

Blowlines

<= 200m. 2-3 bar pressure

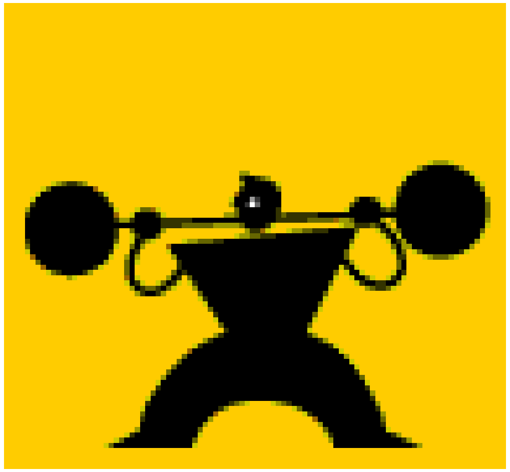


Dilute phase, product airborne.

Mill pneumatics

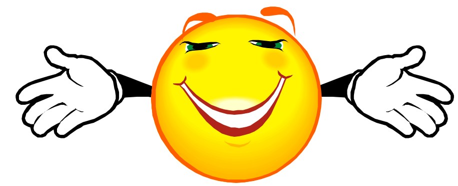
<=100m up to 1.5 bar pressure. High speed.

Mixing Rates: the ability of air to carry products.



Most people can easily carry 25kg.

2.5-3kg of product



1kg of Air

It is all about the WEIGHT of air and the weight of products.

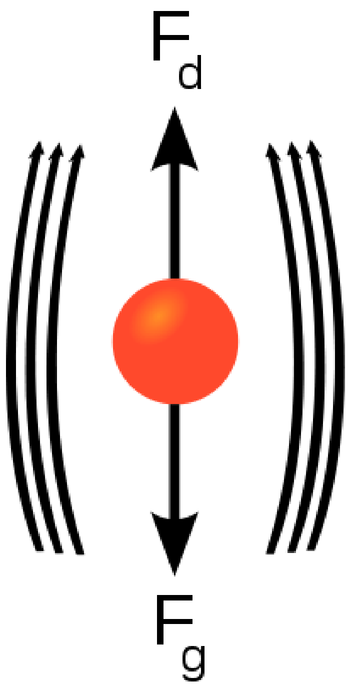
Come and see us in Morocco

Understanding the basics.

- Terminal Velocity
- Volume and density.
- Resistance and pressure.

Terminal Velocity – Wikipedia ®

An object is moving at its **terminal velocity** if its speed is constant due to the restraining force exerted by the air
A free-falling object achieves its terminal velocity when the downward force of gravity (F_g) equals the upward force of drag (F_d). This causes the net force on the object to be zero, resulting in an acceleration of zero.
As the object accelerates (usually downwards due to gravity), the drag force acting on the object increases, causing the acceleration to decrease. At a particular speed, the drag force produced will equal the object's weight (*mg*). At this point the object ceases to accelerate altogether and continues falling at a constant speed called terminal velocity (also called settling velocity). Terminal velocity varies directly with the ratio of weight to drag. More drag means a lower terminal velocity, while increased weight means a higher terminal velocity.



Determining V_{TERM}

At equilibrium, the net force is zero (F = 0);

$$F_{net} = ma = mg - \frac{1}{2}\rho v^2 A C_\mathrm{d}\ .$$

At equilibrium, the net force is zero (F = 0);

$$mg - \frac{1}{2}\rho v^2 A C_\mathrm{d} = 0\ .$$

V_t = terminal velocity,
m = mass of the falling object,
g = acceleration due to gravity,
C_d = drag coefficient,
ρ = density of the fluid through which the object is falling, and
A = projected area of the object.

Solving for *v* yields

$$\sqrt{\frac{2mg}{\rho A C_\mathrm{d}}}\ .$$

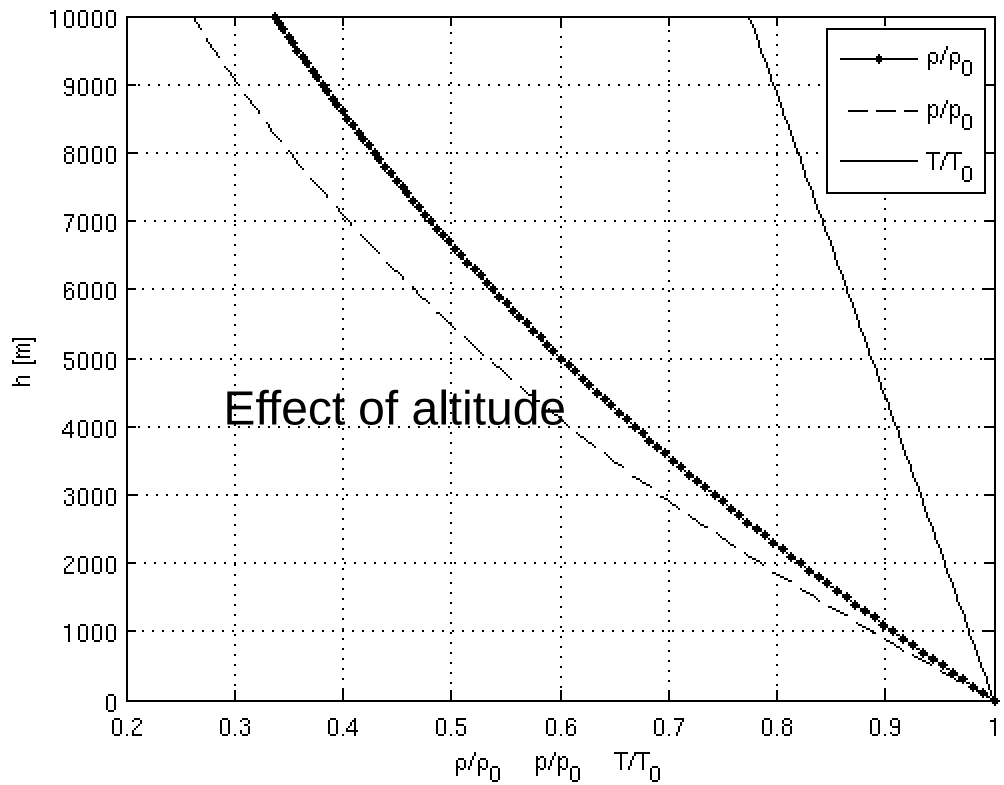
Terminal Velocity – imperial and metric units

	m/sec	ft/min	ft/sec
Corn	9.19	1810	30.17
Soybeans	8.13	1600	26.67
Sorghum	8.18	1610	26.83
Wheat grains	7.77	1530	25.50
Oats	6.20	1220	20.33
Grain dust	0.97	190	3.17

