WOODCOCK & WILSON LTD

FANMANUFACTURERS.COM

Specialists in Manufacturing Industrial Centrifugal, Axial and Independently Certified ATEX and IECEx Fans.

Fan Selection
Servicing & Maintenance

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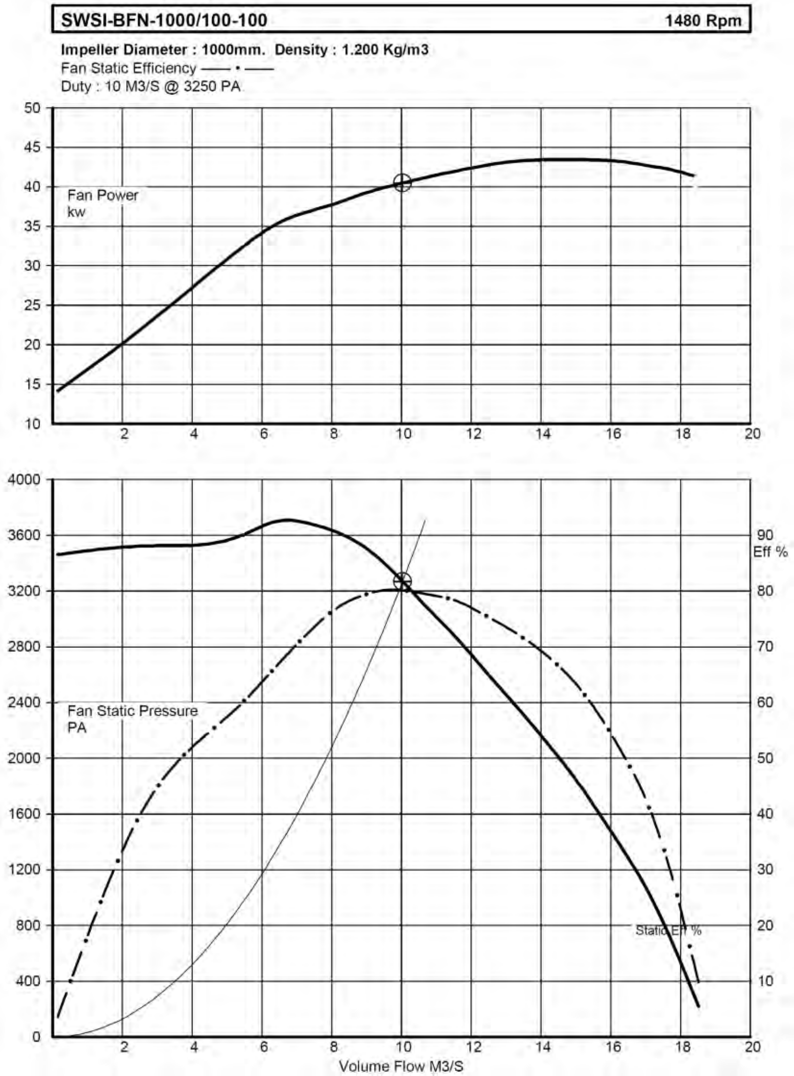
Fans

Key Areas For Coverage

- What is a Fan
- Types of Fan
- Fan Selection
- Fan Laws & Performance Curves
- Understanding your application

What is A Fan?

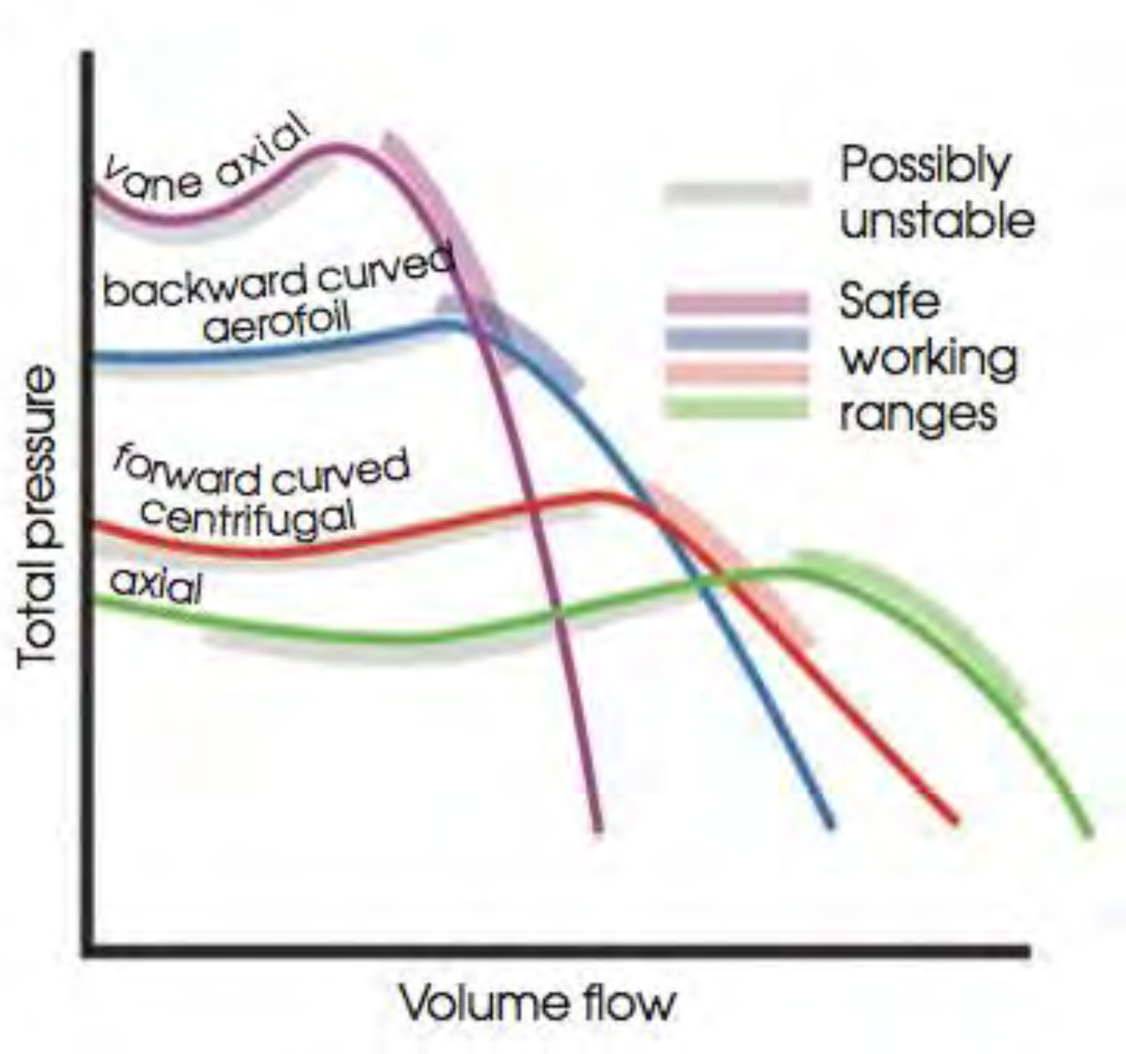
- A fan is a machine for transferring energy into moving air.
- The performance of a fan can be described in terms of Volume Flow, Pressure, Power Absorbed & Efficiency.



Fan Types

Two main fan types:-

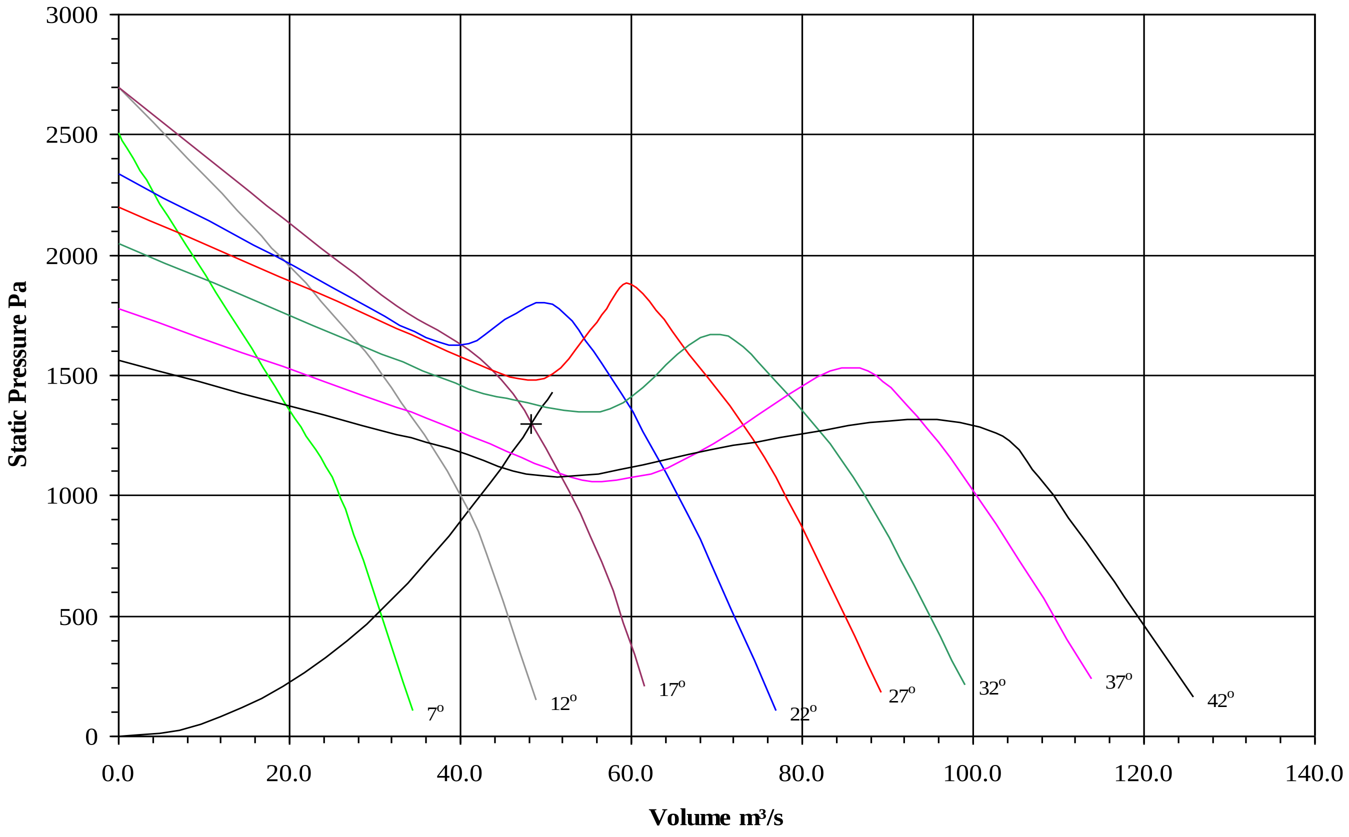
- Axial Flow
- Centrifugal


vane axial
backward curved
aerofoil
forward curved
centrifugal
axial
Total pressure
Volume flow
Possibly
unstable
Safe
working
ranges

Axial Fans

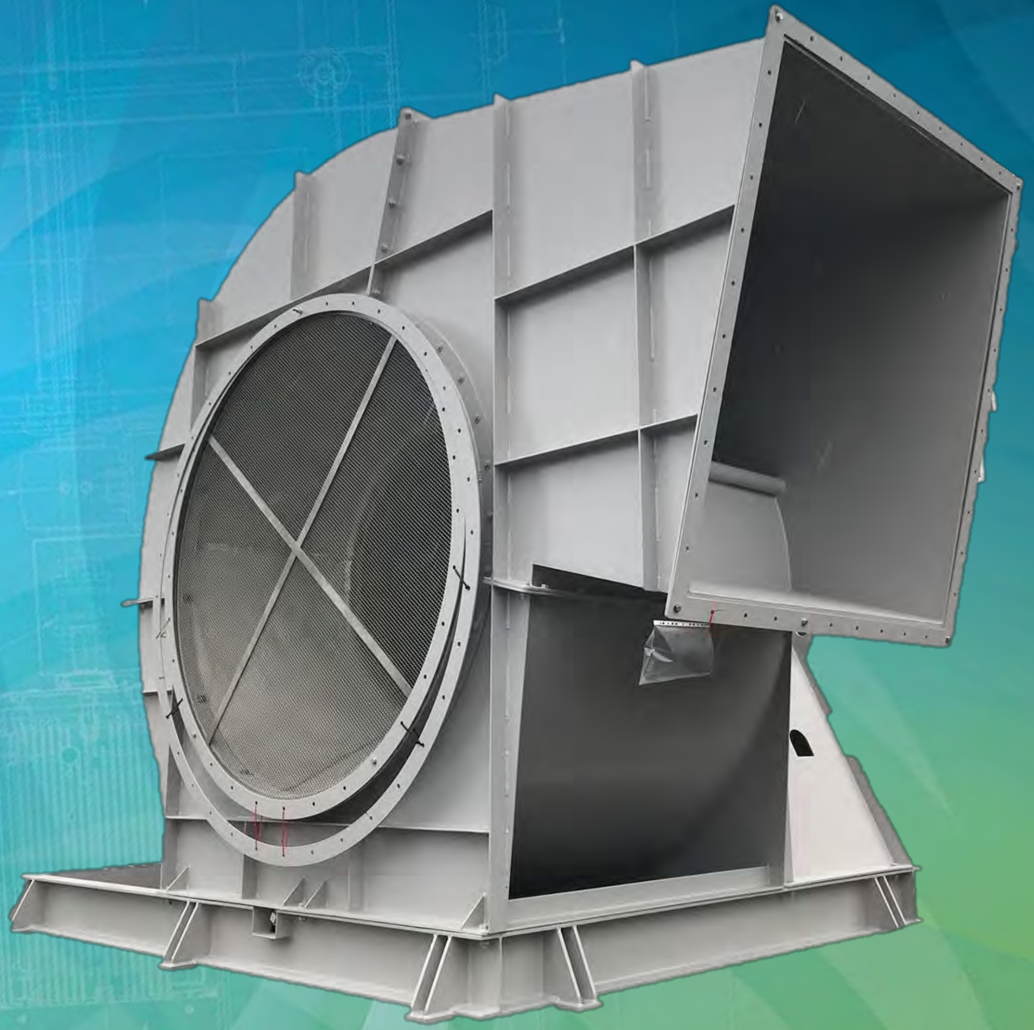
- Generally suited for moving large volumes of air at low pressures.
- Generally low efficiencies- 50%-60%. Larger special designs can achieve static efficiencies in the upper 80's %.
- Larger pitches can have a pronounced stall & can be inherently unstable if selected too far to the left of the fan curve. Should be selected well to the left of peak pressure or select a larger fan at a lower pitch angle.