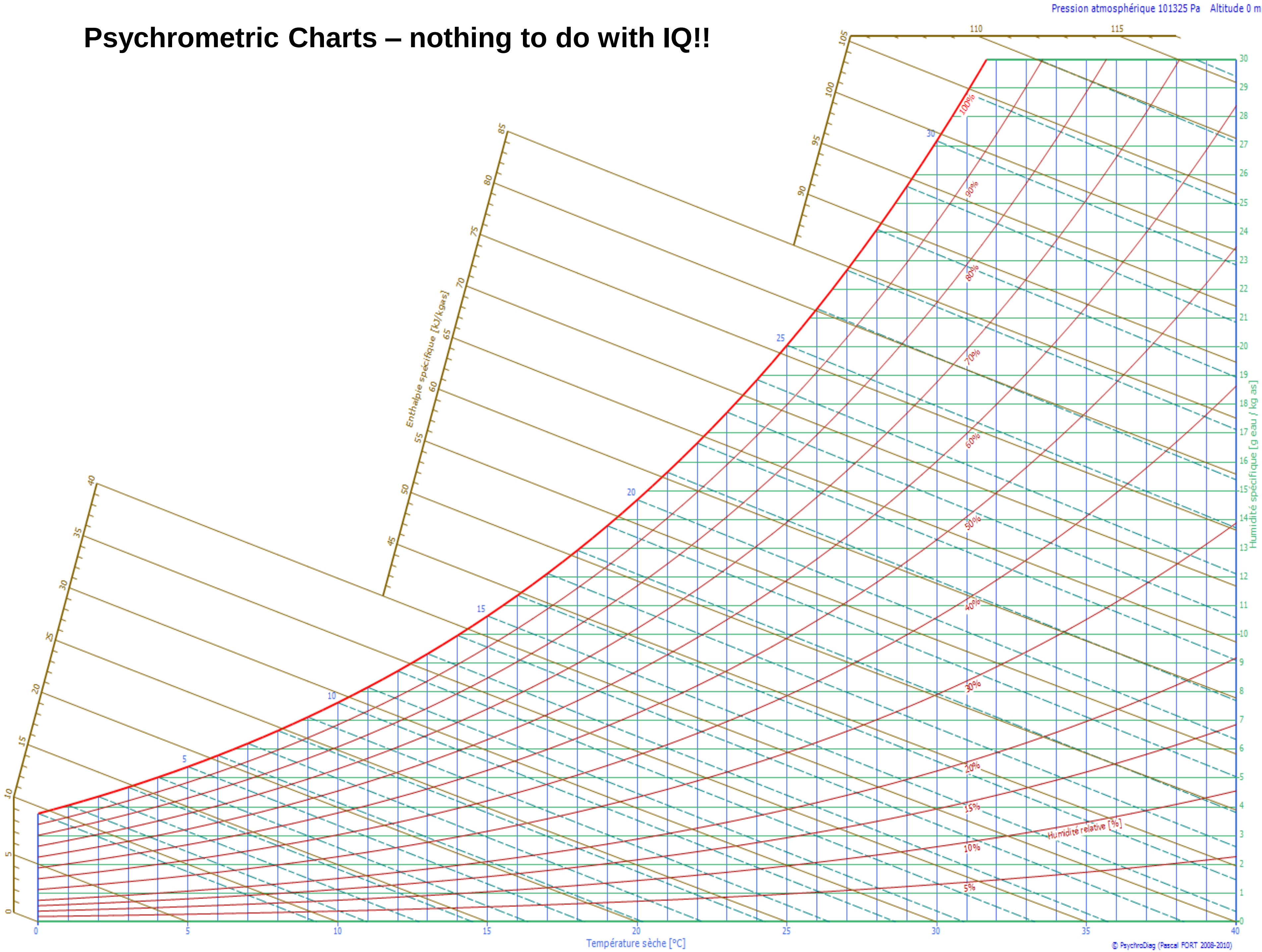
Air Density

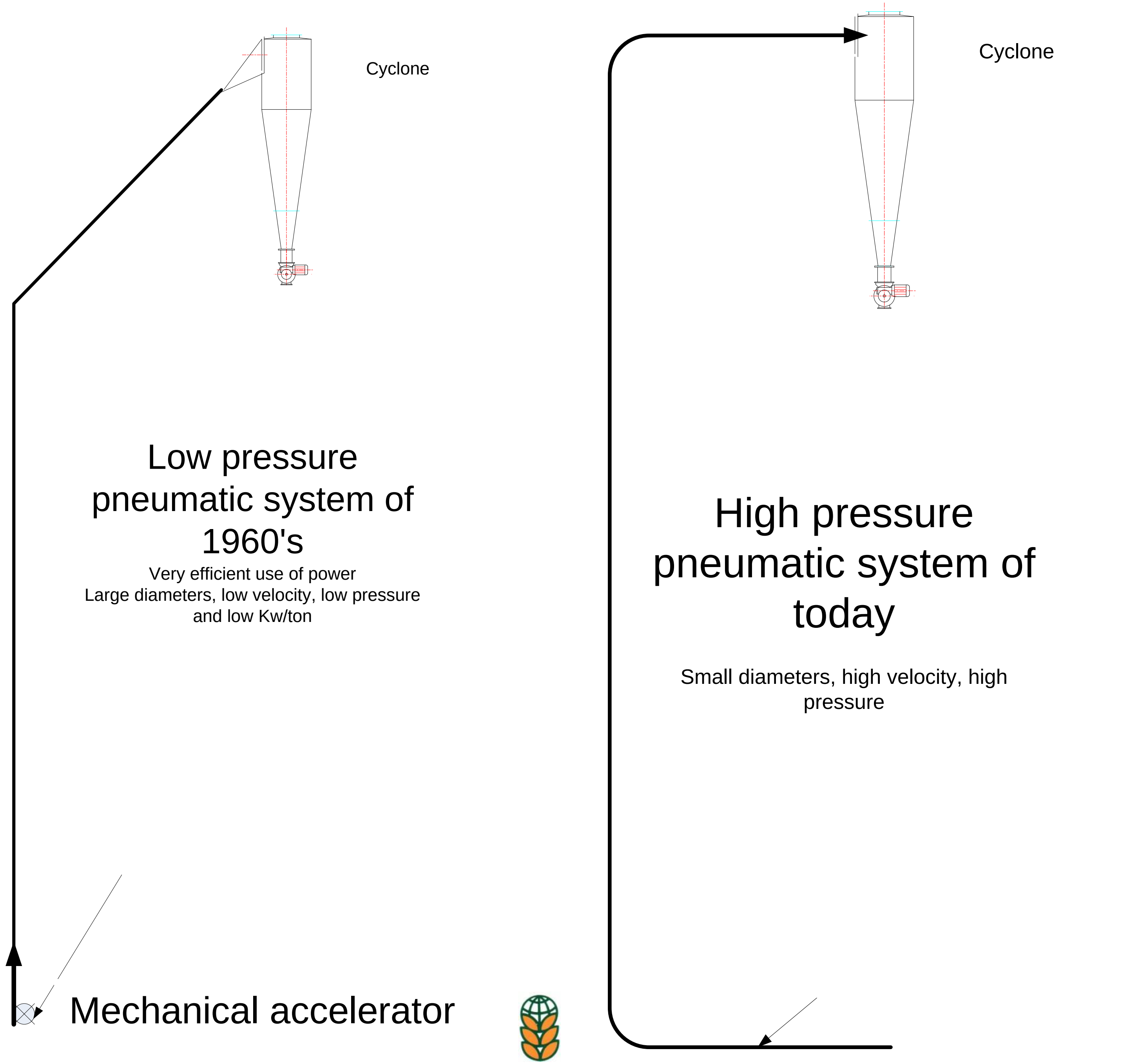
Effect of temperature	
Temperature	Density of air
in °C	ρ in kg·m^{-3}
0	1.292
+5	1.269
+10	1.247
+15	1.225
+20	1.204
+25	1.184
+30	1.164
+35	1.146

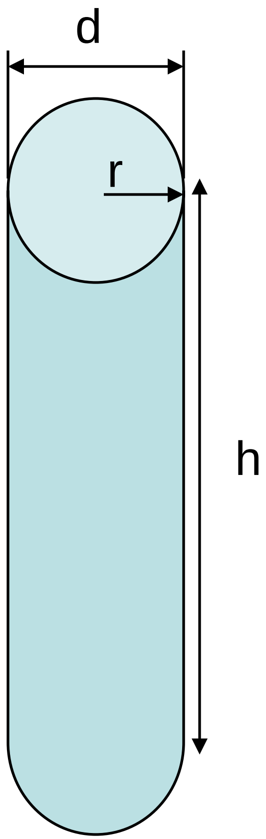
- **Air density is 1.2kg/M3 at 16º C at sea level.**
- **Density reduces with temperature and altitude.**
- **In most parts of North Africa, in summer, the air density can be considered as approximately 1.1 kg/M3**



Psychrometric Charts – nothing to do with IQ!!

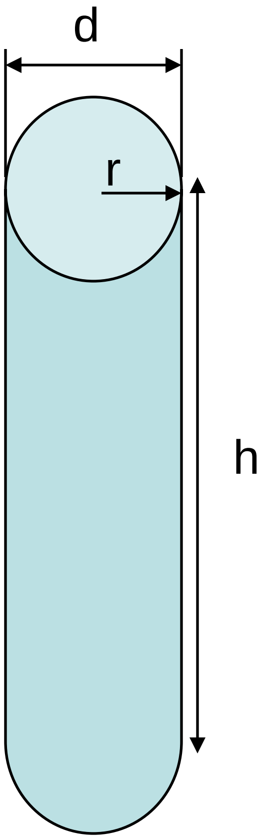


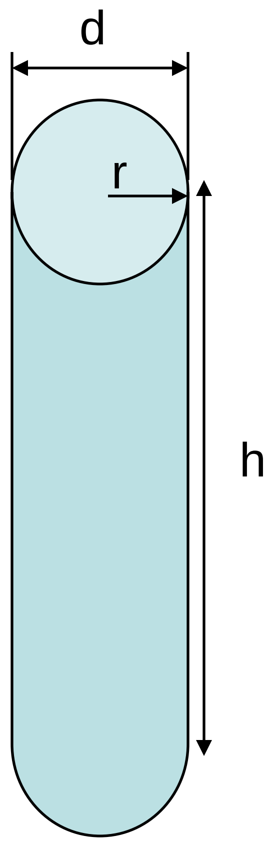

Cyclone
Low pressure pneumatic system of 1960's
Very efficient use of power
Large diameters, low velocity, low pressure and low Kw/ton
Mechanical accelerator
Cyclone
High pressure pneumatic system of today
Small diameters, high velocity, high pressure



$$Volume = \left(\pi . r^2 . h\right)$$

$$\frac{volume}{\pi * h} = r^2$$





$$2x \sqrt{\left(\frac{volume}{(\pi . h)}\right)} = diameter(d)$$

In 1 Second:

H = (velocity of air * 1000) in mm/sec

Volume = (M^3/minute) * (1000^2/60) in mm^3/sec

$$2x \sqrt{\left(\frac{volume}{(\pi.h)}\right)} = diameter(d)$$


Tabarka, Tunisia

For example;

- Feedrate = 1.0kg/sec (3,600kg/hr)
- Mixing rate = 2.5kg/kg of air
- Air Velocity = 22m/sec
- Air Density = 1.2kg/m^3

$$Conveying Volume = \left(\frac{Feedrate}{Mixingrate}\right) / Density$$

$$Conveying Volume = \left(\frac{1kg\ of\ product}{2.5kg/kg\ of\ air}\right) / 1.2$$

= 0.3334 M^3/sec or
333,333,333.33mm^3/sec

$$2x \sqrt{\left(\frac{volume}{(\pi.h)}\right)} = diameter(d)$$

Working in millimeters, we now find that:

$$2x \sqrt{\left(\frac{333333333.33}{(\pi.20000)}\right)} = 140.553\text{mm}$$

Diameter of the pipe for this load = 140.553mm

But – nobody makes 140.553 mm ID pipes = we would use a 140mm i/d pipe (and adjust the mixing rate accordingly).

USE A SPREADSHEET!

Feedrate	1	kg/sec	3,600	kg/hr
mixing rate	2.5	kg/kg air		
Velocity	22	m/sec		
Density	1.2	kg/m3		
Volume	0.3333333	m3/sec		
Volume in mm3	**333333333**	**mm3/sec**		
=SQRT((B8/(PI()*(B5*10000))))				
Radius	70.2765	mm		
Diameter	**140.553**	mm		

Given:
Feedrate, velocity and air density – you can easily work out the pipe diameter. Call the airport if you need to know the air density on any particular day.
The density of air under standard conditions is 1.239 kg per cubic meter under standard conditions. (16 deg C at sea level)

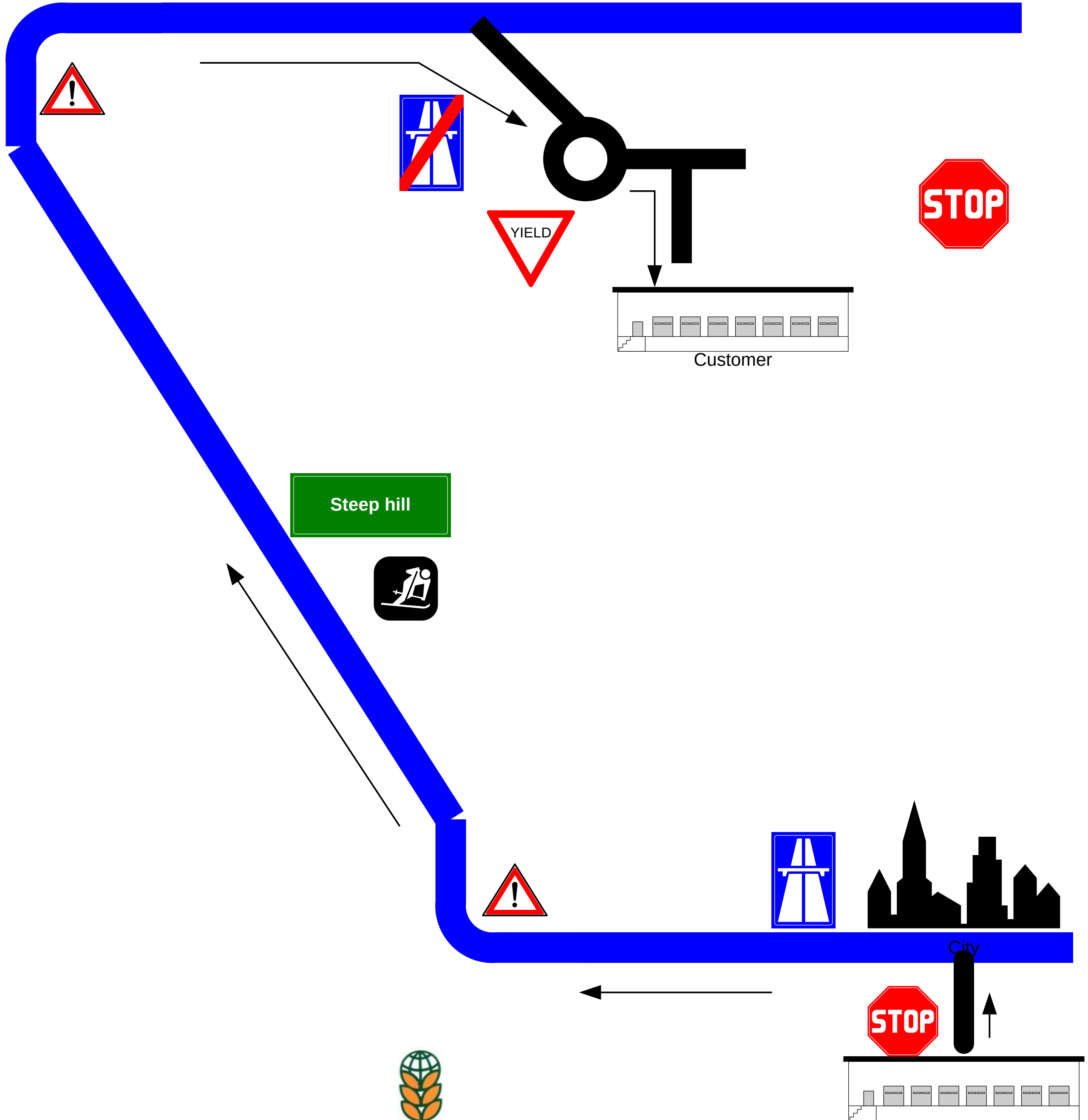
Part 2 - pressure

- Think of a truck delivering flour to a customer.

The energy budget:

Calculating the amount of fuel used by the truck is a function of;

- Size of truck to carry the load
- Distance traveled
- Type of road
- Fuel consumption (hills, corners etc.)
- Part of the fuel is to move the truck, and part for the load.