Axial Fan Curve

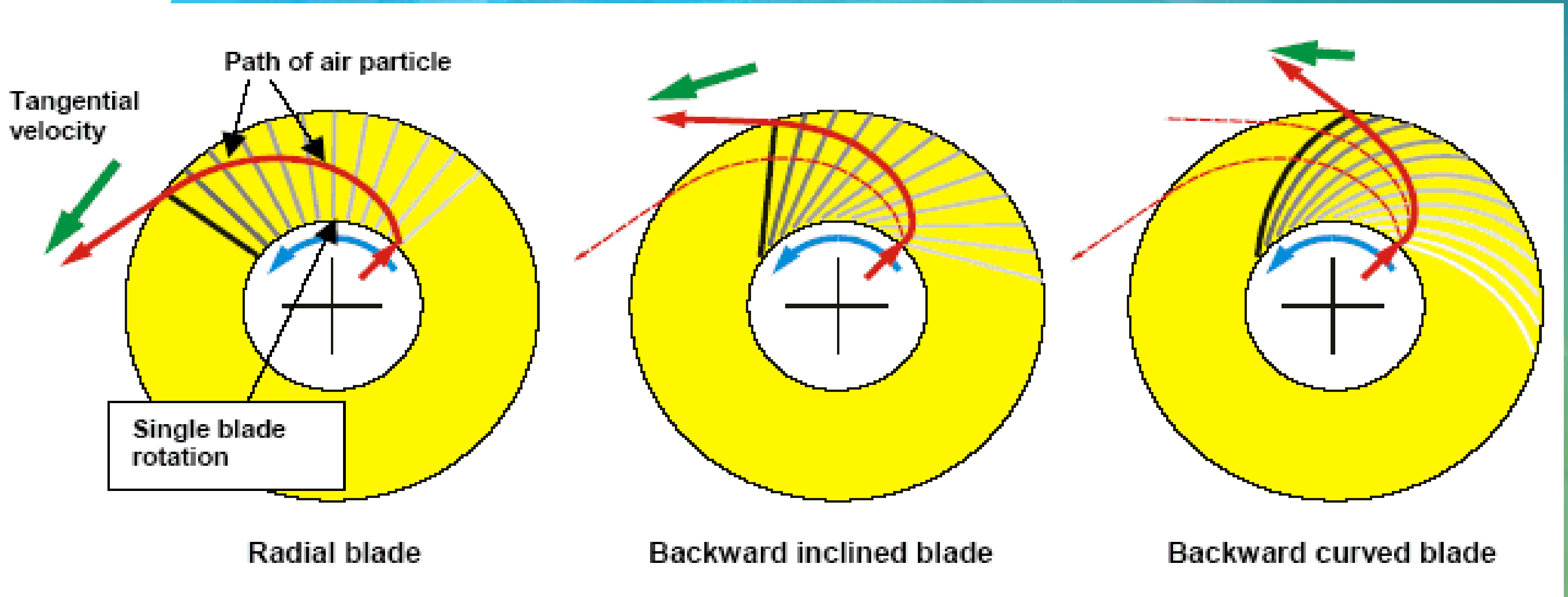


Centrifugal Fans

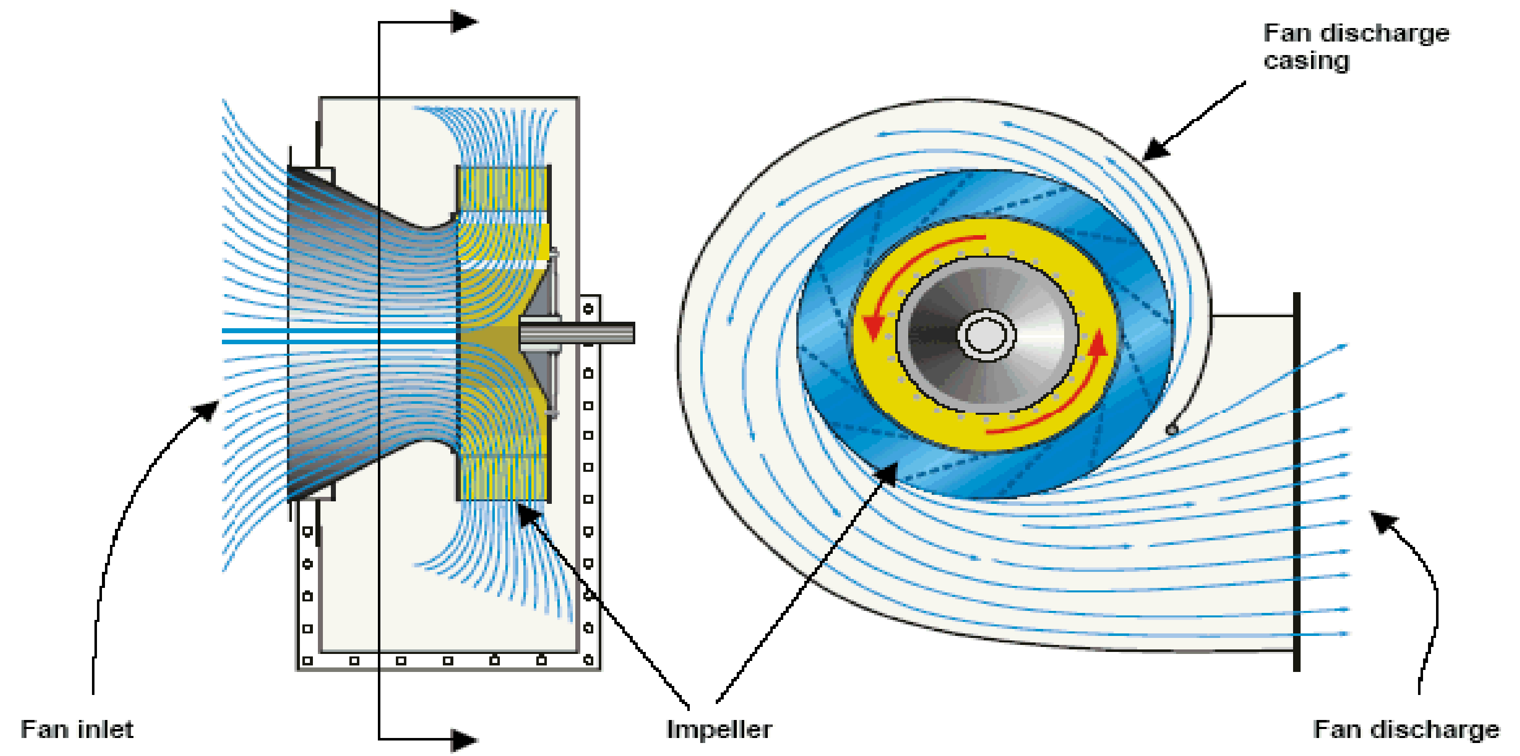
- Air enters axially & exits at 90°.
- Single inlet-all air is drawn in through one inlet. (SISW)
- Double inlet-equal amounts of air drawn in through two opposing inlets. (DIDW)
- Fan case is an expanding volute shape, which assists static pressure regain & directs the airflow in one direction.



Unlike axial flow fans, centrifugal fans principle of operation is to accelerate the air as it passed radially through the impeller.



Velocity profile through a centrifugal fan.



Different types of centrifugal fan Impellers.

Backward Bladed.

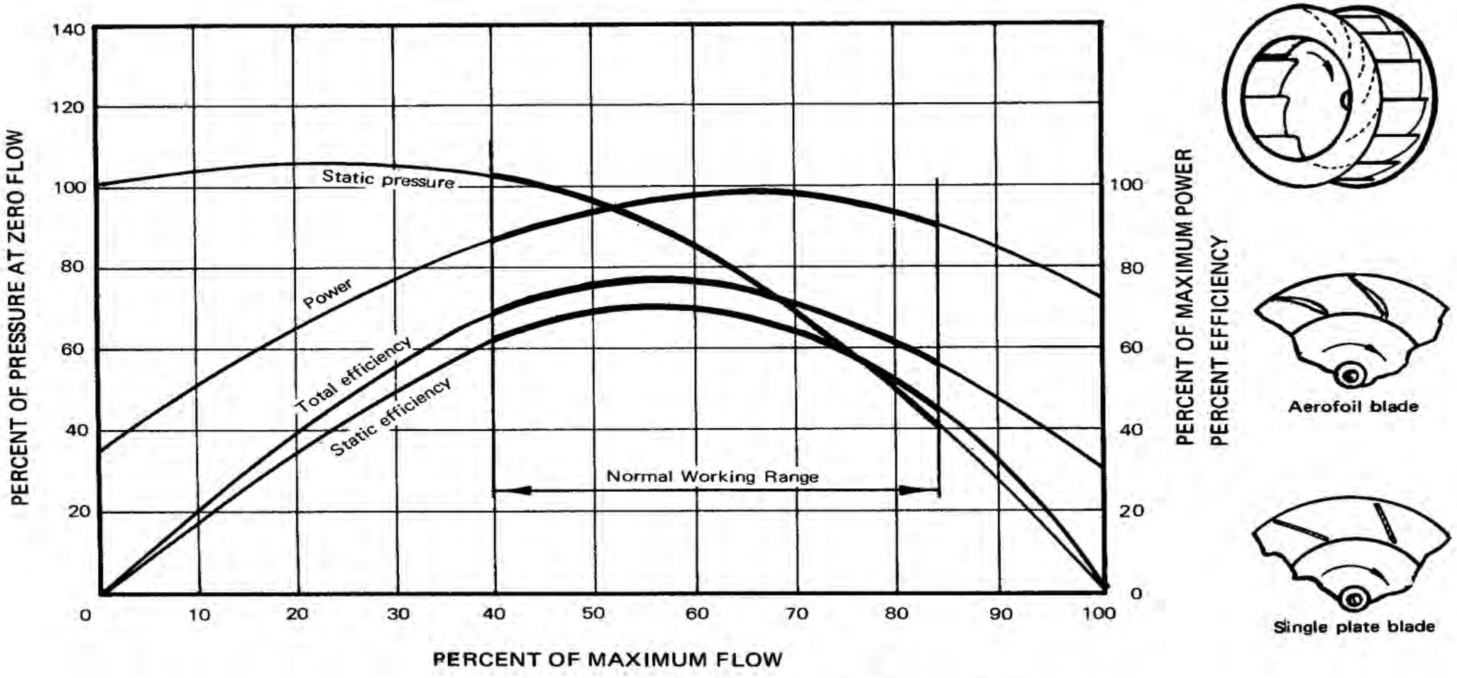
Forward curved.

Radial Bladed.

Backward Bladed

- Flat backward inclined, backward curved & double skin aerofoil.
- High efficiency > 80% static.
- Generally non overloading power characteristic-power absorbed reaches a peak near the maximum efficiency & then becomes lower towards higher flows.
- Can exhibit stall characteristics to the left of peak pressure-this could result in instability & vibration. Fan selection point should always be on the steep part of the curve to the right of peak pressure.
- Can cope with medium erosive gasses in arduous applications.
- Used in HVAC & industrial applications.

Backward bladed impeller characteristic & examples

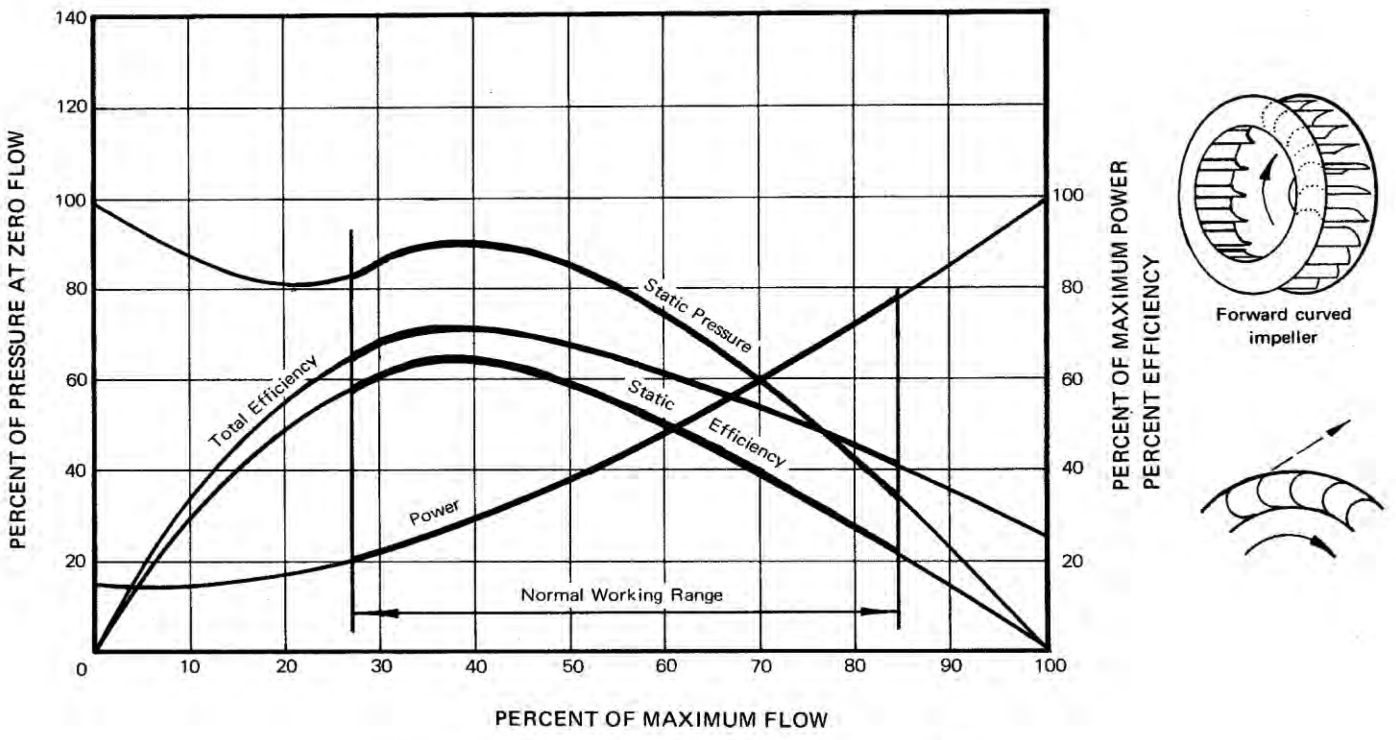


Typical normalised curve for a backward bladed centrifugal fan

Forward curved

- Comparable selections often give a smaller diameter fan than a backward inclined.
- Usually used for large flow rates, low pressure HVAC & air handling unit applications.
- Volume / Pressure characteristic less steep than backward bladed fan.
- No pronounced stall, so can operate over a wider span of the characteristic curve.
- Exhibits an overloading power characteristic – power rises continually towards higher flows.
- Poor efficiency-typically 50% to 60%.

Forward curved (Multivane) characteristic & impeller.

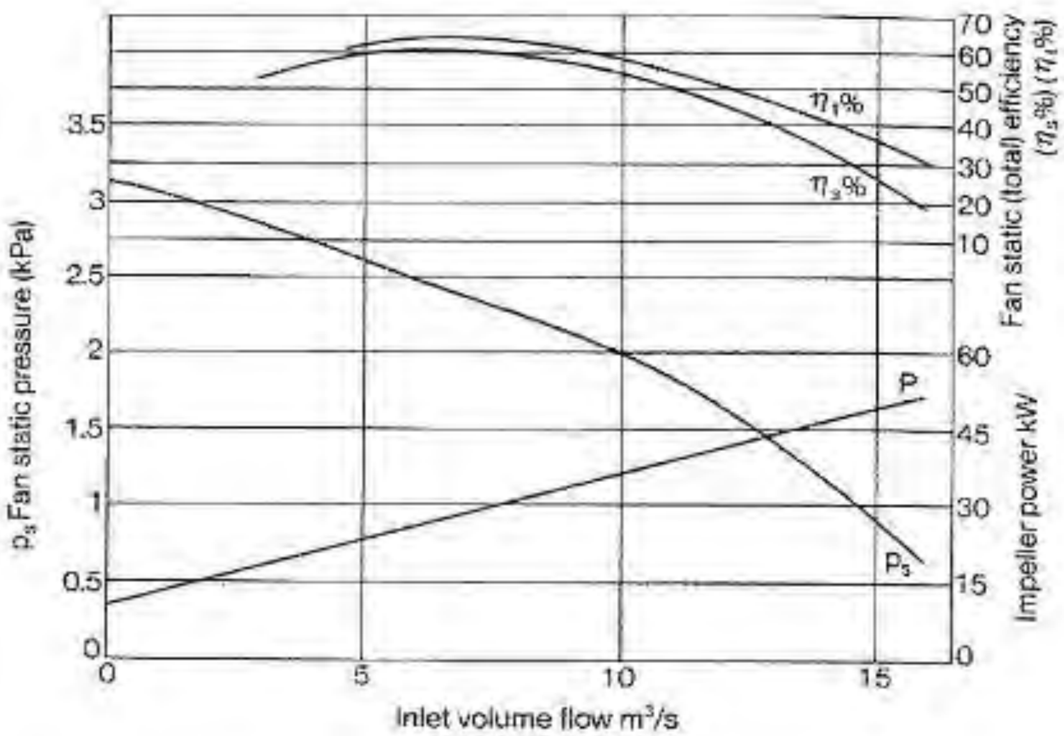


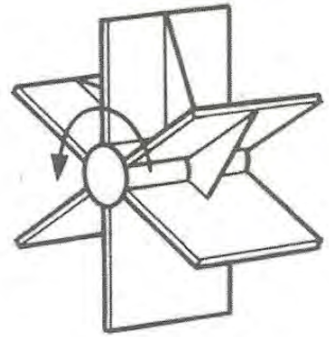
Typical normalised curve for a forward curved centrifugal fan

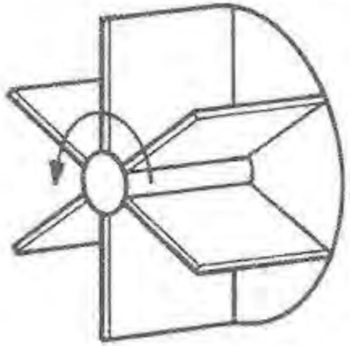
Radial Bladed (Paddle bladed)

- Open paddle, Backplate paddle or Shrouded paddle.
- The un-shrouded version has the highest mechanical strength of all centrifugal types.
- Suitable for heavy dust burdens & high temperatures.
- The characteristic is stable over the whole range of flows.
- Exhibits an overloading power characteristic – power rises continually towards higher flows.
- Narrow types are suitable for high pressure applications such as pneumatic conveying.

Radial Bladed (Paddle bladed)







Understanding your application

Information required to carry out a basic fan selection.

- Flow rate (m³/s, m³/hr, m³/s, cfm, L/s).Actual, Normal or Standard.
- Static Pressure (Pa, kPa, mbar, mm Wg, Ins Wg). The temperature at which the pressure is specified is also required along with the pressure split between inlet & discharge.
- Climatic conditions including temperature, Altitude & Humidity.
- Maximum Operating temperature. If operating at a high temperature, requirement for cold start would also need to be known.
- Zoning safe area/ATEX & now **IECEx**

Information required to carry out a basic fan selection.

Continued ….

- Minimum fan efficiency, if specified.
- Fan arrangement if specified (Direct drive, Direct coupled, v belt etc). The use of an inverter would also have to be indicated.
- Power supply (Voltage, Phase & Frequency).
- Is the fan handling corrosive or erosive gasses.
- Any overall size restrictions, including duct sizes if specified.
- Is single or double inlet required.
- Any noise limitations.