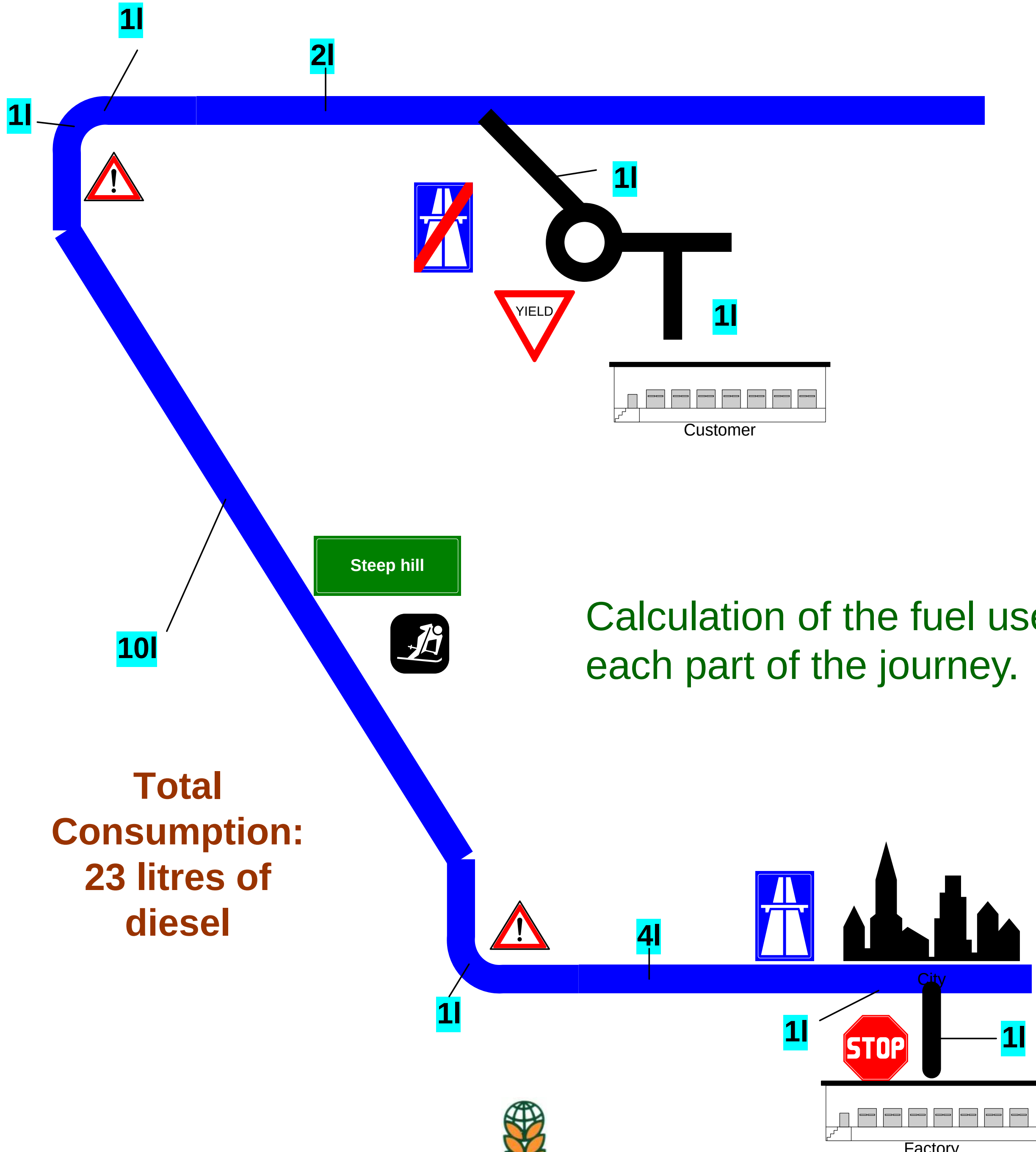
Km total = 10

Stops = 2

Corners = 2

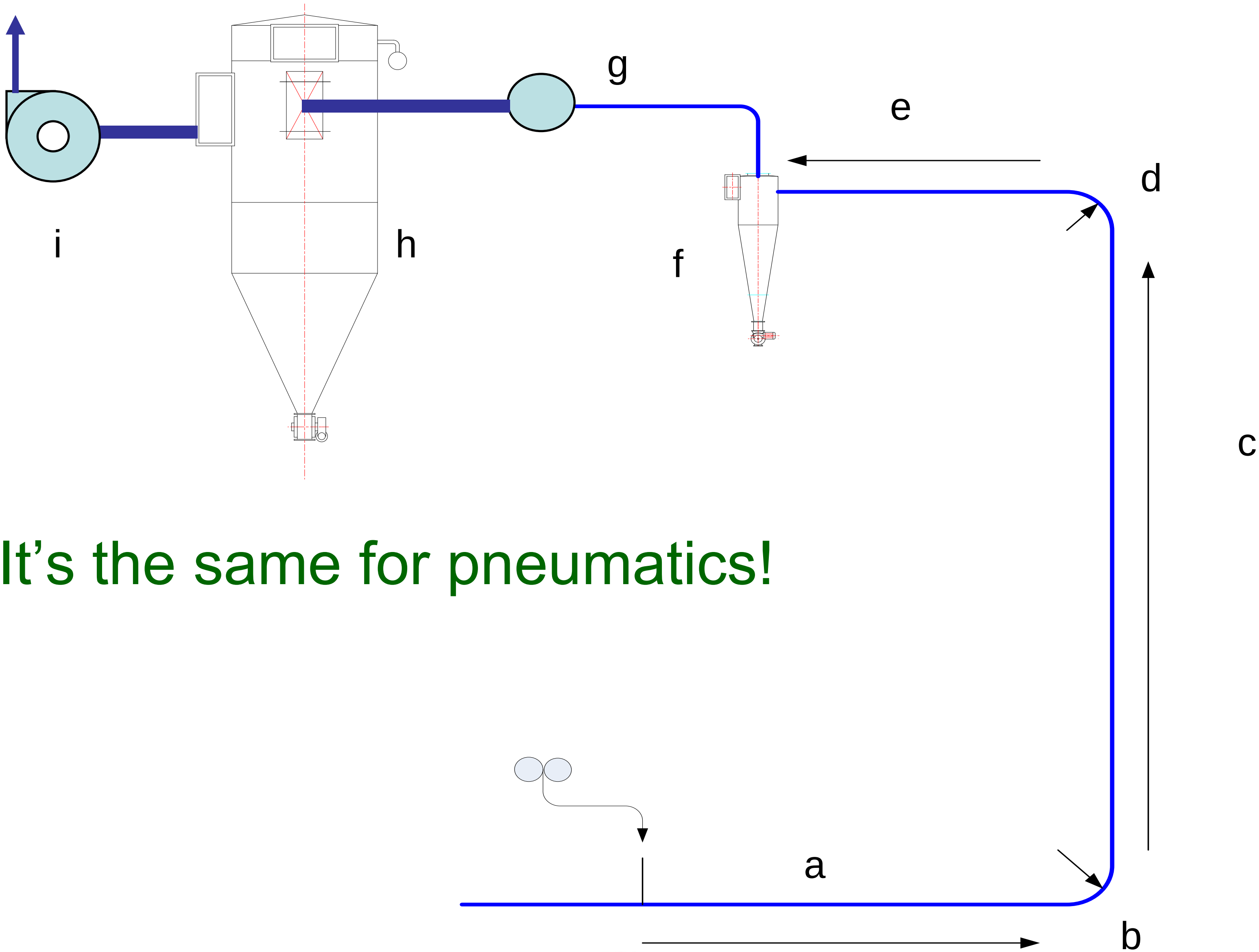
Roundabouts = 1

Hill = 1



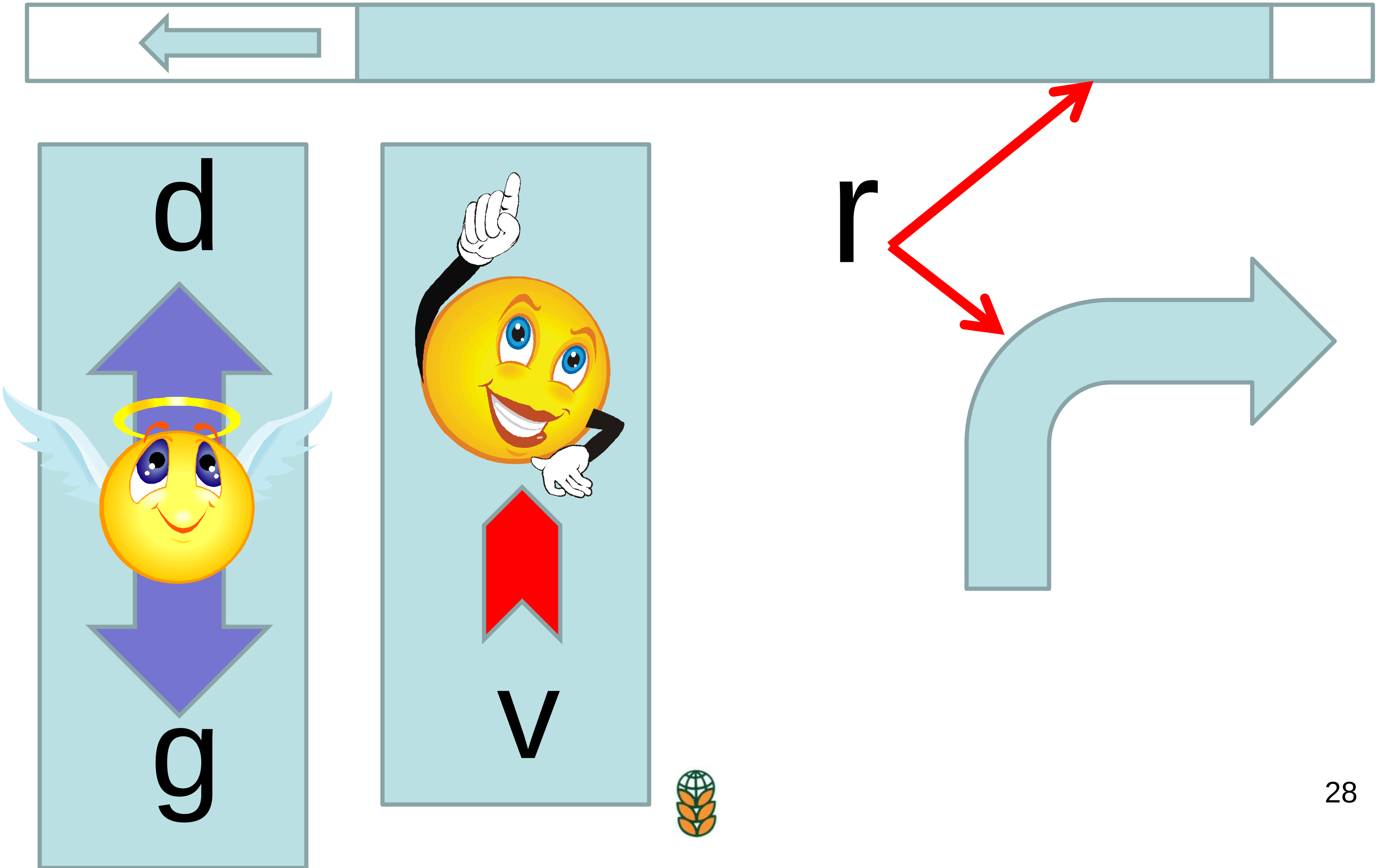
Calculation of the fuel used for each part of the journey.

Total Consumption: 23 litres of diesel



It's the same for pneumatics!