FAN LAWS

Flow Rate varies **directly** as the speed

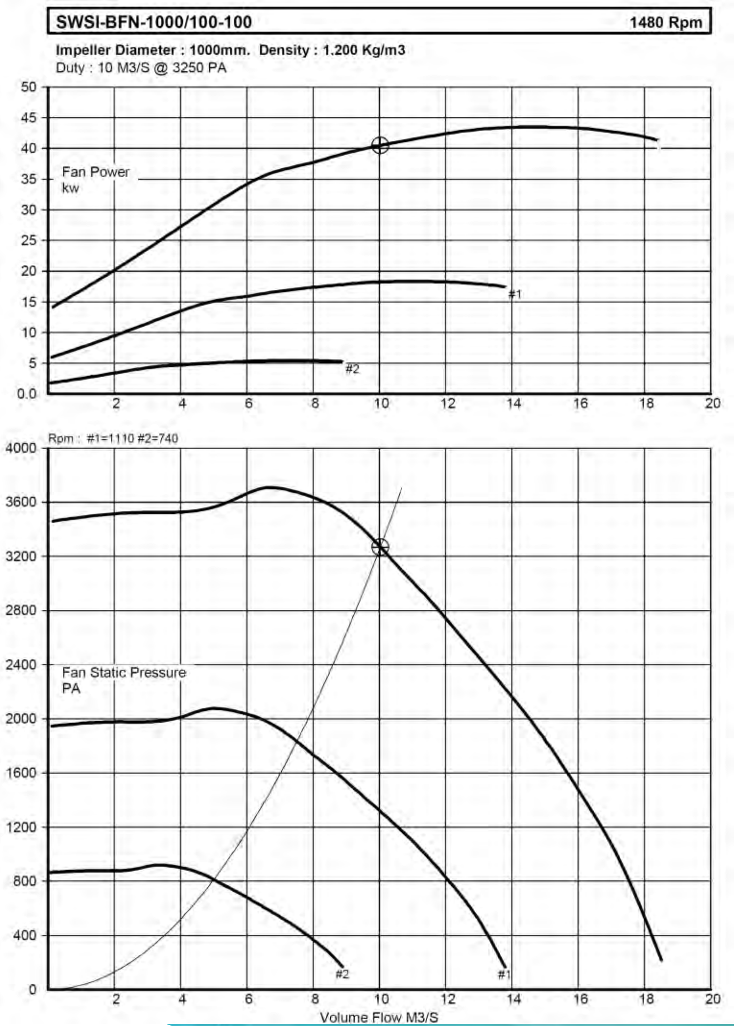
$$Q_2\ m^3/s = (rpm_2/rpm_1) \times Q_1\ m^3/s$$

Pressure varies as the **square** of the speed

$$P_2\ Pa = (rpm_2/rpm_1)^2 \times P_1\ Pa$$

Power varies as the **Cube** of speed.

$$Power_2\ kW = (rpm_2/rpm_1)^3 \times Power_1\ kW$$



Performance Curve Showing Speed Variation

Maximum speed : 1480 RPM.

Reduced speeds :

- 1110 RPM (75%)
- 740 RPM (50%)

Understanding your application

Fan problems

- Installation
- Commissioning
- Trouble shooting
- Fan vibration
- Motor overloading
- Bearing Temperature
- Fan performance

System problems

Factors that influence system effect:

- Elbow or bend too close to fan inlet or outlet
- Abrupt duct transition
- Pre swirl of the incoming air due to duct design. (Swirl in same direction as rotation).
- Dampers not fully open.
- Damper location
- Poorly designed fan drives – large drive pulley - solid rather than spoked.
- Fan inlet or outlet too close to wall or bulkhead.
- Fan inlet box design
- Bend orientations at discharge
- Free discharge – abrupt expansion.
- Weather cowls and hoods

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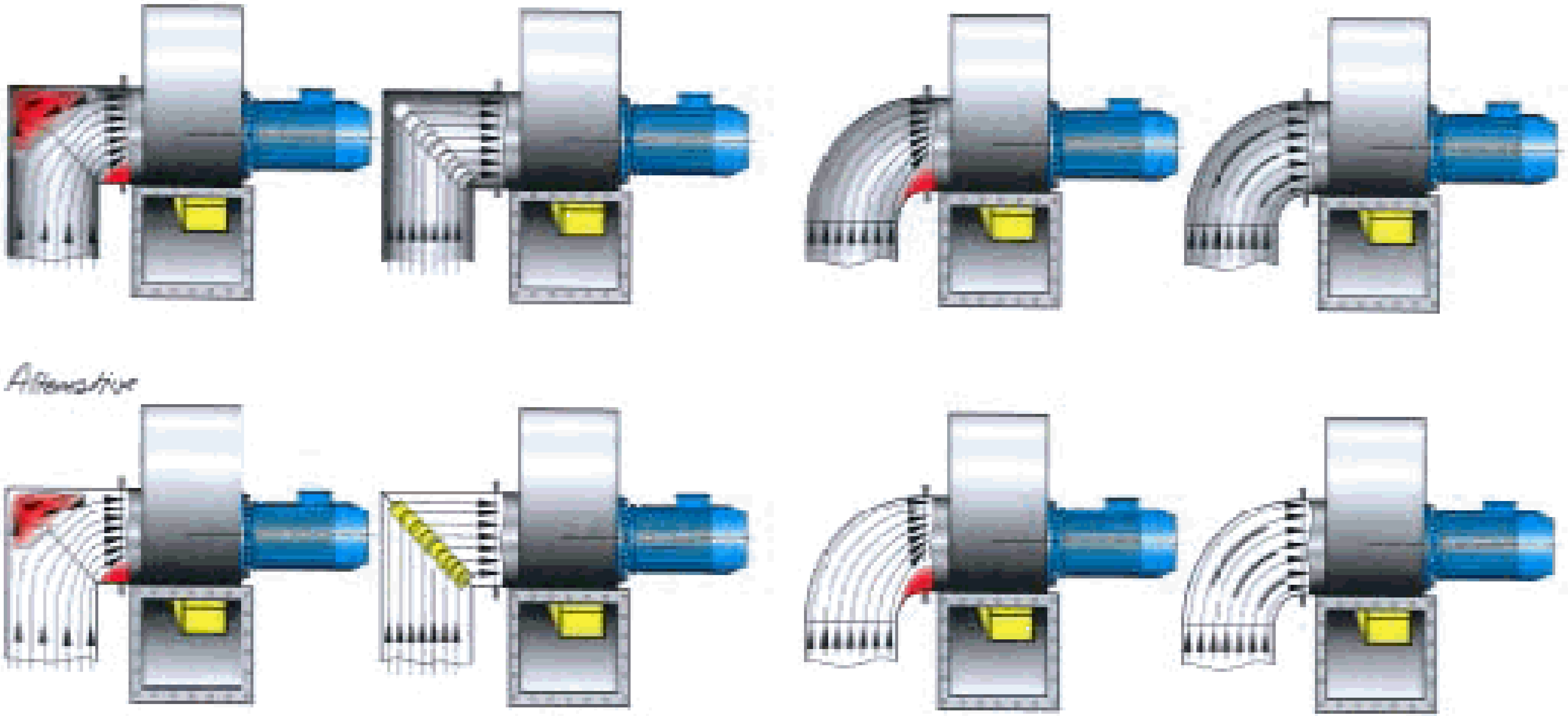
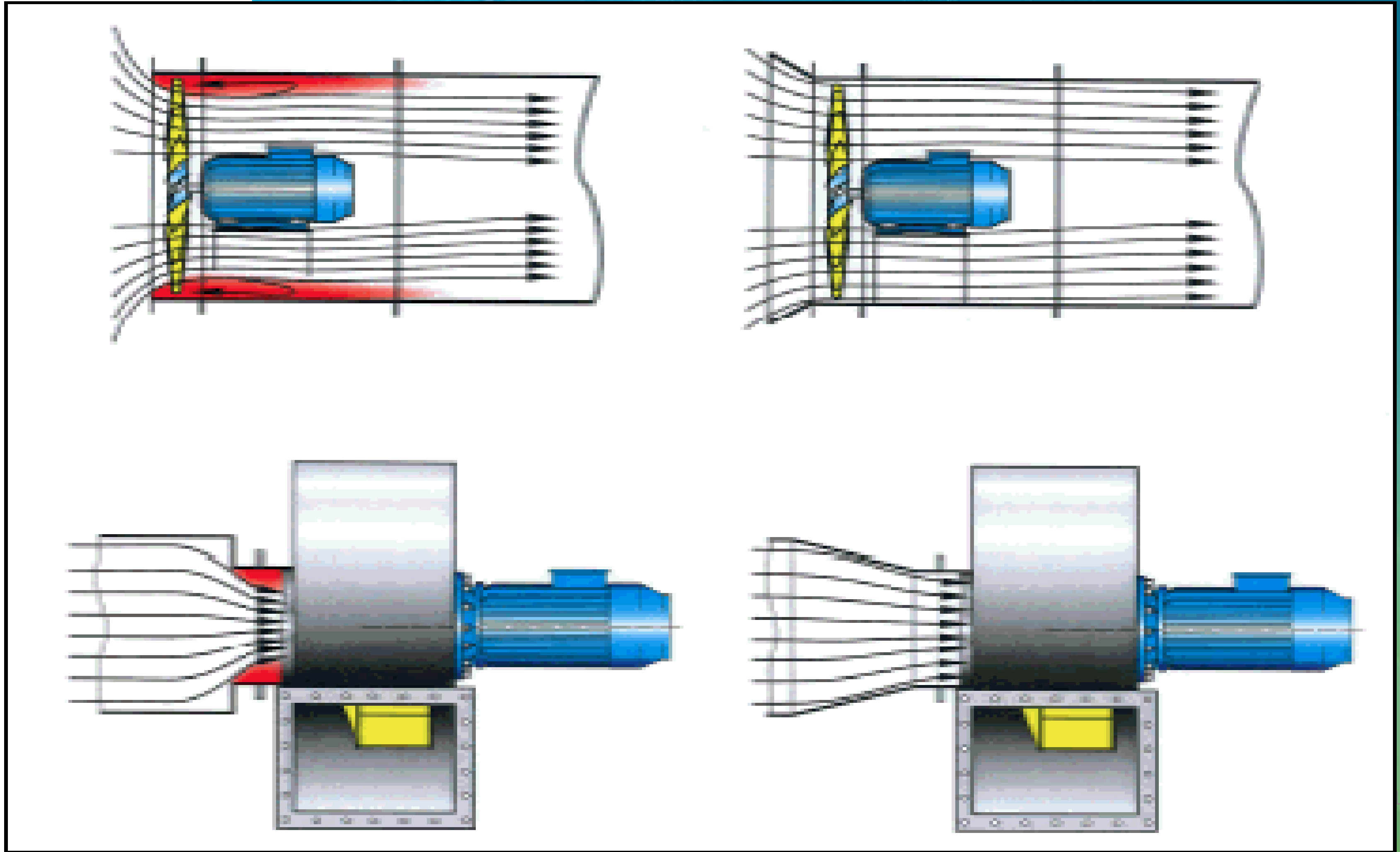
SOME DO'S & DONT'S FOR FAN INSTALLTIONS



DO’S & DONT’S FOR FAN INSTALLTIONS



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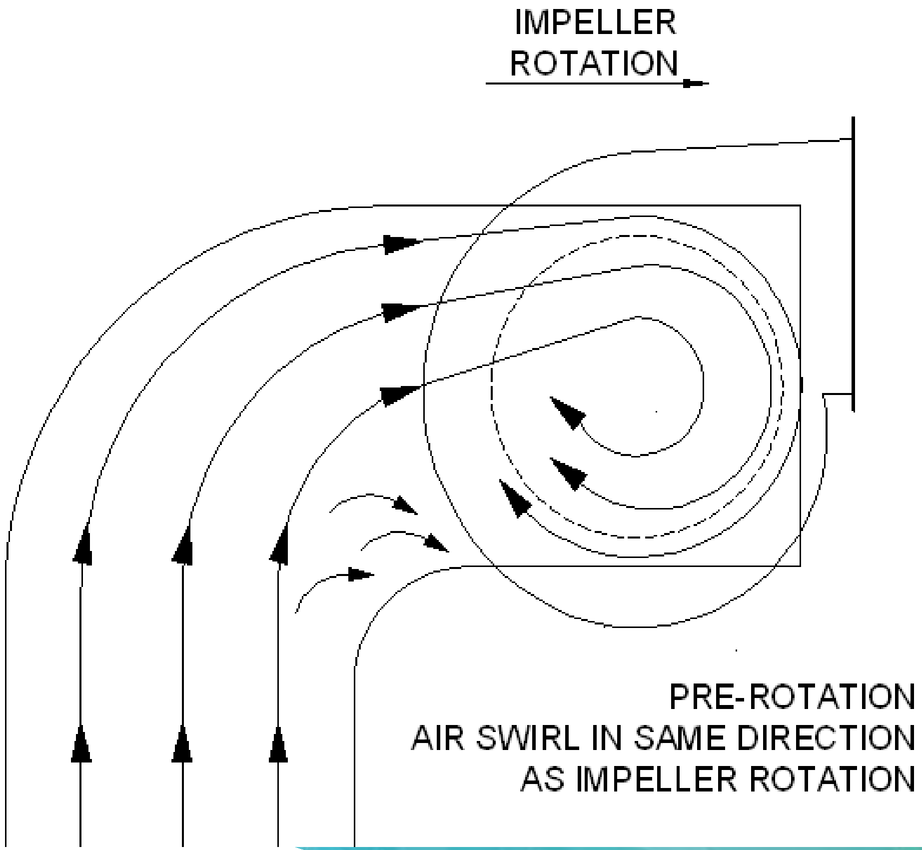

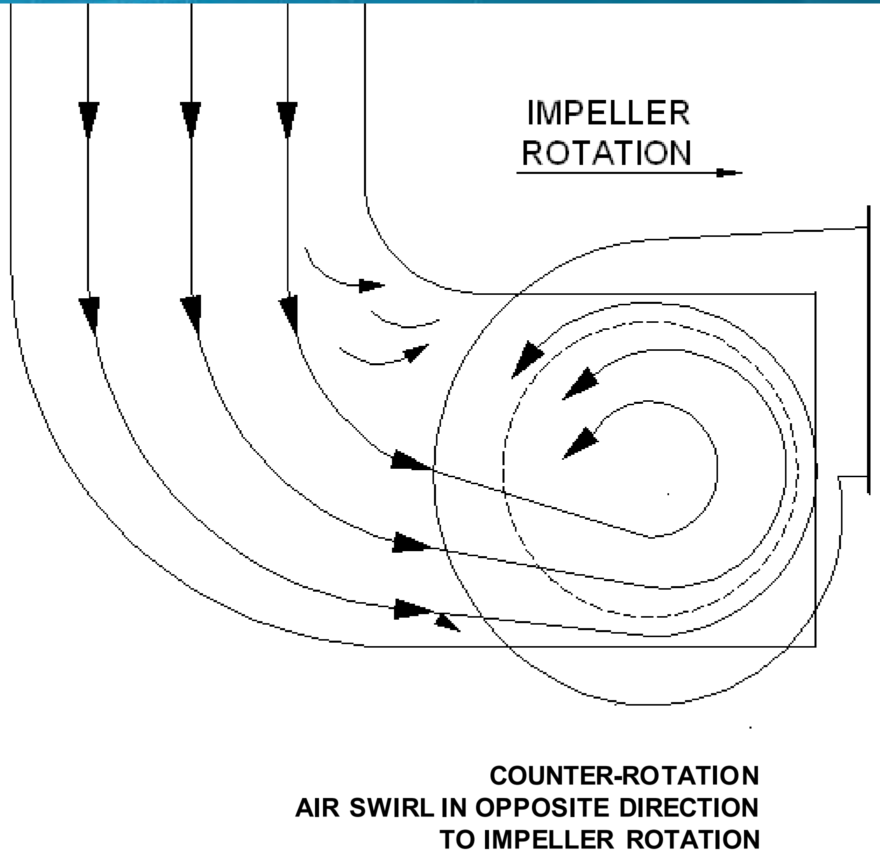

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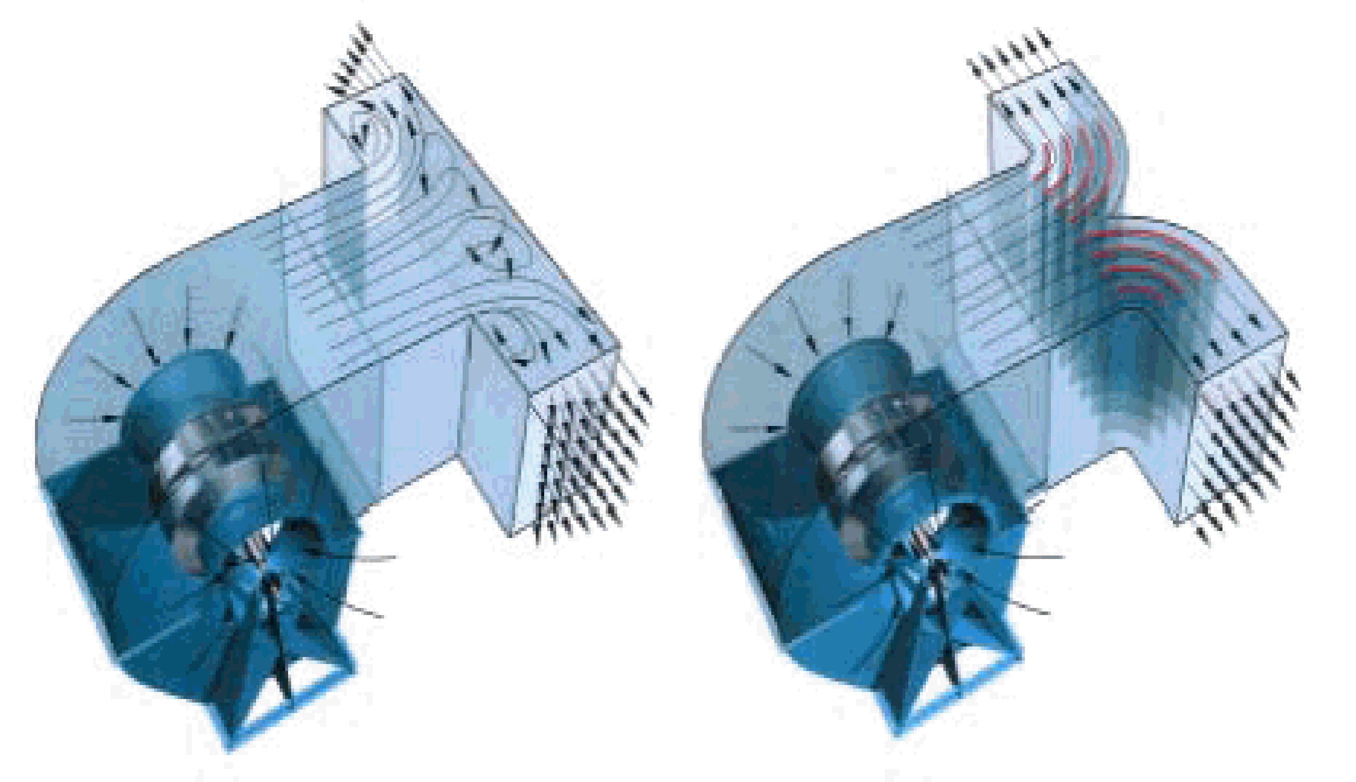