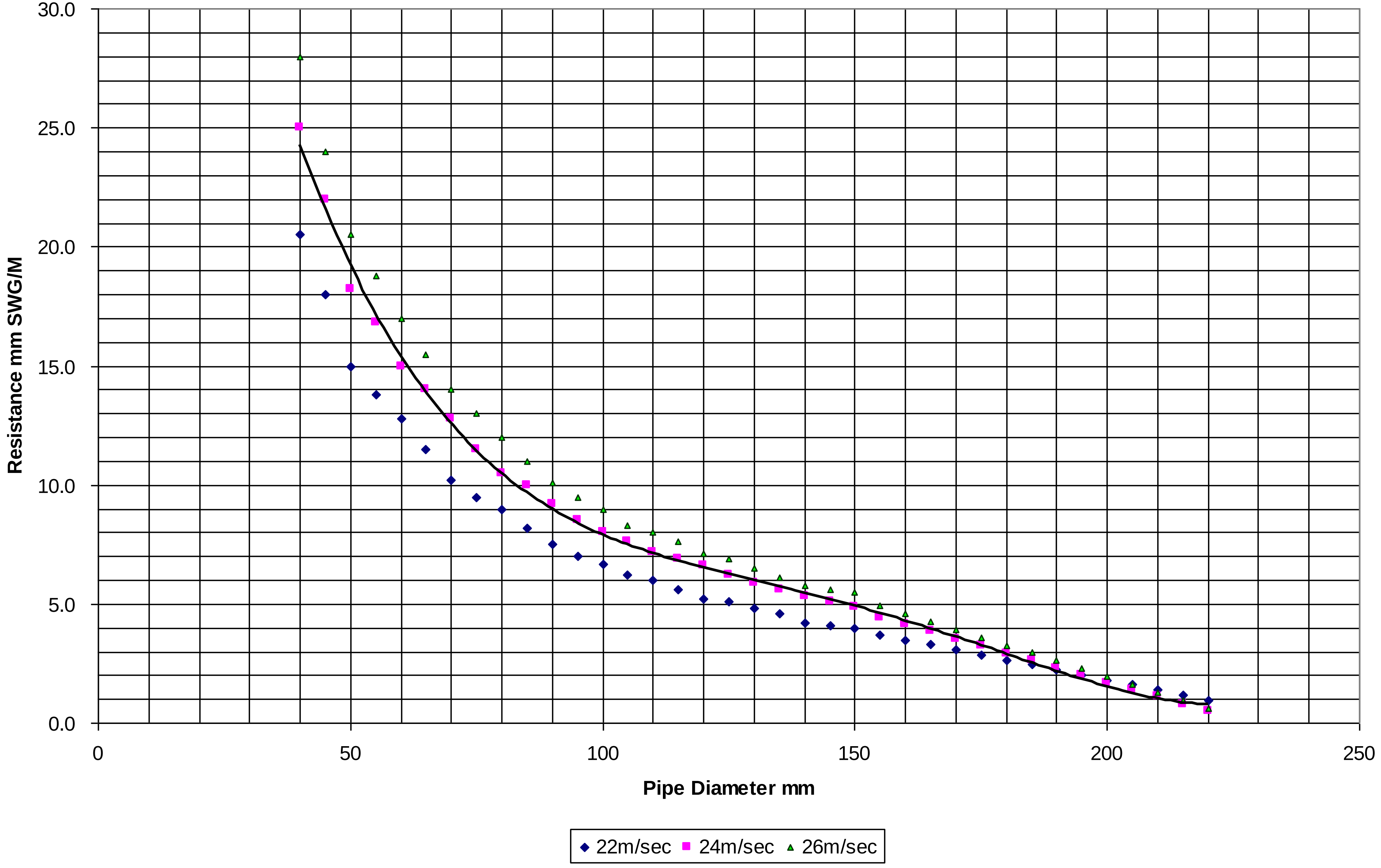
Elements of resistance



Energy to move the truck

IFIM		
Plant:	Blunder Milling	
Land:	Dakar, Sénégal	
Plant Capacity:	250.00	Tonnes per 24 hours
Grain:	Soft Wheat	
Altitude:	12	Metres A.M.S.L
Max ambient temperature:	28	Degrees C
Initial Mixing Rate :	2.5	Kg stock/Kg air
System Velocity :	22.0	Metres / Second
Conveying Density	**1.171**	Kg/M2 Calculated
Resistance Column	3	CALC Calculated

Pneumatic Piping



Line Number	Line	1
From Purpose From	From	Purpose
To Purpose To	To	Purpose
Stock Qty. in kg/h	Stock Qty.	3,600
Selected mixing rate stck:air	mixing rate	2.50
Vertical Conveying Metres	Vertical	25.0
Horizontal Conveying Metres	Horizontal	12.0
No.of Bends V/Horiz	V/Horiz	1
No.of Bends H/Vert	H/Vert	1
No.of Bends H/H	H/H	1
Calculated Air volume cbm/h	Air volume	1,229
Calculated Pipe Diameter	Pipe diam	140.5533
Resistance column		3
Resistance mm/m	ResistanceM	4.2 mm/m
Metres	ConveyingM	42 m

Resist Mix Rate <=2.5	lowmixrate	1.60
Resist Mix Rate >2.5	himixrate	0.96

Basic Air Pressure mm W.G.	Pbasic	320

Accleration Resistance mm W.G	Paccel	71
Horizontal Pipe resist mm W.G	Phoriz	48
Vertical Pipe resist mm W.G	Pvert	246
Bends (all) Pipe resist mm W.G	Pbends	101
Conveying Pressure mm W.G.	Pconv	465
Total Line Pressure mm W.G.	Ptot	785
Manifold Loss mm W.G.	Pmanif	12.5
Total Pressure mm W.G.	Ptot	797

Seal Leakage cbm/hr	Vseal	123

Total Volume cbm/hr	Vtot	1352
Total Volume cbm/min		22.530
Total Volume cbm/sec		0.375

Line Number	2	
From	B1a	
To	B1 Sift	
% of B1 Stock	25.0%	
Stock Qty. in kg/h	2,604.17	
Air volumecbm/h	749.89	Calc
CalculatedPipeDiameter	110.00	Calc
Selected mixing rate	2.96	
Vertical Conveying Metres	25.00	
Horizontal Conveying Metres	12.00	
No.ofBends V/Horiz	1.00	
No.ofBends H/Vert	1.00	
No.ofBends H/H		
Basic Air Pressure mm W.G.	393.20	Calc
Accleration Resistance mm W.G	83.96	Calc
HorizontalPipe resistmm W.G	46.81	Calc
Vertical Pipe resist mm W.G	291.28	Calc
Bends (all)Pipe resistmm W.G	71.75	Calc
Conveying Pressuremm W.G.	493.80	Calc
Total Line Pressuremm W.G.	887.00	Calc
Seal Leakage cbm/hr	74.99	Calc
Manifold Loss mm W.G.	13.00	Calc
TotalPressure mm W.G.	900.00	Calc
Total Volume cbm/hr	824.88	Calc

Energy budget for a single conveying line.

So you want the formulae?

- **Basic Pressure**: =(ResistanceM*ConveyingM)+(120*(VELOCITY/20)^2)
- **Acceleration**:=sel_mixing_rate*(9.83*(24-VELOCITY)*(22-VELOCITY)-17.33*(26-VELOCITY)*(22-VELOCITY)+3.54*(26-VELOCITY)*(24-VELOCITY))
- **Horizontal Conveying:** =Horizontal*sel_mixing_rate*IF(sel_mixing_rate<=2.5,lowmixrate,highmixrate)
- **Vertical Conveying:** =Vertical*sel_mixing_rate*(4.2*(VELOCITY-24)*(VELOCITY-22)/(26-24)/(26-22)-4*(VELOCITY-26)*(VELOCITY-22)/(24-26)/(24-22)+3.93*(VELOCITY-26)*(VELOCITY-24)/(22-26)/(22-24))
- **Bends**=sel_mixing_rate*20*(VELOCITY/20)^2*(2/3*(C13+C14)+1/3*C12)
- **Seal leakage** = Air_volume*10%