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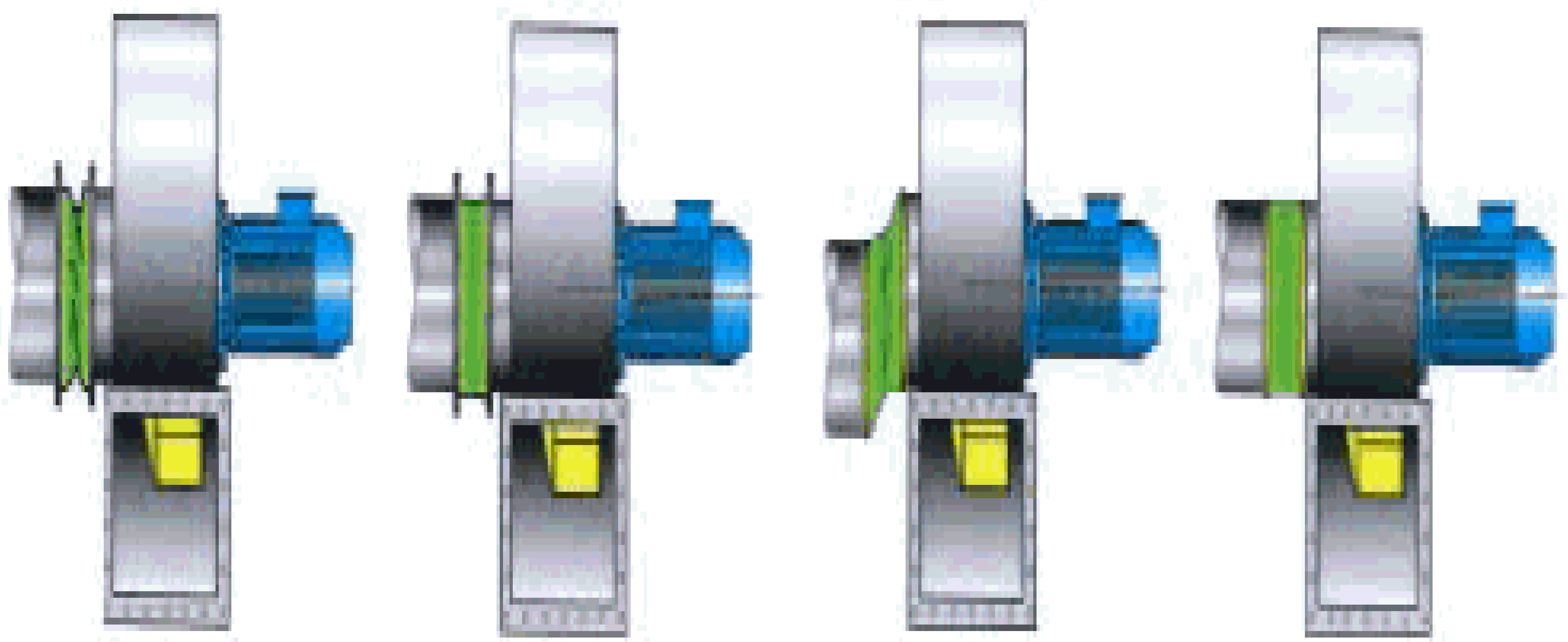
SOME DO'S & DONT'S FOR FAN INSTALLTIONS



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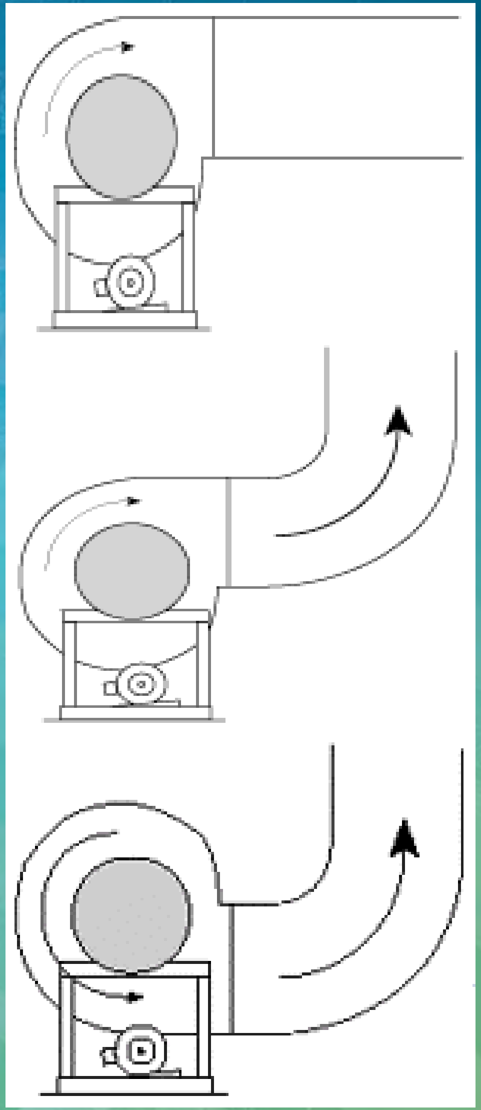
Good Air Flow

Poor Air Flow

Good Air Flow



Uneven Ground & Inadequate Fixings

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Fan installed with AVM

Commissioning

4.2 Pre Commissioning Checks

1. On arrival at site the fan Category, Temperature Class etc. should be checked to confirm compliance with site requirements.

Checks prior to attachment of inlet and discharge ducting.

1. Check fan inlet and discharge for dirt and foreign items, if possible check the inlet ducting and discharge ducting for same.
2. Check inside fan case for dirt and foreign items. It will be necessary to remove inspection / access doors.
3. Check running clearance between inlet cone and impeller eye. Factory Setting is given on Item 'H' of Quality Verification Check List.
4. Check that all moving parts can rotate freely and that no fouling occurs.

Checks after fitting inlet and discharge ducting.

1. Check that the fan is firmly bolted to the floor or steelwork.
2. Check that anti-vibration mounts, if fitted, have been levelled. If not level in accordance with details in installation and maintenance instructions.
3. Check that drive pulleys and belts are correctly aligned and that belts are tensioned correctly. If not adjust in accordance with installation and maintenance instructions.
4. Check that all guards and terminal covers are in place, fitted correctly and firmly secured
5. If flexible connections are fitted with inner sleeves, check that the inner sleeves do not protrude into fan inlet or discharge duct

4.4 Commissioning

The fan should be run for an extended period and the following items measured and logged.

<u>Temperature</u>

NDE & DE fan bearing surface temperatures. Note: temperatures will vary dependent on load and speed. Normal operating temperatures would be between 40 - 50°C but it is more important that temperatures level off below 80°C.
Measure every 10 minutes until 3 successive equal or below readings are obtained.

Fan case temperature at discharge.

Where temperature monitoring equipment is fitted to bearings and case this must be utilised and readings noted for future reference.

Note: Any surface temperature must be below the temperature class specified for the equipment which in this case is:

Electrical

Measure motor line voltage and input current on each phase, log and check that average current is below full load current on motor nameplate.

Vibration

Measure vibration levels on DE & NDE fan bearings. These readings should be generally in line with figures shown in Fan Balance Section of User Instructions Documentation.

Where vibration monitoring Equipment is fitted this must be utilised and readings noted for future reference.

Belt Tensioning

After 24 hours running or when convenient, stop fan, isolate and check belt tension.
Adjust if necessary.

Underperforming

Reasons for fans underperforming

Fan system problems

Fan wrongly selected

Fan running in the wrong direction.

Fan running at the wrong speed.

Fan incorrectly manufactured.

System problems

- Fans will only meet the duty point shown on the performance curve under “ideal” installation conditions.
- Ideal conditions are seldom obtainable in practice consequently there will always be some “SYSTEM EFFECT”.

Fan wrongly selected

Again this will be unusual but must be considered as part of a fault diagnosis. Check that the fan has been selected in accordance with the specification & requirements.
This may include the following :-

- Selection pressure not referred to the correct section ie –ve on inlet +ve on discharge or combination of both.

- Selection pressure not referred to the correct temperature or altitude.

- Selected fan not taking account of existing or required inlet & discharge duct sizes.

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Fan running in the wrong direction

While the fan is running up or coasting to a stop, check that the rotation is correct relative to fan type & discharge orientation.

Check that the impeller handing is correct for the selected rotation.

Examples for centrifugal & axial fans are shown on next two slides

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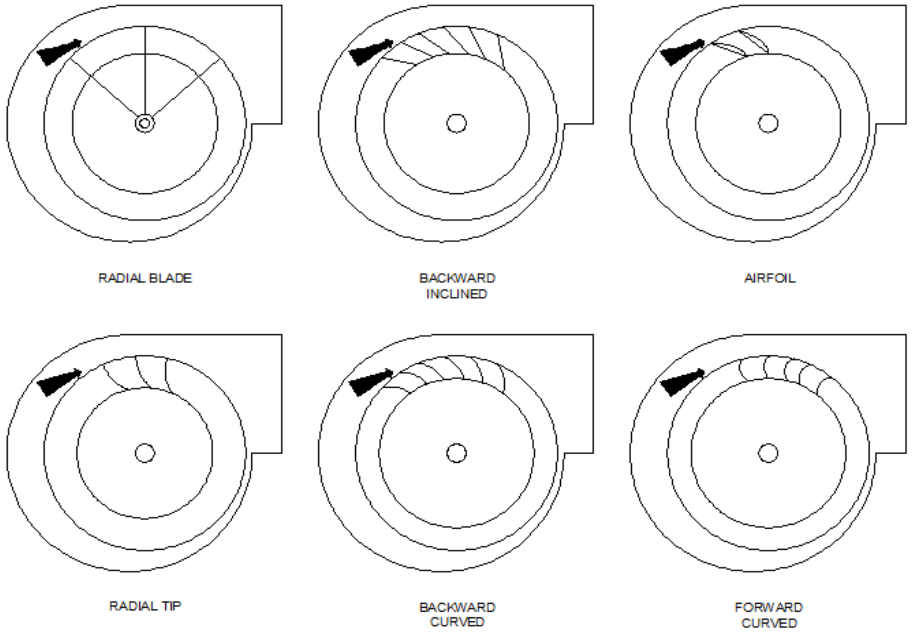
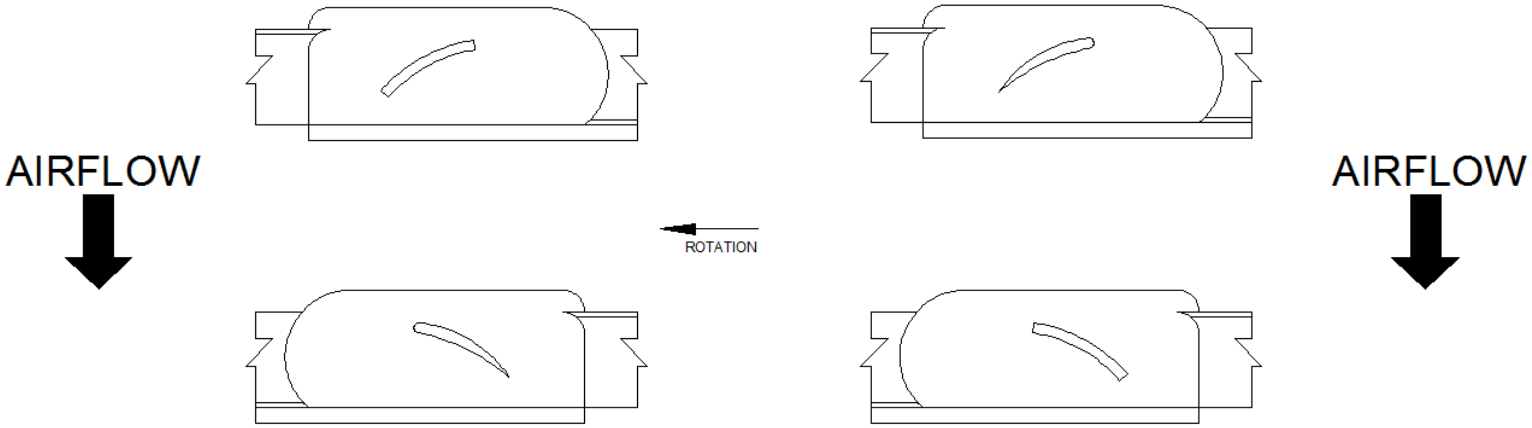
Types of Centrifugal Impellers



Types of Centrifugal Fan Impellers

Correct Rotation for Axial Flow Impellers



Correct Rotation for Axial
Flow Impellers

Fan running at the wrong speed

- Check the required running speed with the supplier. (Note : If the fan is v belt drive the final running speed may be different from the original selected speed due to the use of standard pulley diameters.
- Measure actual fan speed with tachometer or other instrumentation.
- If the fan is operated via an inverter, the fan may be designed to run at a specific speed (motor frequency) other than 50 or 60 Hz. If the fan is v belt drive the motor frequency will probably not be the fan speed.

Fan wrongly selected (Continued)

Selected fan oversized relative to available space constraints (This may lead to bad inlet & discharge conditions).

Wrong running speed selected ie 50Hz Instead of 60Hz & vice versa on direct driven fans.

Over Performing

Reasons for fan over performing.

Fan speed too high

System has less resistance to flow than anticipated.

This is a common occurrence & is due to over estimation of system pressures when calculating the system resistance.

On fans with overloading power characteristics this could result in the motor being overloaded.

Over Power

Reasons for fans to be overpower.

Fan speed too high.

Fan selected at high temperature but run cold.

System has less resistance to flow resulting in the fan working further down its characteristic at a higher power absorbed (The power absorbed could be considerably higher on a fan with a overloading power characteristic).

Mechanical contact of moving & stationary parts (shaft rubbing on seal or impeller catching the inlet cone).

V Belt drive over selected (Drive efficiency low due to too many belts).

Over Power (Continued)

Reasons for fans to be overpower.

Motor & fan pulleys miss-aligned.

Fan inlet conditions creating air swirl in the operate direction to rotation (This will result in increased fan performance & power absorbed).

Fan Mechanical (Balance & Vibration) Problems

Fan balancing & vibration is in accordance with BS848-7 BS ISO 14694.

Woodcock & Wilson Ltd have selected “Fan application category : BV-3 for fans ≤ 37kW & BV-4 for fans >37 kW.

The balance quality grade for these categories are G 6.3 & G 2.5 respectively.

The tables on the next two slides are taken from the above standard.

They give vibration limits for tests in manufacturers work-shop & recommended vibration limits for fans operating in situ.