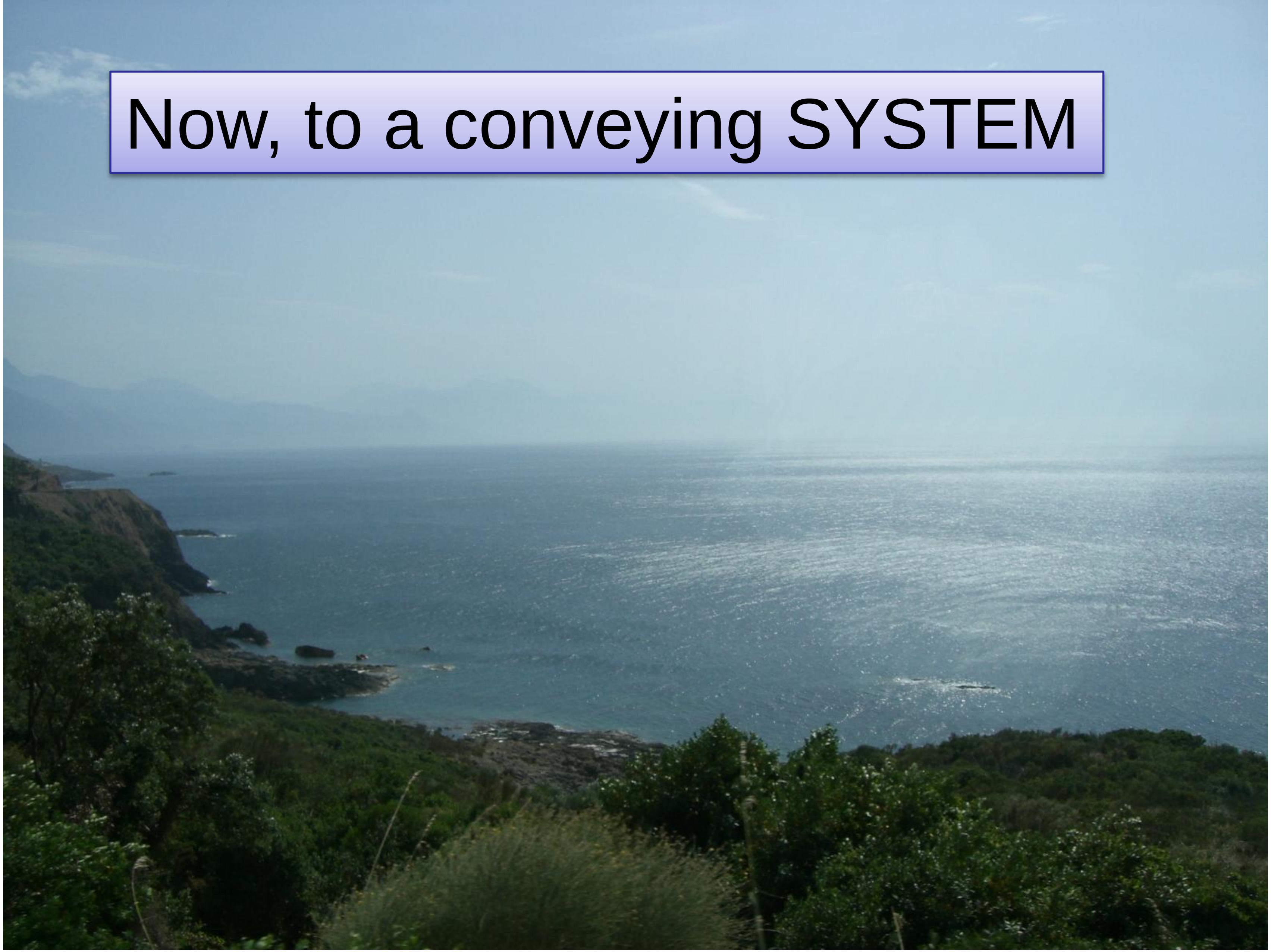
IF YOU WANT THE FORMULAE BEHIND THESE – READ THE BOOK!

For <u>this</u> ONE conveying line:

- Total volume: 825 M^3/hr
- Total pressure: 900 mm swg
- Capacity: 2,600 kg/hr
- Lift Diameter: 110 mm Ø
- Cyclone Size: 360 mm Ø

NOW it gets a little tougher:

Now, to a conveying SYSTEM

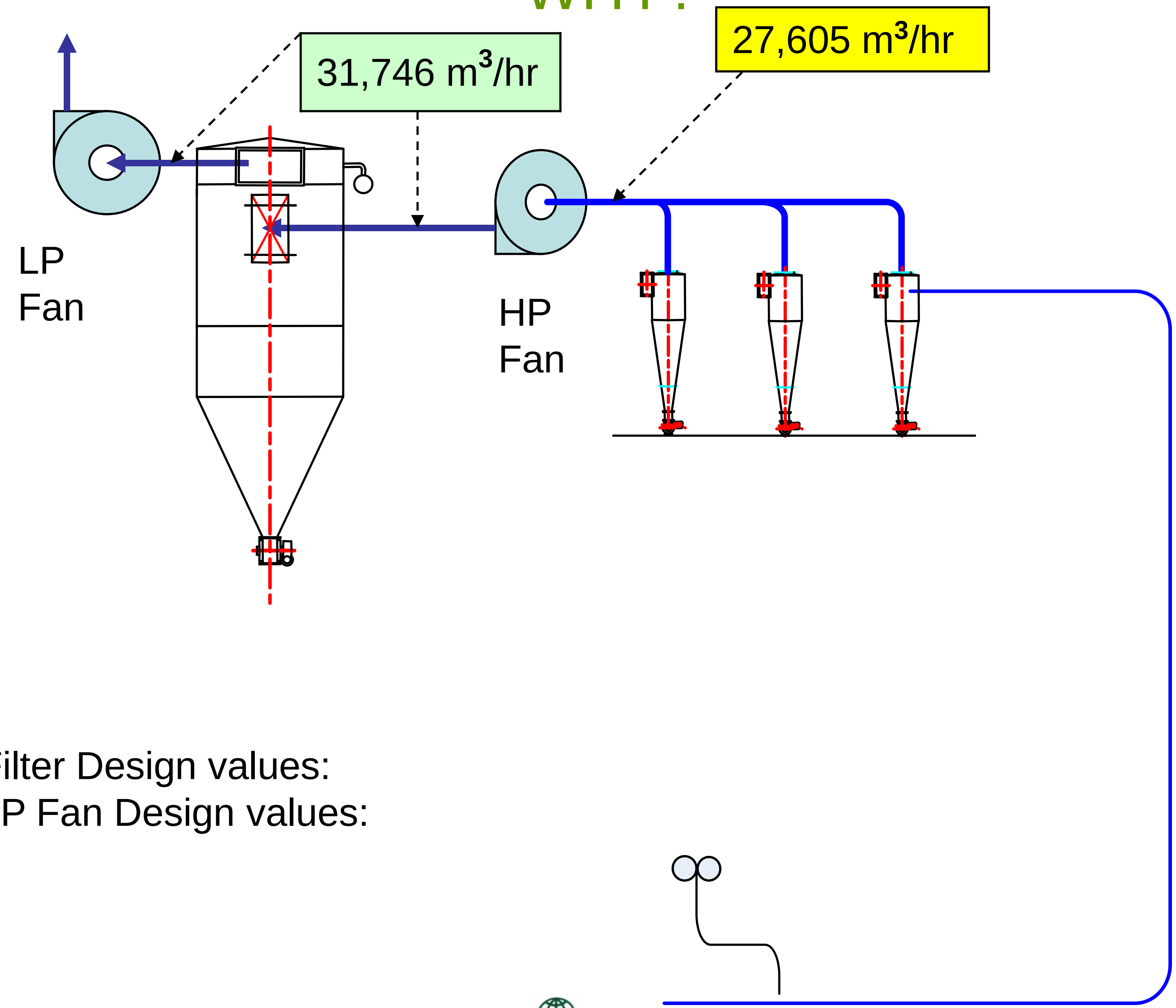


Corniche Kabiyle, Jijel, Algeria

Fan Selection Data ;	Blunder Milling	
Item	**Pressure**	**Volume**
Conveying System	925 mm WG	24,004 cbm/hr
Manifold to Filter	36 mm WG	-
Filter Resistance	60 mm WG	-
Manifold to Fan	35 mm WG	-
Manifold from Fan	35 mm WG	-
Jet Cap resistance	25 mm WG	-
Totals	1,117 mm WG	24,004 cbm/hr
Mixing and Imbalance %	**15** %	
Fan Design values	1,284 mm WG	27,605 cbm/hr
	OK	460.076 cbm/min
		7.668 cbm/sec