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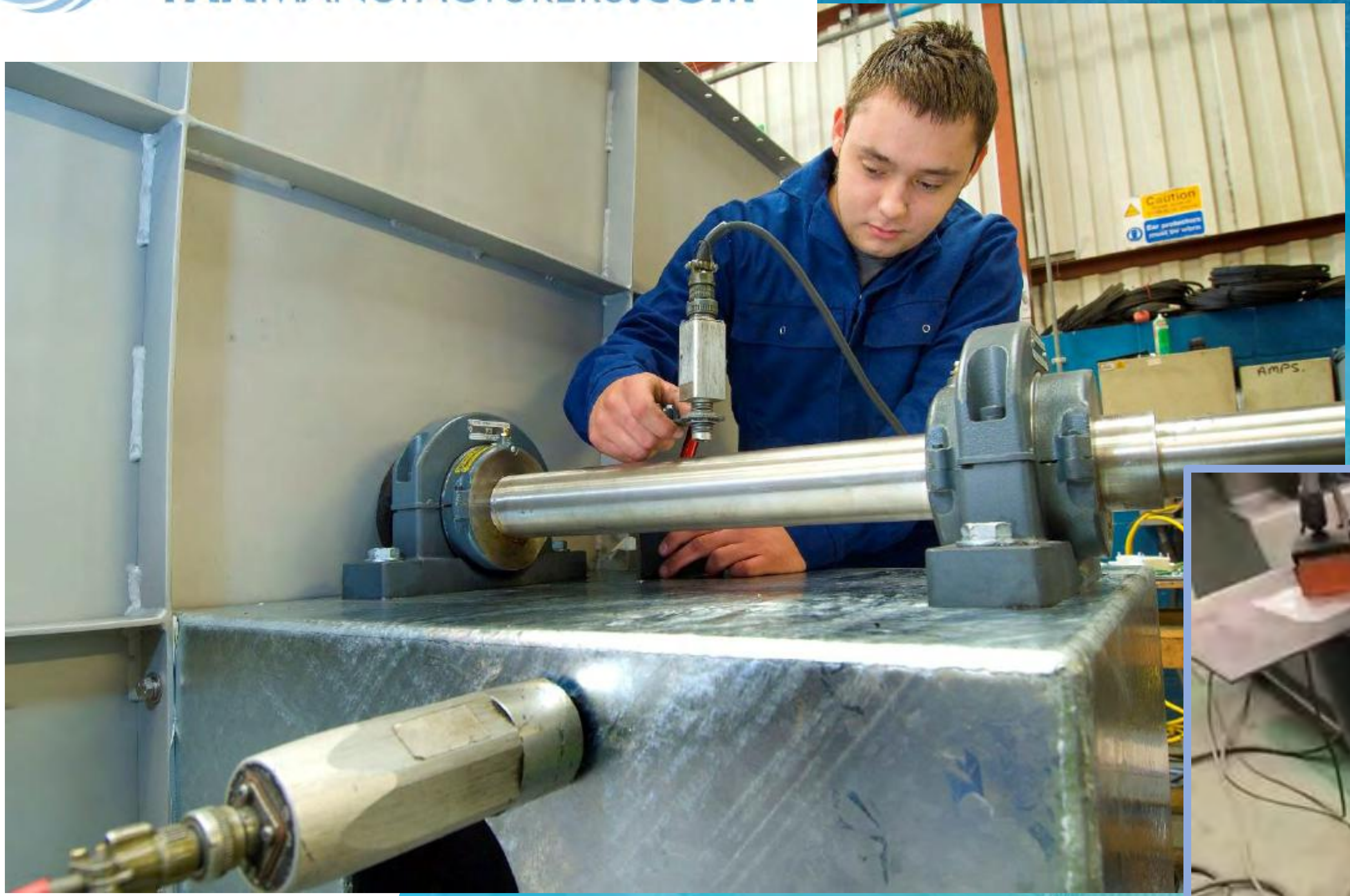

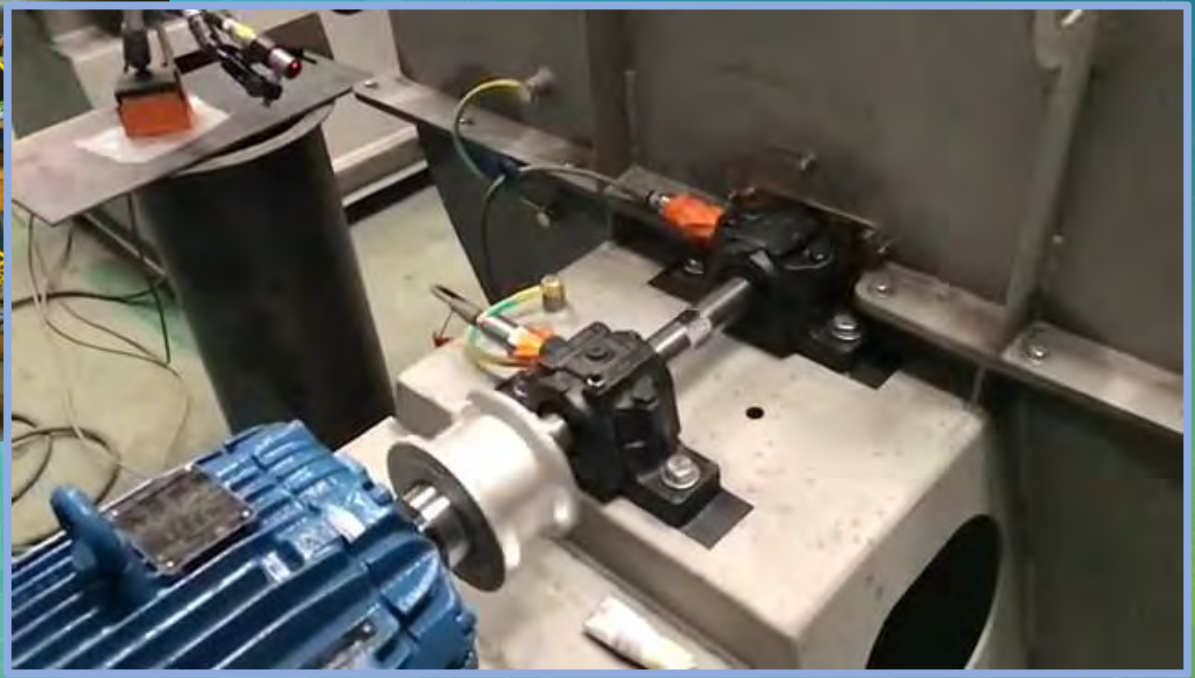

Fan vibration limits for fans operating in situ.

Condition	Fan-application category	Rigidly Mounted mm/s		Flexibly mounted mm/s	
		Peak	r.m.s	Peak	r.m.s
Start-up	BV-3	6.4	4.5	8.8	6.3
	BV-4	4.1	2.8	6.4	4.5
Alarm	BV-3	10.2	7.1	16.5	11.8
	BV-4	6.4	4.5	10.2	7.1
Shut-down	BV-3	12.7	9	17.8	12.5
	BV-4	10.2	7.1	15.2	11.2

The vibration levels on the table before are guidelines for acceptable operation of fans.

The vibration level of newly commissioned fans should be at or below the "start up" level.

Historical data is an important factor when considering vibration severity.

A sudden & maintained change in the vibration level may indicate the need for prompt inspection or maintenance.

Possible reasons for excessive vibration experienced during commissioning

- Fans test run & balanced in the manufacturers works & delivered as a complete, fully assembled fan.
- Mechanical problems:-
- Damage to fan during transport causing out of balance or misalignment problems
- Foreign bodies on impeller causing out of balance.
- Fan pedestal distorted during installation causing drive chain misalignment.
- Incorrect selection or fitting of anti-vibration mounts.
- Loose holding down bolts.
- Defective foundations.

System or system effect problems :-

System has greater resistance to flow than anticipated resulting in the fan operating further up the characteristic in a stalled section. Depending on fan type, vibration may be experienced when operating in the stalled area.

On fans fitted with inlet vanes or inlet louvers on an inlet box, vibration may be experienced at lower vane angles due to a condition known as inlet cone vortex.

Bends or other obstacles fitted to the fan inlets or discharge may cause airborne instabilities resulting in vibration (see “V fan system problems “in “underperforming” section).

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Fan Maintenance & Servicing

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Where great service matters

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Read the manual
Review commissioning data

It is advisable to engage the services of a Woodcock & Wilson Ltd service engineer to carry out or supervise commissioning of the fan, however if the client or clients representative is to carry out this work the following pre-commissioning checks, starting and commissioning procedures must be adhered too. The check lists must be completed, signed, dated and returned to Woodcock & Wilson.

Over 400 ATEX fans were delivered last year
we have not received any commissioning data!

Ex

IEC IECEx

Fan Servicing
Dependent on the application

Monthly

1. Where applicable with the fans stopped remove the fan casing drain plug, allow any accumulation of liquid to drain away and then replace the plug.
2. Remove casing inspection doors and look inside for excessive dirt build up and clean if necessary. Check for damage to impeller or evidence of any rubbing contact.
3. If possible check running clearance between impeller eye and inlet cone.
4. shaft seal for damage or wear and replace if necessary.
5. Ensure any monitoring devices are operating correctly.

Fan Maintenance & Servicing

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Annually

A thorough annual inspection and maintenance procedure should be carried out by an engineer experienced in ATEX/IECEx applications

Remove the bearing caps and examine the condition of bearings and seals.

Thoroughly examine flexible joints for damage or deterioration.

Inspect all steelwork and repair any damaged paint areas.

Examine the condition of brass anti-spark materials for wear, corrosion or deterioration and replace if necessary.

Remove drive guard and inspect drive belts for wear or deterioration. Check for any evidence of rubbing between shafts, pulleys and guards. Check belt tension.

Vibration Levels

Possible reasons for increased vibration levels after successful commissioning :-

Dust or product build up on the impeller.

Impeller deterioration due to wear or corrosion.

Fan bearing deterioration.

Component looseness (Impellers, couplings pulleys etc).

Product Build Up

Under Greasing

Over Greasing

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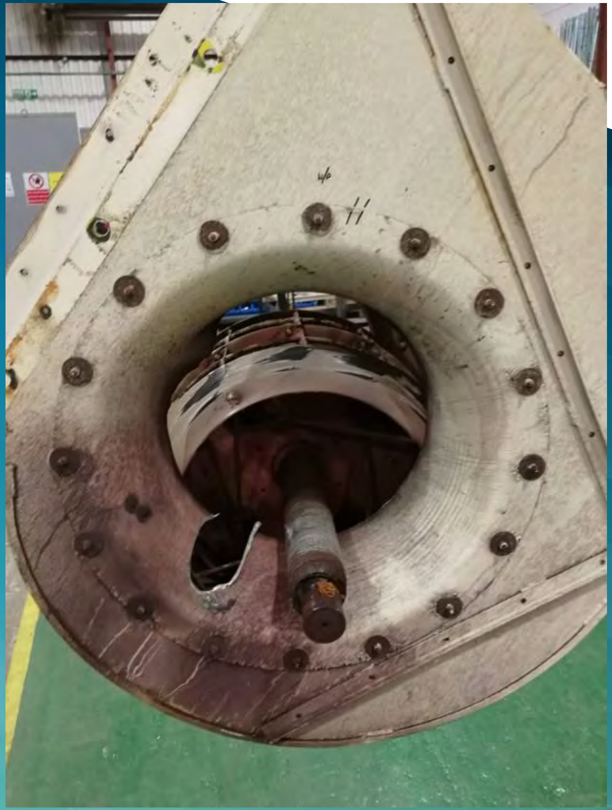
Poor Maintenance



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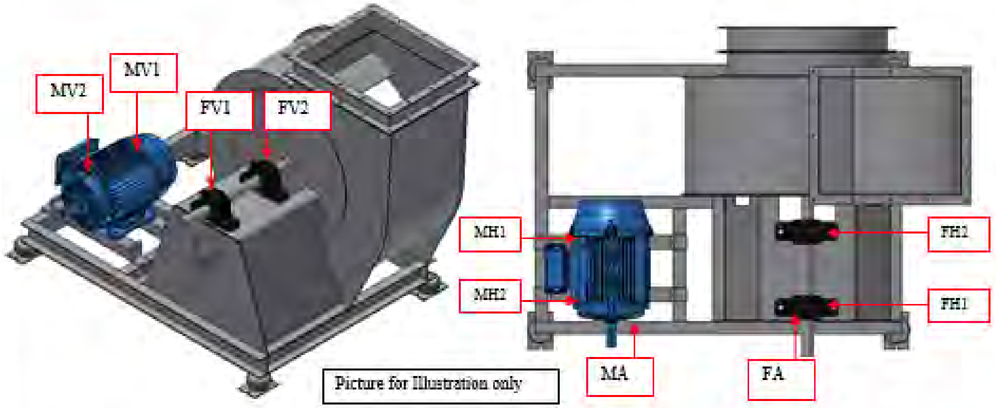
Report Sheet

Our Ref:	C#####	Date Of Report:	08 February 2019
Company:		Date Of Works:	
F.A.O:		Page:	1 of 3



Picture for Illustration only

Fan Manufacture & Serial No:		Inverter Driven:	
Fan Size & Type:		Inverter Hz:	
Fan Plant ID Ref:		Fan pulley & taper-lock:	
Motor Speed:		Motor pulley & taper-lock:	
Motor Power:		Belt Details:	
Bearing Details:		Other Details:	

Version 02

CFM

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Report Sheet

Our Ref:	C#####	Date Of Report:	08 February 2019
Company:		Date Of Works:	
F.A.O:		Page:	2 of 3

Pre-Works										
HZ	Mtr Horizontal		Mtr Vertical		Mtr Axial	Fan Horizontal		Fan Vertical		Fan Axial
	H1	H2	V1	V2	A	H1	H2	V1	V2	A
mm/s										
G's										

Pre-Works Comments:

Post-Works										
HZ	Mtr Horizontal		Mtr Vertical		Mtr Axial	Fan Horizontal		Fan Vertical		Fan Axial
	H1	H2	V1	V2	A	H1	H2	V1	V2	A
mm/s										
G's										

Post-Works Comments:

Complete Fan Maintenance Ltd
Airstream Works, Blackmoorfoot Road, Crosland Hill, Huddersfield, HD4 7AA, United Kingdom.
Internet: www.completefanmaintenance.com Email: sales@completefanmaintenance.com
Tel: +44 (0) 1484 461 777 Fax: +44 (0) 1484 462 333
Registered in England No. 3387958

Report Sheet

Our Ref:	C#####	Date Of Report:	08 February 2019
Company:		Date Of Works:	
F.A.O:		Page:	3 of 3

Photos:

Signature -

Report Sheet

Our Ref:	C#####	Date Of Report:	08 February 2019
Company:		Date Of Works:	
F.A.O:		Page:	4 of 3

APPENDIX 1

Vibration

WW/CFM use ISO14694:2003 as a point of reference when making any assessments in relation to a fans mechanical operational performance (balance and vibration levels).

Vibration is an important factor in assessing the overall performance of a fan. It gives a general indication of the fan units running condition and can be used to alert the operator to possible future operational issues.

Although other standards exist and cover the general vibration of machines, these are limited due to their generic nature. ISO14694 is written especially for fans and covers specific areas such as:-

- Design evaluations
- In – situ testing
- Condition monitoring
- Fan structure considerations
- Quality assessment

The International standard ISO14694 specifies limits for vibration of fans in varying applications, installations and sizes.

The standard classifies a fans size and application into Balance and Vibration categories (BV Categories), as below

Application	Example	Driver power (kW)	Application category, BV
Residential	Ceiling fans, attic fans, window AC	≤0.15 >0.15	BV-1 BV-2
HVAC / Agricultural	Building ventilation and air conditioning commercial	≤3.7 >3.7	BV-2 BV-3
Industrial Process / Power Generation	Baghouse, scrubber, conveying, combustion air, boilers, pollution control, wind tunnels	≤300 >300	BV-3 See ISO10816
Transportation and Marine	Locomotive, automobiles	≤15 >15	BV-3 BV-4
Transit / Tunnel	Subway emergency ventilation, tunnel fans, jet fans, garage ventilation	≤75 >75	BV-3 BV-4
Petrochemical Process	Hazardous gases, process fans	≤37 >37	BV-3 BV-4
Computer – chip manufacture	Clean rooms	any	BV-5

The *in situ* vibration levels recommended by ISO14694 are not solely on the balance condition of the fan. Other factor have an influencing effect on overall vibration, such as quality of installation, mass and stiffness of the supporting structure, accessory rotating equipment (belts, couplings, motors) along with duct design and aerodynamic performance.

The vibration limits given below are guidelines for the acceptable running condition of a fan in various BV categories. These are unfiltered velocity readings taken on the bearing housing in mm/sec RMS.

The vibration level of a newly commissioned fan should be below "start-up". It is expected that the vibration level will increase with time due to wear and other effects. In general, any vibration reading below "alarm" is reasonable and safe.The standard recommends that any vibration levels are recorded above "alarm", then an investigation should be carried out immediately to find the cause and rectify. Operation at this condition should be carefully monitored and limited to the time required for correction.

If vibration levels reach beyond "shut-down", then immediate corrective action should be taken or the fan should be turned off. Failure to reduce vibration below "shut-down" levels to something acceptable could result in bearing failure, cracking of rotor parts and fan housing structural welds and ultimate catastrophic failure.

Condition	Application Category	RIGID MOUNTING mm/sec RMS	FLEXIBLE MOUNTING mm/sec RMS
Start-up	BV-1	10	11.2
	BV-2	5.6	9.0
	BV-3	4.5	6.3
	BV-4	2.8	4.5
	BV-5	1.8	2.8
Alarm	BV-1	10.6	14.0
	BV-2	9.0	14.0
	BV-3	7.1	11.8
	BV-4	4.5	7.1
	BV-5	4.0	5.6
Shutdown	BV-1	NOTE 1	NOTE 1
	BV-2	NOTE 1	NOTE 1
	BV-3	9.0	12.5
	BV-4	7.1	11.2
	BV-5	5.6	7.1

NOTE 1 : Shutdown levels for BV-1 & BV-2 applications should be based on historical data.Historical data is of primary importance when assessing vibration levels of a fan. Any sudden changes in in vibration magnitude warrants immediate investigation. A benchmark should be understood for each individual installation based on general operating levels.

Any Questions

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BOHS / ILEVE
LEV - Extracting the best practices
Birmingham – February 2019

Tracer gas test to verify fume cupboard containment

Melvyn Sargent MILEVE

Member of British Standards Institute LBI/001/01 Laboratory furniture and fittings
Member of CEN TC 332 WG4 Fume cupboards and associated ventilation
Member of the Institute of Local Exhaust Ventilation Engineers

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Health and Safety at Work (1)

Those who supply, own and use Local Exhaust Ventilation (LEV) have legal duties:

- The employer of the people being protected by the LEV has legal responsibilities under the Health and Safety at Work Act 1974, the Control of Substances Hazardous to Health Regulations (COSHH) 2002 (as amended) and the Management of Health and Safety at Work Regulations 1999 (MHSWR).

- LEV suppliers have legal responsibilities under the Health and Safety at Work Act 1974; the Supply of Machinery (Safety) Regulations 2008 (SMSR), including 'essential health and safety requirements'.

- Service providers have legal responsibilities under the Health and Safety at Work etc. Act 1974 and the The Construction (Design and Management) Regulations 2015

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Health and Safety at Work (2)
Control of Substances Hazardous to Health - COSHH

Summary of COSHH regulations 2002 and Local Exhaust Ventilation (LEV):

Reg 6 – Risk assessments
Asses the hazardous, risks and formulate and assessment to provide control

Reg 7 – Prevention and control of exposure
Guide to establish elimination, substitution, reduction, control and management of identified risk

Reg 8 – Use of Control Measures
Employer has a duty to ensure training and correct use of the control by employees and to monitor, inspect, test, report and rectify defect or failures with the control measure

Reg 9 – Maintenance, Examination & Testing of Controls
Employers shall ensure all local exhaust ventilation systems are thoroughly examined and tested at least once in a 14 month period to ensure effective control is provided.

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Health and Safety at Work (3)
COSHH Reg. 7 – Prevention & Control of Exposure

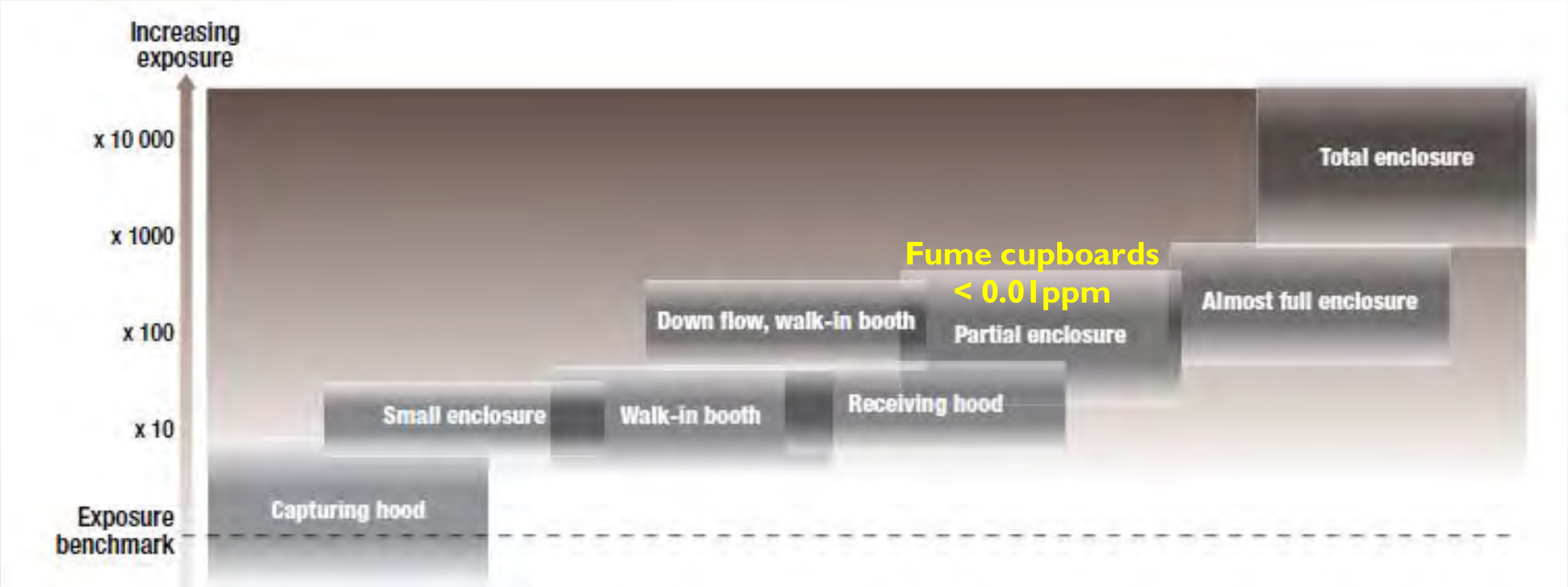

Figure 9 'Effectiveness of various types of LEV' - HSE /HSG 258 Controlling airborne contaminants at work

The designer needs to understand how effective LEV is in each specific situation. It should be capable of adequately controlling the contaminant cloud. For example, an LEV hood capable of reducing exposure 10-fold is unsuitable to control a source capable of emission at 50 times a benchmark exposure value. However, there is limited information on the effectiveness of LEV. Figure 9 proposes some indicative ranges for the effectiveness of various types of LEV.

This image and text copied from page 23 Controlling airborne contaminants at work - A guide to local exhaust ventilation (LEV) ISBN 978 0 7176 6415 3

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Confidence in selection assessment (1)

Where is tracer gas testing for fume cupboard containment a requirement?

- For compliance with BS EN 14175-2:2003 – Fume cupboards Part 2 Safety and performance requirement. Always performed for type test but optional at commissioning and periodic/maintenance inspections.

- When following guidance in HSG 258 'Controlling airborne contaminants at work' section 354 advises 'Fume cupboards and microbiological safety cabinets should also be further tested according to appropriate British or European standards'.

- As specified in BREEAM – Hea 03 Safe containment in laboratories – Assessment criteria 2 :- 'Where containment devices are specified, their manufacture and installation is carried out in accordance with national best practice standards for safety and performance requirements in laboratory containment devices, or are manufactured and installed in accordance with the following standards: 2.a General purpose fume cupboards: EN 14175 Parts 1-7 (as appropriate)'

Confidence in selection assessment (2)

When is tracer gas testing for fume cupboard containment recommended?

- **Where** the COSHH risk assessment specifies a minimum containment for the fume cupboard or includes a maximum ppm leakage value for containment at type test or as installed requirement.
- **Where** confirmation of containment for fume cupboards pre 2003 which may not have been tested in accordance with BS EN 14175-2:2003 – Fume cupboards Part 2 Safety and performance requirement is required.
- Where fume cupboard containment must be quantified at different sash positions, with varying air volume (VAV) flows (min-normal-max), during dynamic sash operation, with disturbances to flow of air into the workspace (robustness) and for high thermal loads in workspace
- **When** a ppm value of fume cupboard containment in 'as installed' environment is required.
- **When** a ppm value of fume cupboard containment in the 'as used' configuration is required.

Important metrics used in the evaluation of fume cupboards performance (1)

Smoke visualisation:- Provides visual indication of direction and turbulence of air but no quantitative value of fume leakage from fume cupboard

Velocity profile:- Enables a quantitative value to be assigned to the air speed and subject to instrumentation the airflow direction.
Data can be used to calculate velocity turbulence but no quantitative value of fume leakage from fume cupboard

Pressure monitoring:- Will indicate quantitative value for pressure drop of the fume based on extract volume flow; configuration of fume cupboard baffles; sash position and any control system fitted but provides no quantitative value of fume leakage from fume cupboard

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Important metrics used in the evaluation of fume cupboards performance (2)

Tracer gas containment :- Provides quantitative value of leakage comparing ppm of gas released in fume cupboard workspace with ppm leakage of tracer gas measured in specific locations external to the fume cupboard workspace.

Used to determine leakage for static sash, dynamic sash and during disturbance to the laminar flow of air entering through front of fume cupboard and for high thermal loads.

Air exchange efficiency:- Using tracer gas released in workspace measures decay time of gas in ductwork to calculate quantitative value for purging of gas from workspace (air change)

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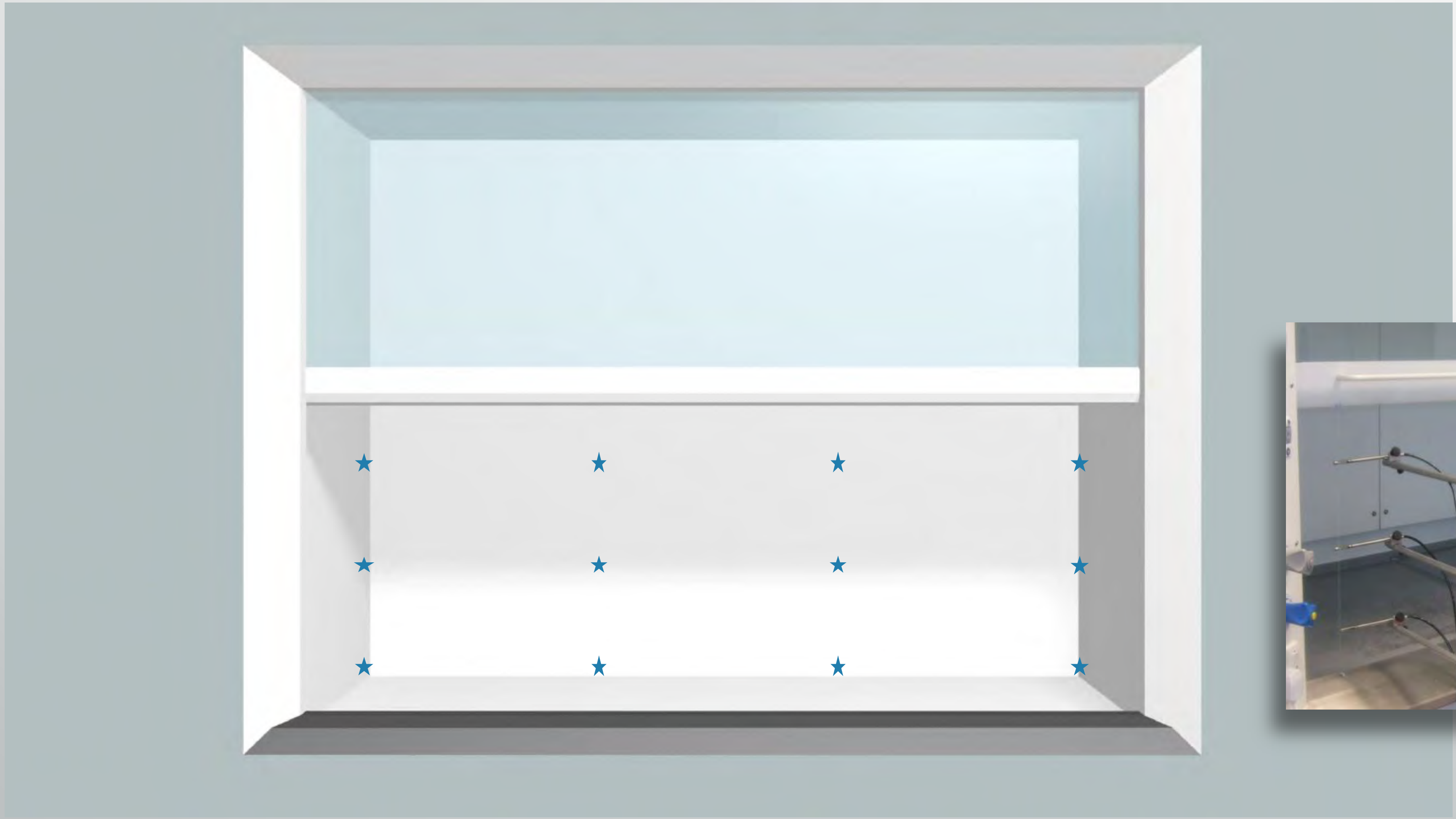
Effects of loading on containment (1)

Review of velocity and tracer gas containment results obtained using a standard fume cupboard and a constant extract volume flow under empty and loaded conditions

- Standard 1200mm (internal) fume cupboard sash set at 500mm
- Volume flow to provide 0.5m/s when sash raised to 500mm
- Face velocity measurements (3 x 4 positions) inner plane
- Containment tracer gas test (9 position samples x 6 cell positions) inner plane
- Studied loading of equal sized boxes in different arrangements within workspace
- Each box – 415mm x 265mm x 340mm (L x H x D)
- Positioned with the front face of each box 200mm from the plane of the sash

Effects of loading on containment (2)
Face velocity measurement positions



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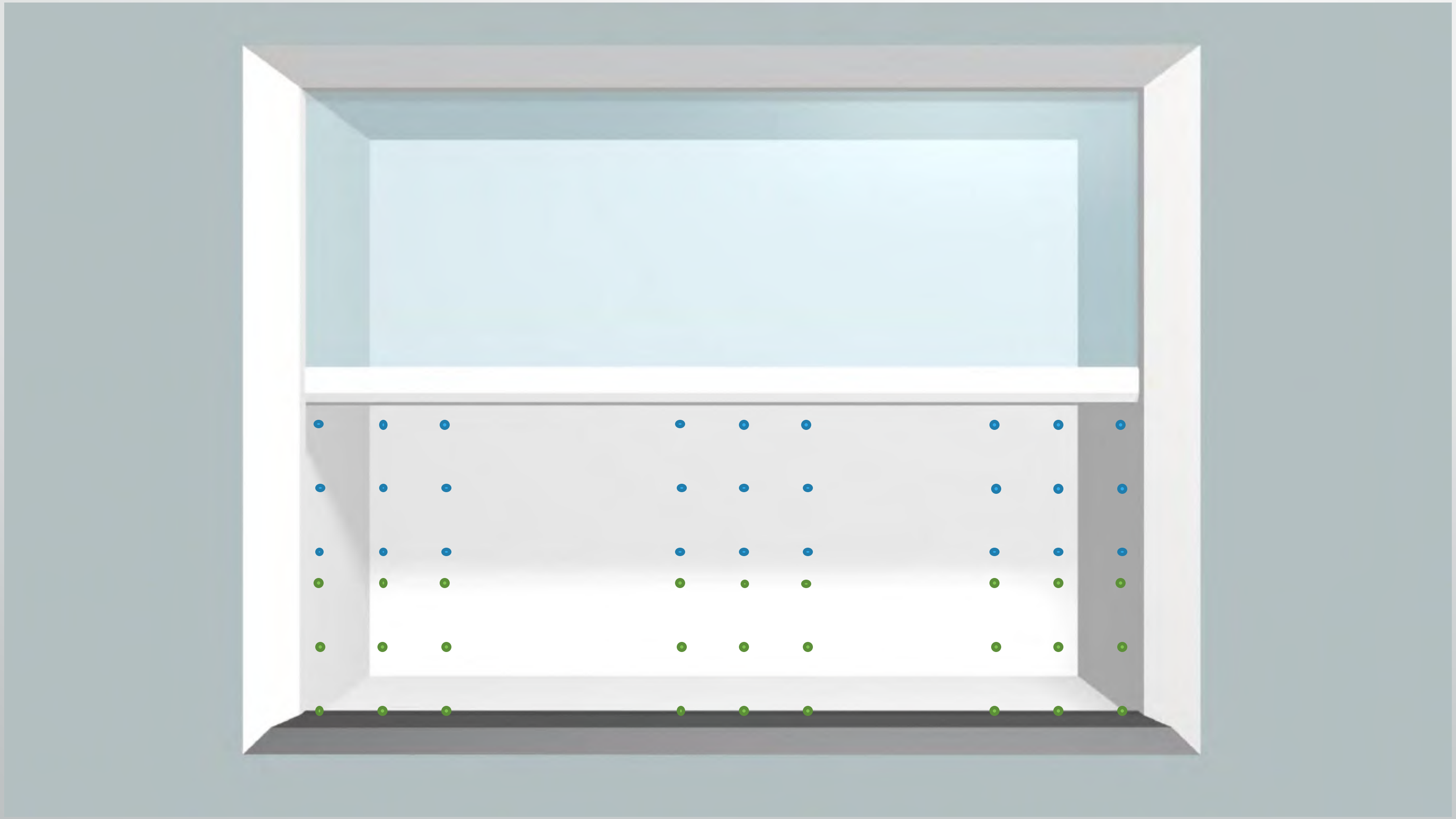
Effect of loading on containment (3)
Containment tests – positions

Effect of loading on containment (4)
Containment measurements – 6 positions
(for this fume cupboard)



Effect of loading on containment (5)
FC loading scenarios

Effect of loading on containment (6)
Face velocities (m/s)

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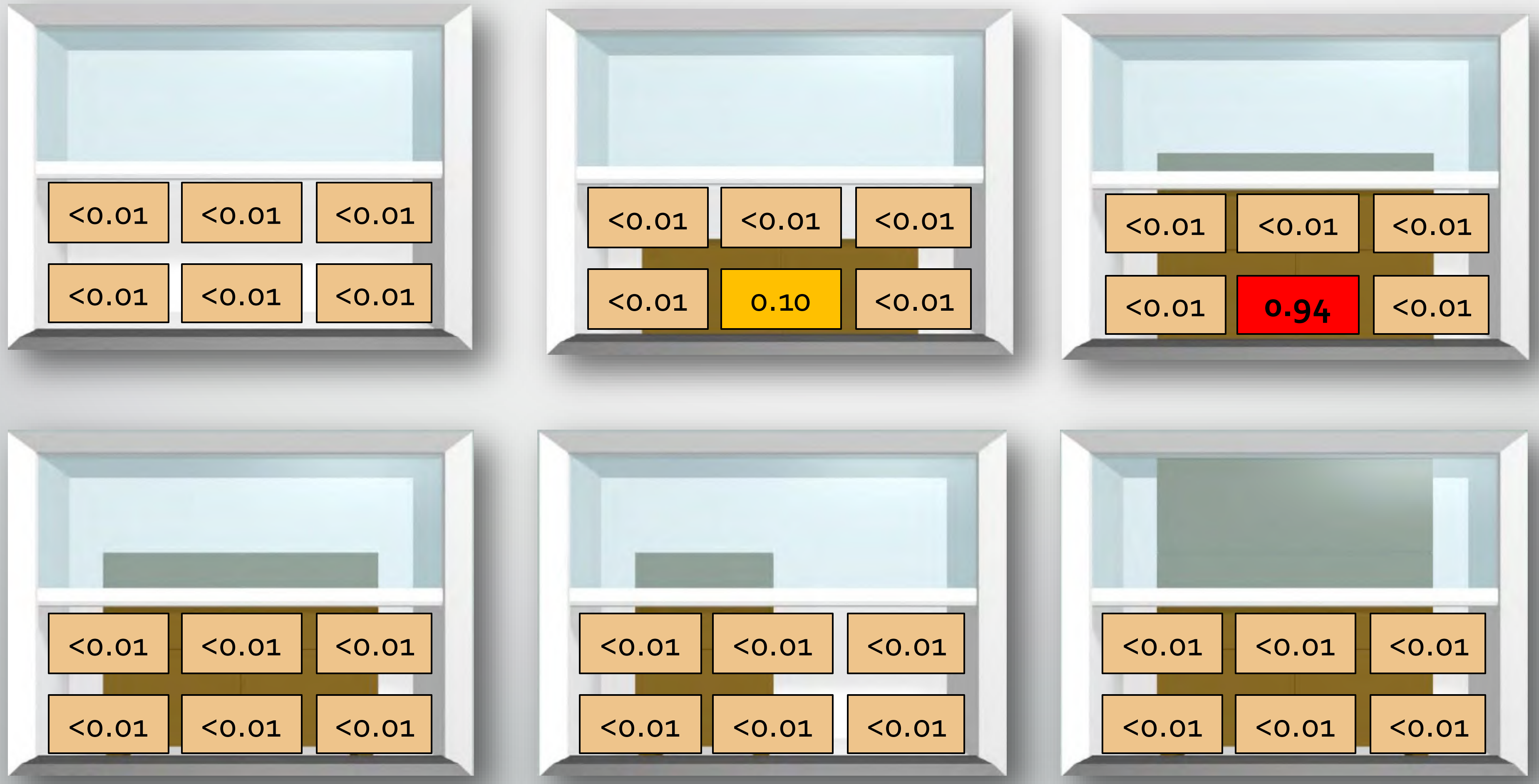
Effect of loading on containment (7)
Containment – SF6 concentration (ppm)