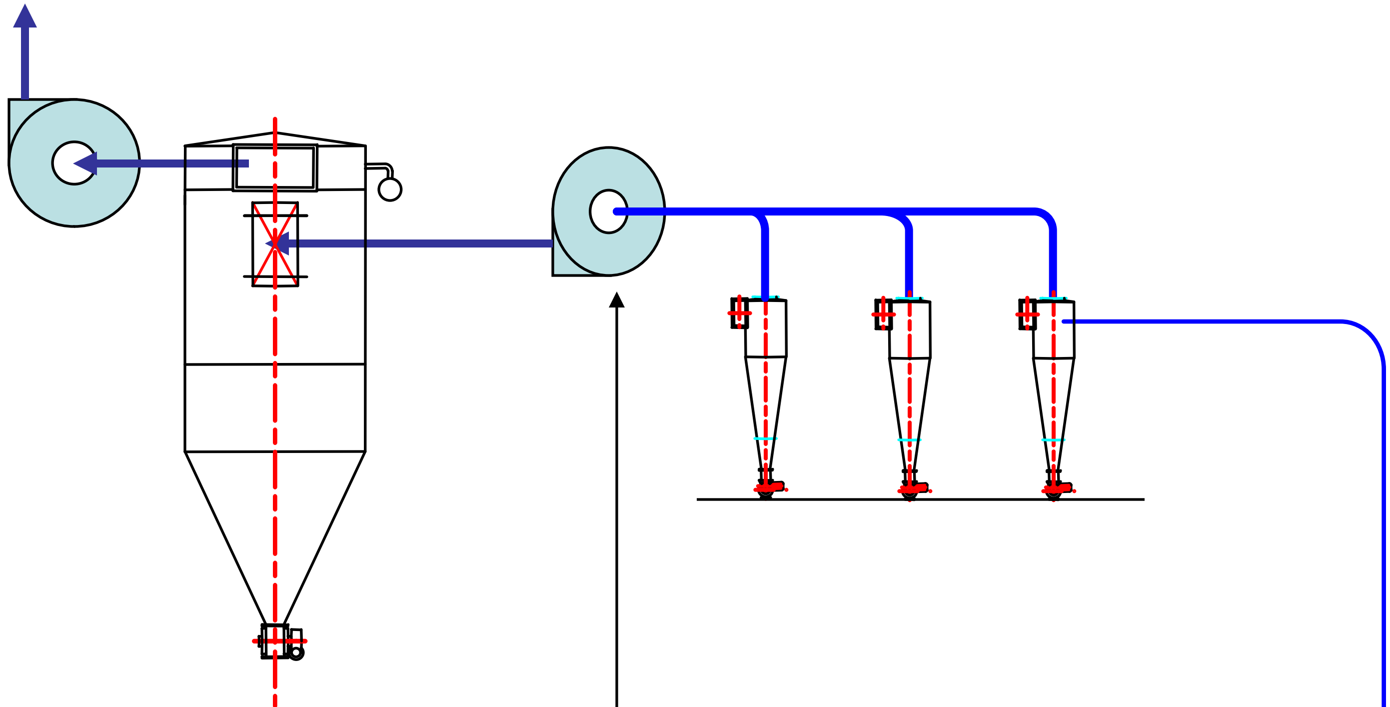
Temperature	28 Degrees
Altitude	12 mamsl
Fan Inlet Pressure & Volume Density	1.171 Kg/CbM
Estimated Power consumption :-	164.09 Kw

WHY?

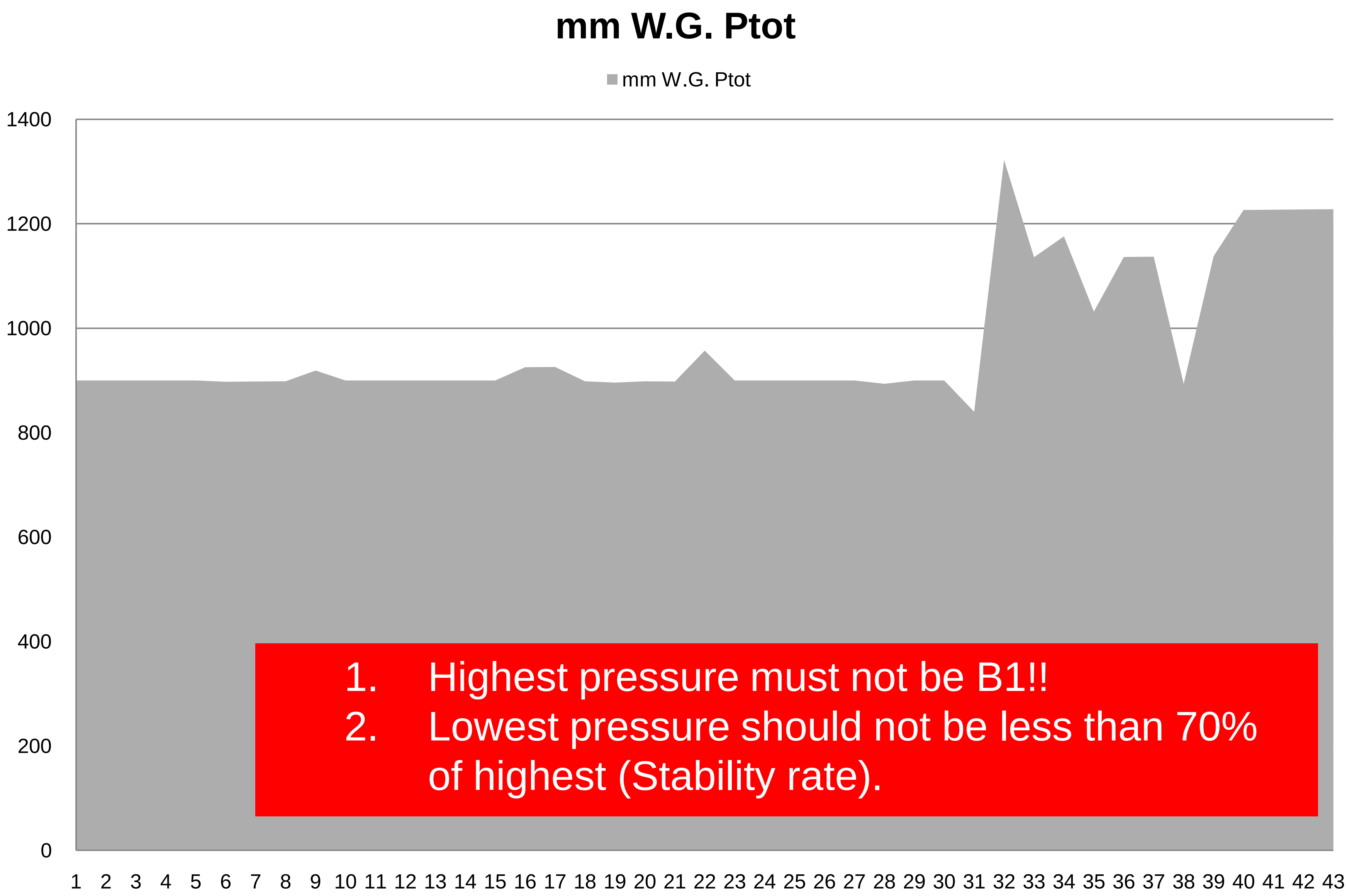


Filter Design values:

LP Fan Design values:



Filter Design values:	1,284 mm WG	**27,605 m^3/hr**



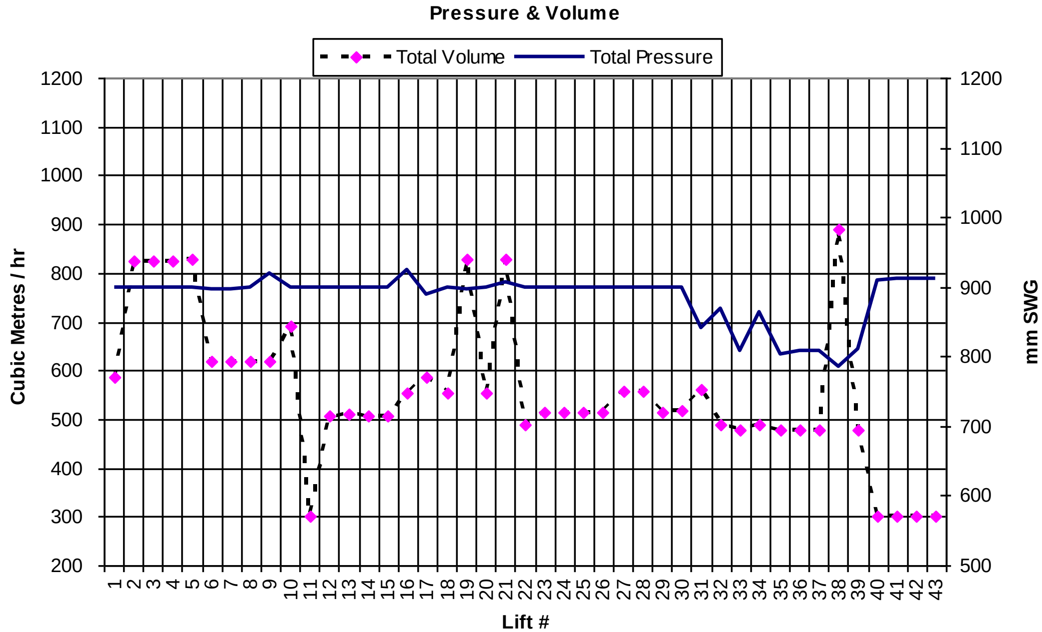
1. Highest pressure must not be B1!!
2. Lowest pressure should not be less than 70% of highest (Stability rate).

STABILITY

Stability = pMin/pMax

Systems should be >= 80%

B1 MUST NOT BE pMax.



PMin in system 786 mm swg

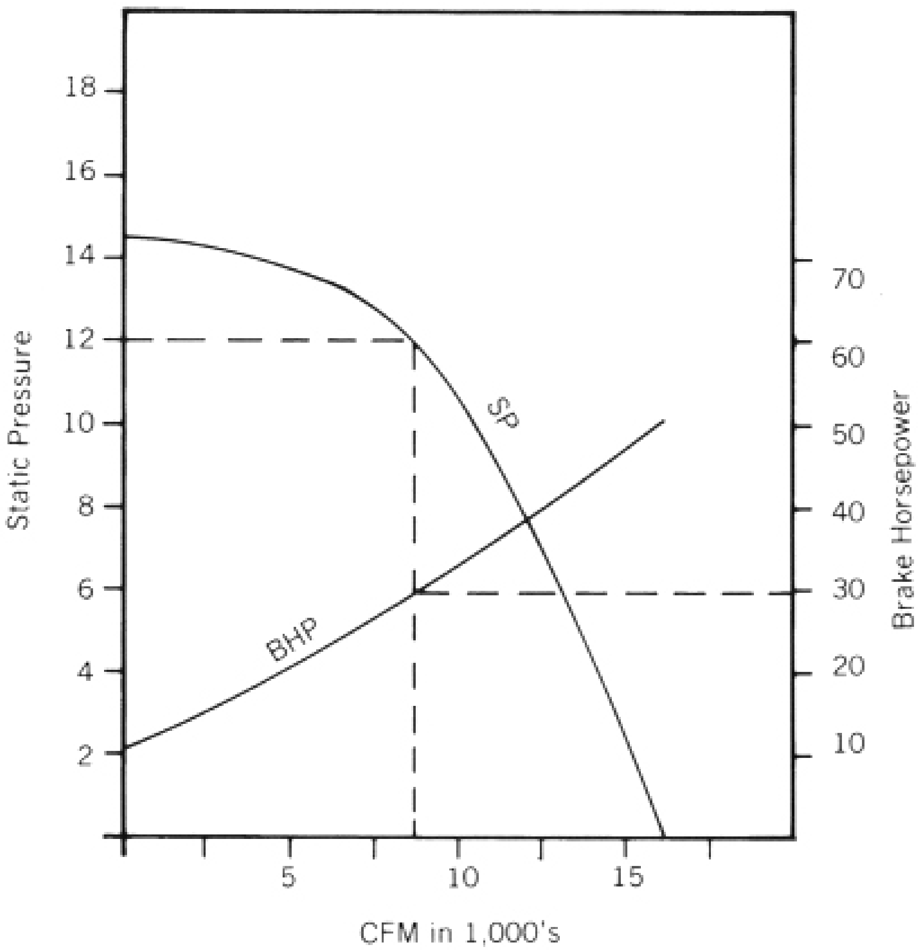
PMax in system 925 mm swg

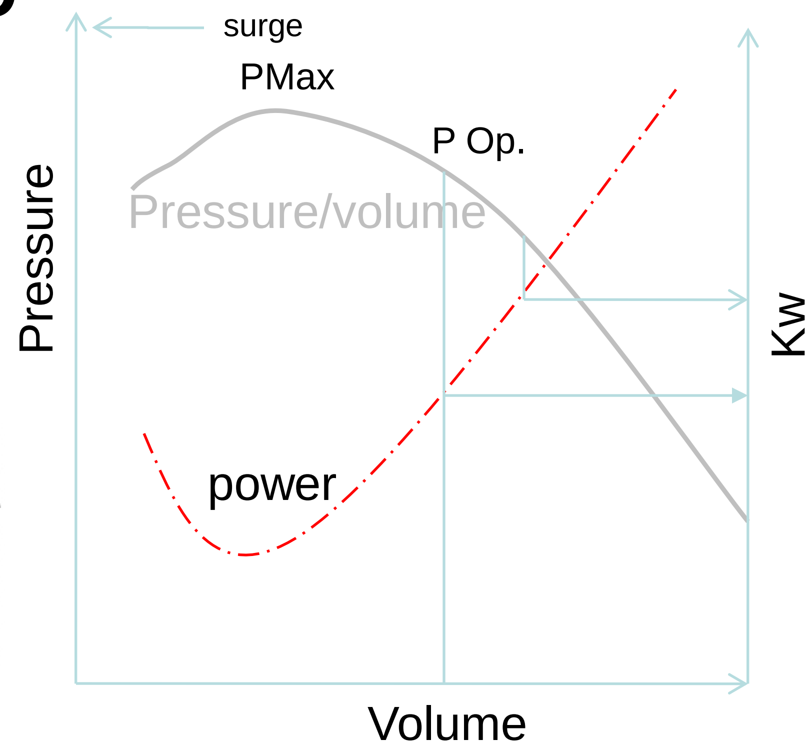
Stability 85% percent

Lifts 43 count

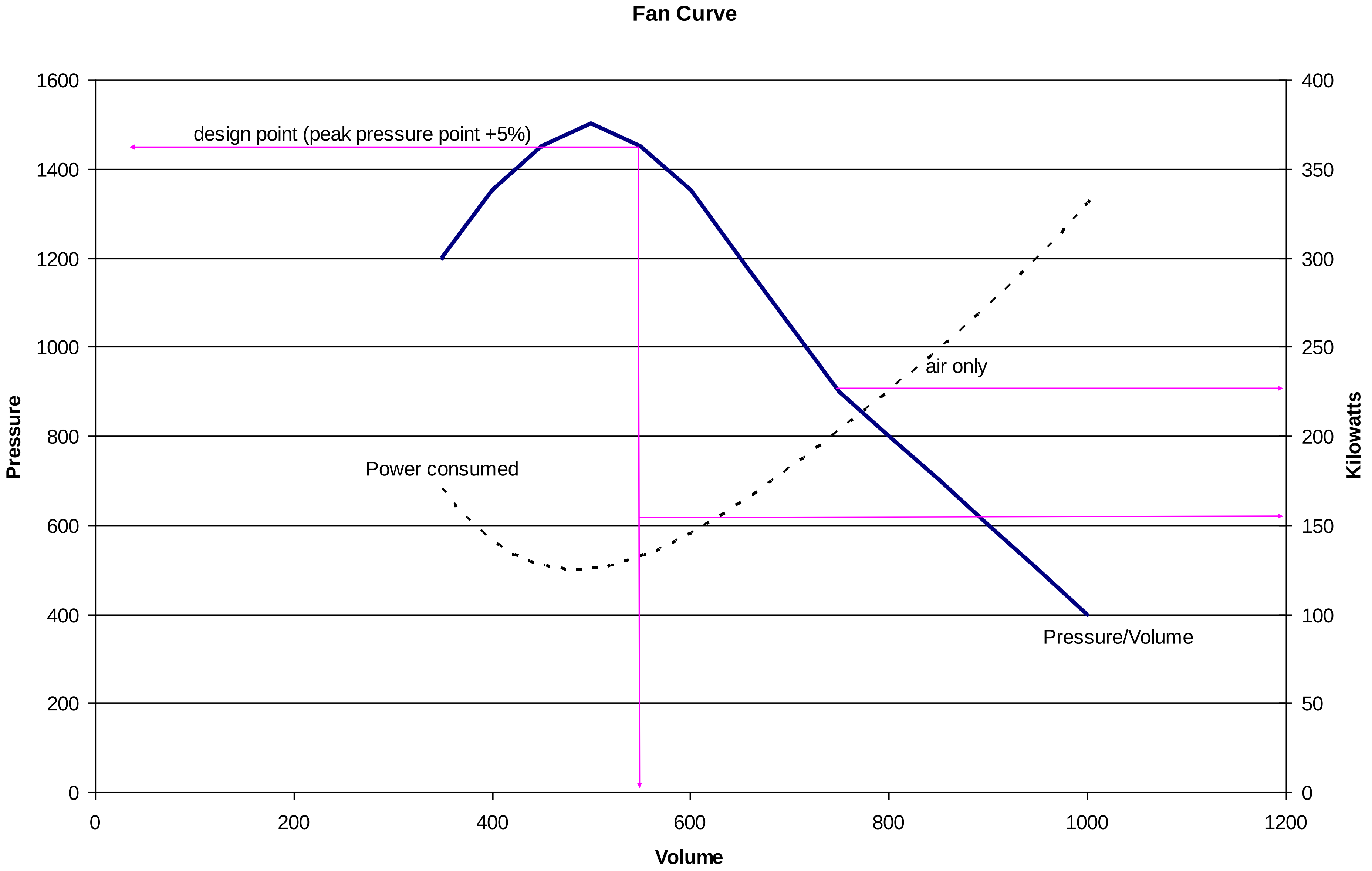
Stable System

Understanding a fan curve.





More air = more power & less pressure.



Q: What happens when you close the main air valve?

Fan Laws

1. Volume varies as RPM.

2. Static Pressure varies as square of RPM.

3. Power varies as cube of RPM

Double the rpm = square the pressure = cube the power.

What does this mean?

Item	Original	Revised	
Speed	2,500	2,900	RPM
Volume	23,000	26,880	Cu M / Hr
Pressure	1,200	1,614	mm swg
Power	212	330	Kw

Be very careful playing with the speed of your fan!

In summary

- **Pneumatic conveying is quite simple – pneumatic <u>systems</u> are NOT.**
- This presentation is not designed to teach you how to design a system, but to understand how one works.
- **<u>PLEASE REFER TO YOUR EQUIPMENT SUPPLIERS FOR GUIDANCE</u>!! – they are the only ones who know everything about how YOUR system was designed.**

- From all of us at US Wheat, THANKS FOR YOUR ATTENTION – this is not an easy subject to transmit in 20 minutes.
- Ngiyabonga, Enkosi and Thank You!