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Effect of loading on containment (8)
Summary and Final summary of the blockage tests

Velocity

- Lower average air velocities when loaded
- Variation increases with loading – particularly if the obstacles are not raised
- Doesn't provide information on containment

Containment

- Excellent when empty (sensitivity!)
- Also excellent with raised blockages
- Issues when blockages placed on the base of the FC
- Scenario 3 – Smoke tests identified poor containment

Critical to fume cupboard performance:

- The environment
- Design
- Use, training and working practices

Face velocity is an important metric but not necessarily the most important parameter

Principal UK Standards for Fume Cupboards – BS EN 14175 (1)

BS EN 14175 - Fume cupboards

BS EN 14175-1:2003 - Part 1 - Vocabulary

BS EN 14175-2:2003 - Part 2 Safety and performance requirement

BS EN 14175-3:2003 - Part 3 Type test methods

BS EN 14175-4:2004 - Part 4 On-site test methods

DD CEN/TS 14175-5:2006 - Part 5 Rec. for Installation & Maintenance

BS EN 14175-6:2006 - Part 6: Variable air volume fume cupboards

BS EN 14175-7:2012 Part 7: Fume cupboards for high heat and acidic load

Principal requirements of BS EN 14175-3:2003 & 4:2004 (2)

BS EN 14175-2:2003 - Fume cupboards
Part 2: Safety and performance requirements

The safety requirements in BS EN 14175-2:2003 provide guidance for the construction of fume cupboards and serves as basis for testing of fume cupboards. It describes two different procedures to investigate fume cupboard safety and performance.

a) **Type testing** in accordance with the requirements given in
BS EN 14175-2:2003 Fume cupboards Part 2: Safety and performance requirements.

b) **Testing on-site** in accordance with the requirements given in
BS EN 14175-2:2003 Fume cupboards Part 2: Safety and performance requirements
using test methods in BS EN 14175- 3:2003 Fume cupboards-Part 3:Type test methods
The testing on-site of an individual fume cupboard installed in a specific location and does not constitute a type test. Testing on-site results cannot be transferred to further production of the design or model of the fume cupboard tested on site.

Inspection and tests BS EN 14175 -3:2003 & 4:2004 (1)

- For compliance with BS EN 14175 Part 3 Type test methods all of the test (8 currently relate to air movement) described shall be performed including compliance methods for calculations and the format/presentation content of BS EN 14175 reports.

- For compliance with BS EN14175 Part 4 On Site test methods the selection, number and type of tests is subject to prior agreement between parties and there is no obligation on any party to perform all of the tests described.

- BS EN14175 Parts 6 Variable air volume fume Cupboards and Part 7 Fume cupboards for high heat and acidic load requires compliance with BS EN 14175 Part 3 and Part 4 plus additional type test requirements and on site tests described in Parts 6 or Parts 7.

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Inspection and tests BS EN 14175-3:2003 & 4:2004 (2)

- BS EN 14175 does not specify requirements for a fume cupboards operational (as installed) velocity, volume flow, pressure, containment or air exchange efficiency performance.

- BS EN 14175 comments on room air velocity profiles and effects of room supply air jets
  - BS EN 14175-3:2003 sect 4.2 Test Room conditions < 0.1m/s
  - BS EN 14175-4:2004 sect 5.8 Room air velocity > 0.2m/s may reduce containment
  - DD CEN/TS 14175-5:2006 sect 4.2.6 room air velocity <0.2m/s within 0.4m of sash
  - National Annex sect NA.2.6.6 prevent supply air jet >0.3m/s in occupied zone

- BS EN 14175 does not specify or offer guidance on fume cupboard performance banding

- BSI panel LBI/001/01 'Laboratory Furniture' and CEN TC332 WG4 'Fume cupboards and associated ventilation' were requested to consider performance banding for fume cupboards. Both organisations confirmed performance bandings would not be included in EN 14175 but acknowledged performance bandings may feature in National regulations or published papers

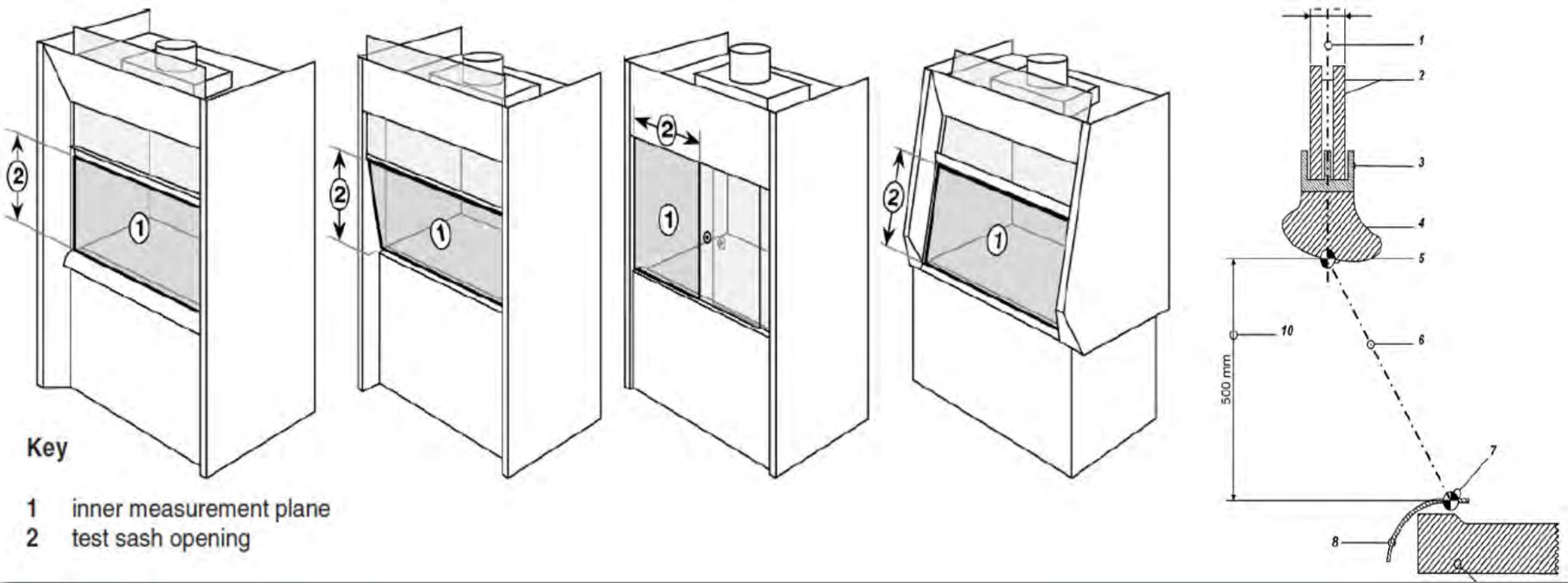
Inspection and tests BS EN 14175-3:2003 & 4:2004 (3)

Commonly specified on site tests from BS EN 14175 Part 4 On site test methods specific to the fume cupboard devices are:

- **Inner plane velocity** using hot wire anemometer
- **Inner plane containment** using SF6 tracer gas and infra red gas analyser
- **Outer plane containment** using SF6 tracer gas and infra red gas analyser
- **Outer plane robustness of containment** using SF6 tracer gas and infra red gas analyser
- **Volume flow** using hot wire anemometer or pitot tube
- **Flow visualisation** using smoke tracer and if necessary hot wire anemometer
- **Fume cupboard pressure drop test** using manometer
- **Sound pressure** using a sound level meter
- **Flow alarm monitor test** in accordance with manufacturers instruction

Inspection and tests BS EN 14175-3:2003 & 4:2004 (4)

Inner Measurement Plane BS EN 14175-3:2003 – 3.2 Figures 1 & 2



Inspection and tests BS EN 14175-3:2003 & 4:2004 (5)

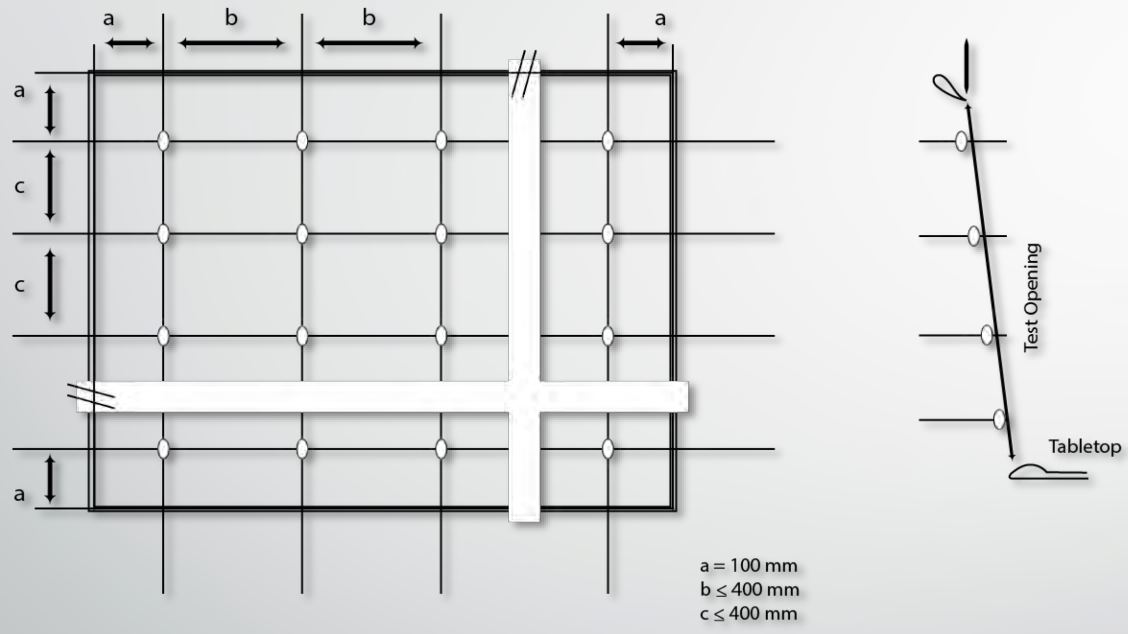
5.7 Airflow visualisation

Visually check air flows around fume cupboard and in the sash opening area using a visible tracer, such as smoke distributed with impulse ≤ 0.2m/s generated approx. 400 mm in front of the fume cupboard with release vertically upward towards the room ceiling.

If turbulence is noted carry out a velocity test in accordance with **5.8 Room air velocity test**

Inspection and tests BS EN 14175-3:2003 & 4:2004 (6)

BS EN 14175-3:2003 5.2 Face velocity 5.2.2 probe & grids (inner plane)



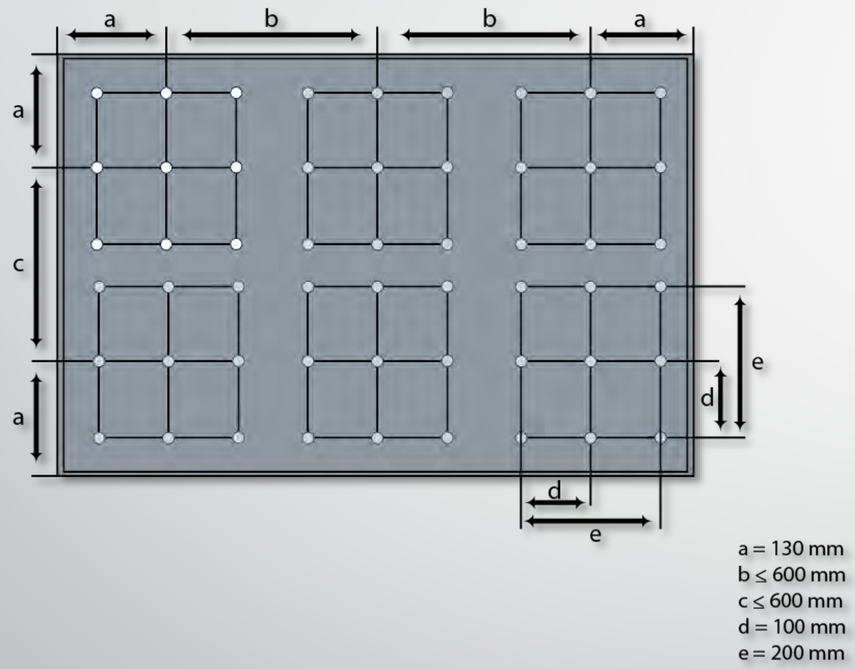
Note:
Grid and measuring procedure differs from Figure 48 described in section 354 of HSG258

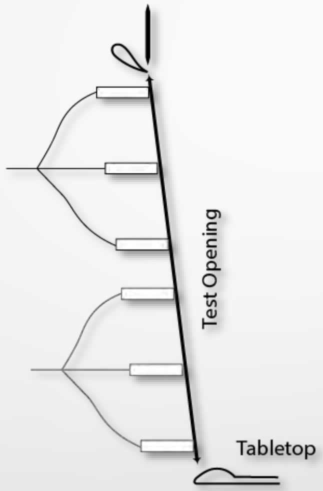
Note: Illustrative, lap top not in operational opening during test

- Measure and record the individual velocity perpendicular to the inner measurement plane at intervals of 1,0 s or less for at least 60 s
- Anemometer unidirectional with time <0,5 secs - uncertainty of individual measurement shall not exceed 0,02m/s in 0,21,0m/s range
- For each extract volume flow rate setting, the flow rate shall be measured in the extract duct in accordance with EN ISO 5167-1. The uncertainty of measurement shall not exceed ± 5 %.

Inspection and tests BS EN 14175-3:2003 & 4:2004 (7)

BS EN 14175-3:2003 5.3 Containment 5.3.3 probe & grids (inner plane)





- Gas analyser shall have a detection level of 10^{-8} or less volume fraction of the tracer gas
- Tracer gas comprised of 90% nitrogen and 10% SF6 delivered at flow rate of 2,0 l/min
- Measure and record the tracer gas (SF6) concentration for 360 s.

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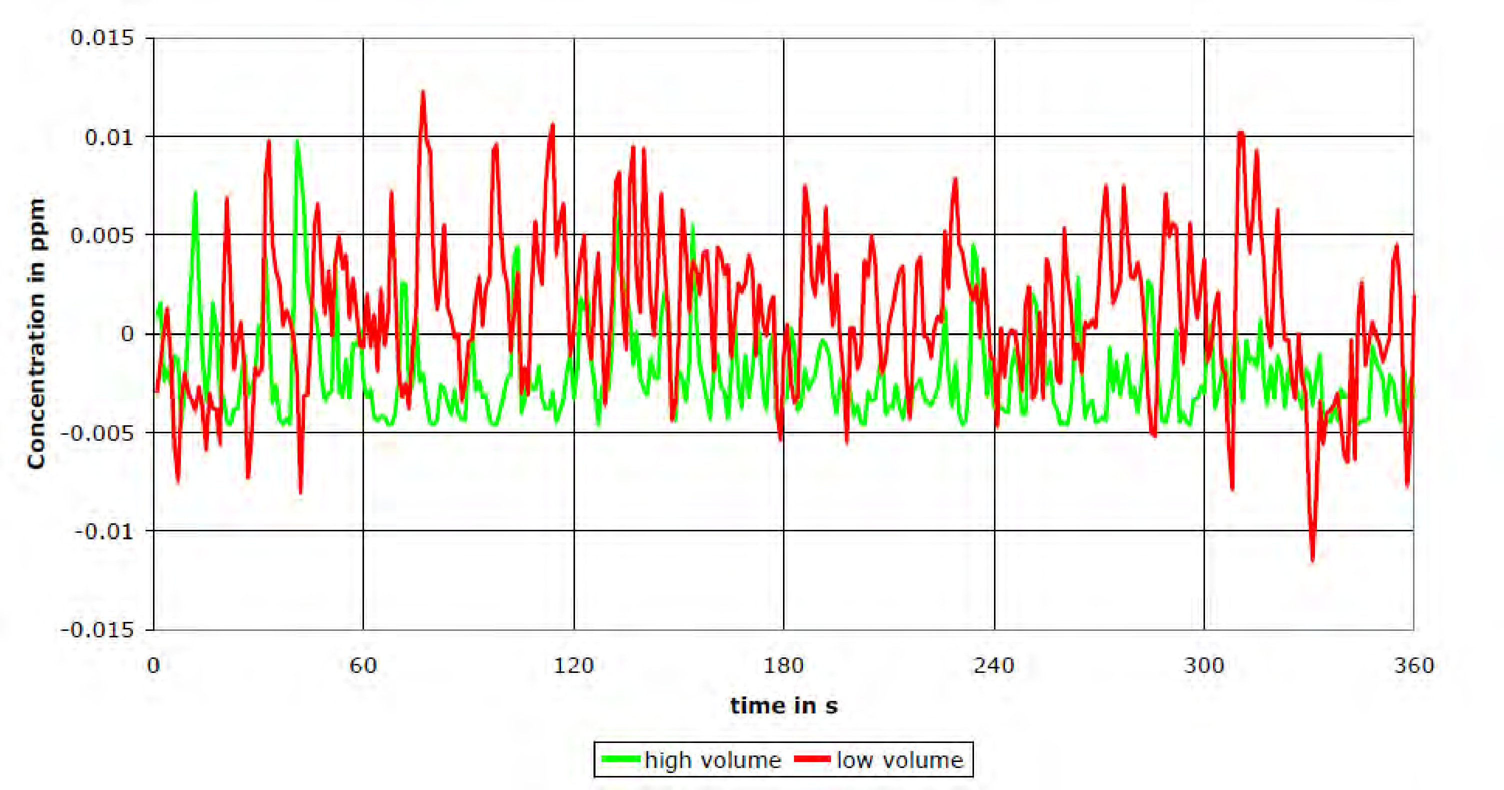
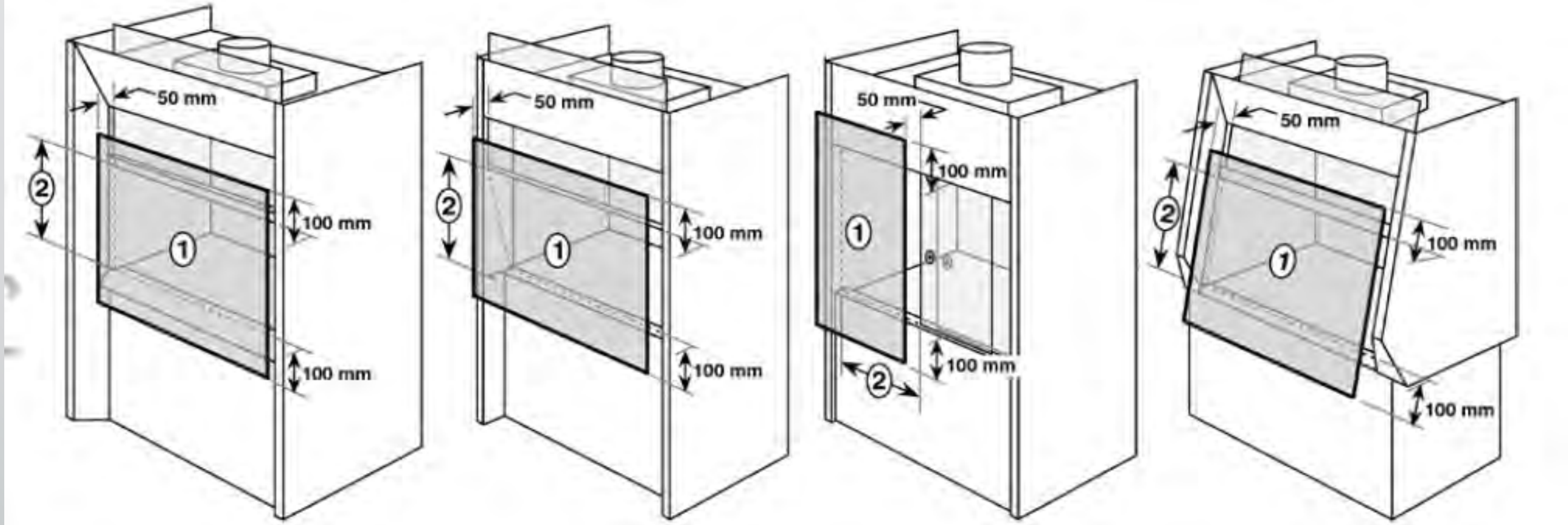
Inspection and tests BS EN 14175-3:2003 & 4:2004 (8)

BS EN 14175-3:2003 Containment inner plane example graph



Inspection and tests BS EN 14175-3:2003 & 4:2004 (9)

Outer measurement plane BS EN 14175-3:2003 – 5.3.4

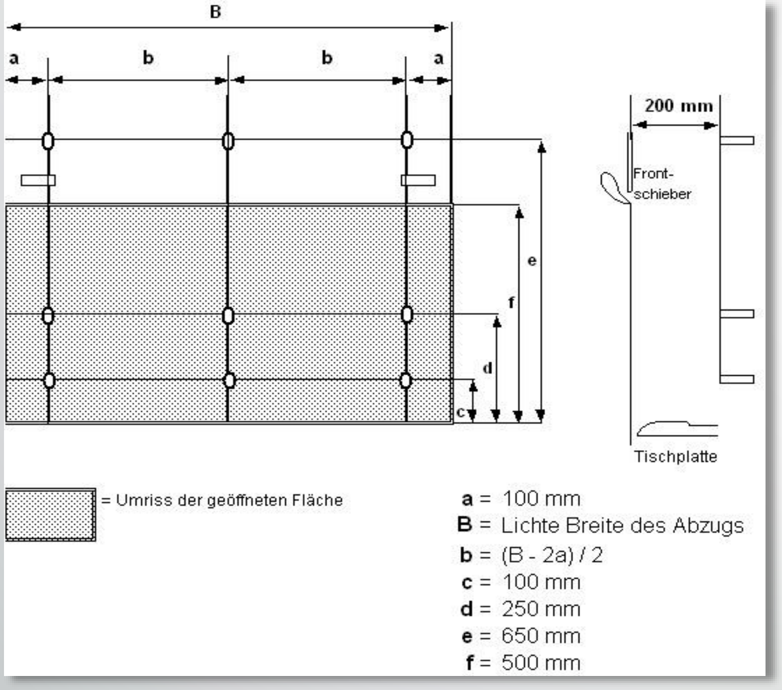


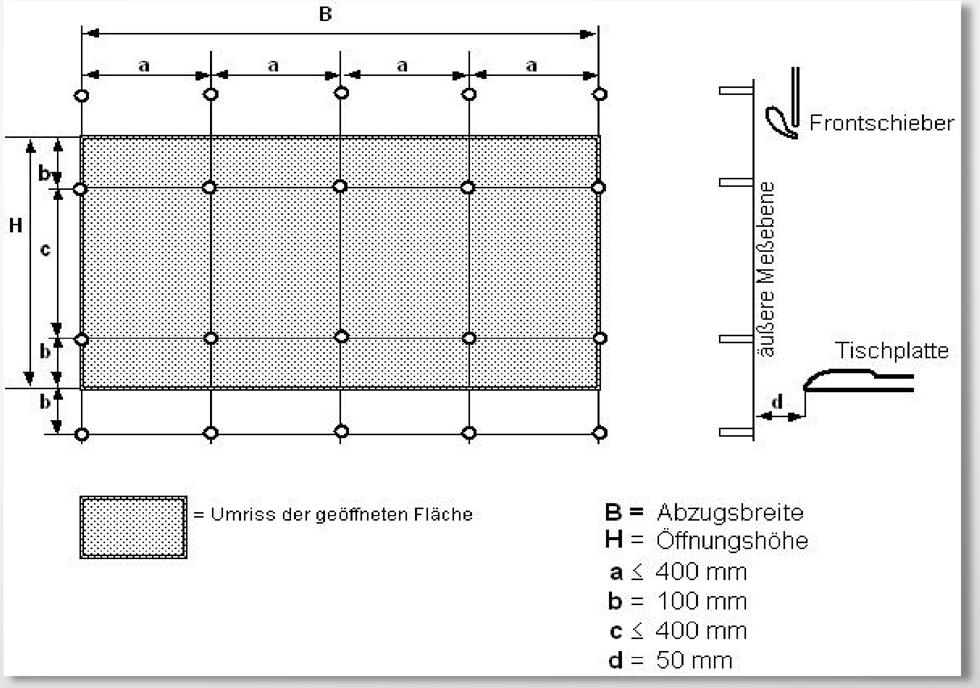
Key

1 outer measurement plane
2 test sash opening

Inspection and tests BS EN 14175-3:2003 & 4:2004 (10)

BS EN 14175-3:2003 5.3 Containment 5.3.4 injector probe & grids (outer plane & robustness)



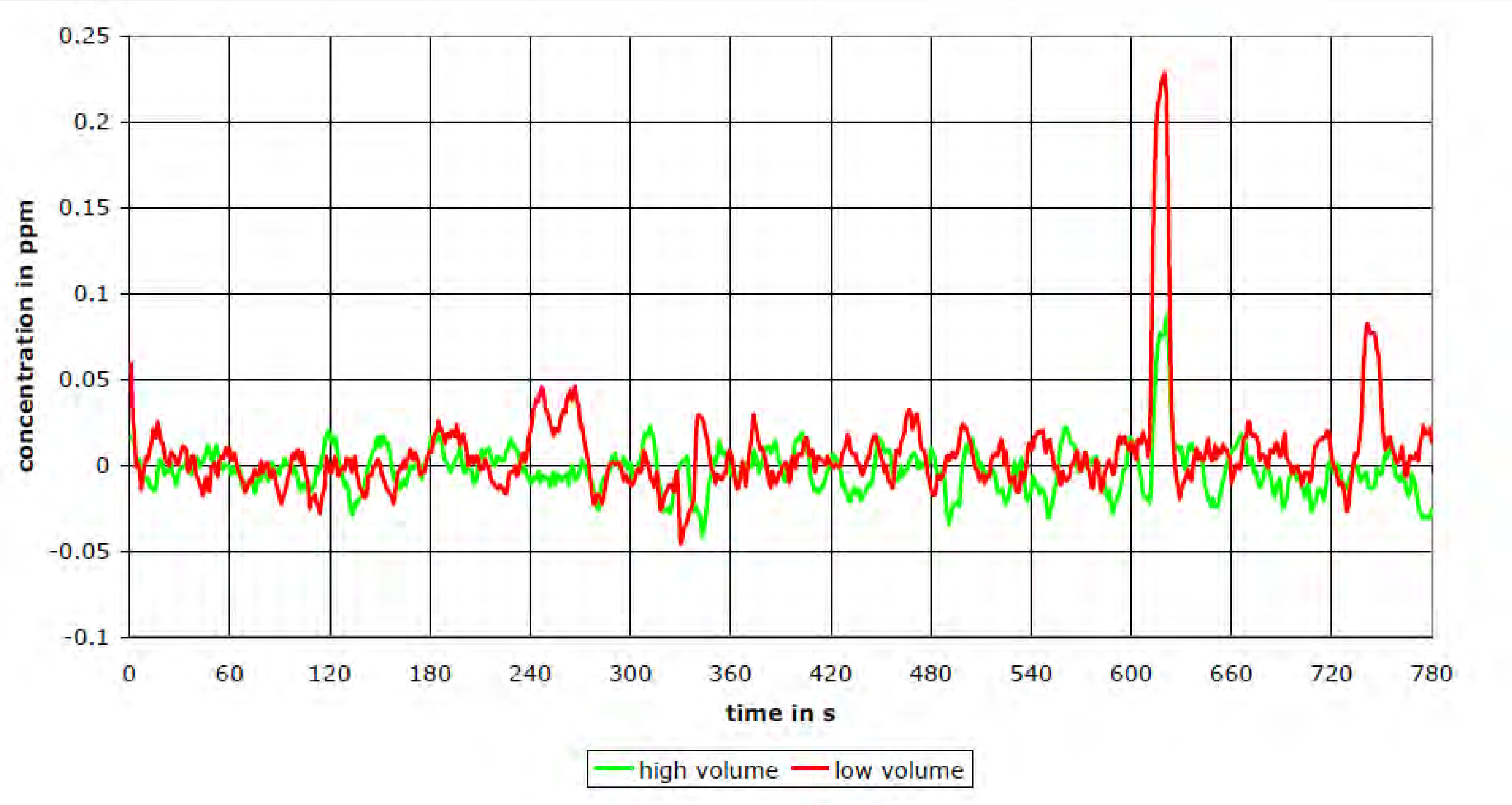


Receiving probes position ‘c’ ≤400 mm is distance for horizontal sash
When applied to opening with a vertical sash position ‘c’ is ≤ 200 mm

- Gas analyser shall have a detection level of 10^{-8} or less volume fraction of the tracer gas
- Tracer gas 90% nitrogen and 10% SF6 delivered at 0,5 l/min from each injector total flow rate of 4,5 l/min
- Measure and record the tracer gas (SF6) concentration for a period of 780 s. Commence then after 360 s close the sash to its minimum opening for 240 s then open to test sash opening and test for further 180 s

Inspection and tests BS EN 14175-3:2003 & 4:2004 (11)

BS EN 14175-3:2003 Containment outer plane test example graph



Measure and record tracer gas (SF6) concentration for a period of 780 s.
Commence then after 360 s close the sash to its minimum opening for 240 s
Then open to test sash opening and test for further 180 s

Inspection and tests BS EN 14175-3:2003 & 4:2004 (12)

BS EN 14175-3:2003 5.4 **Robustness of Containment**

Using the Outer Plane and containment configuration

- Gas analyser shall have a detection level of 10^{-8} or less volume fraction of the tracer gas
- Tracer gas 90% nitrogen and 10% SF6 at 0,5 l/min from each injector total flow rate of 4,5 l/min
- In addition a flat rectangular plate 1,9m high x 0,4m wide x 20mm thick positioned on a moveable platform 0,2m from floor and 0,4m from sash plane in front of the fume cupboard.

- Set sash test opening then start tracer gas as for outer plane test

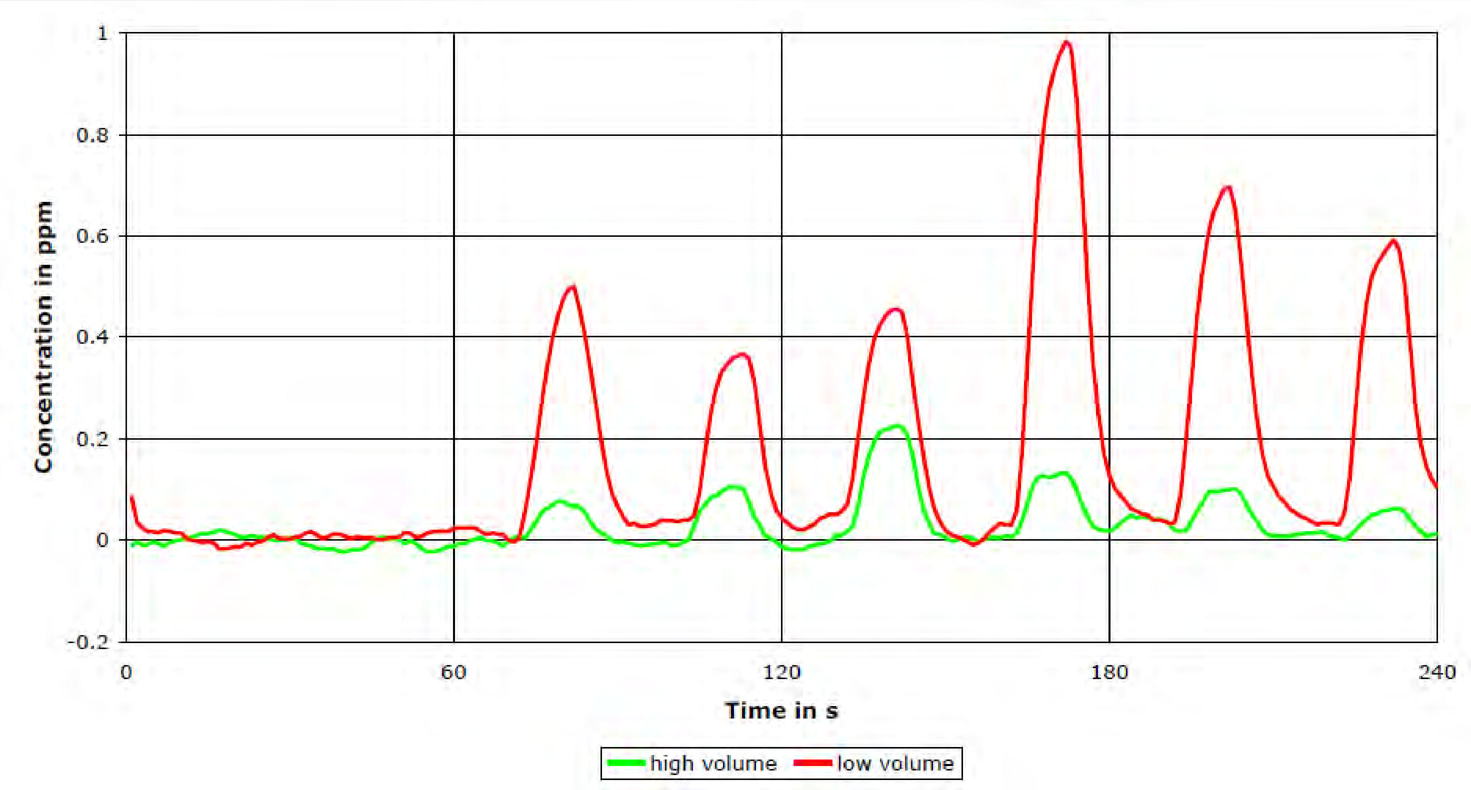
- During test make 6 traverses at 1,0 m/s across fume cupboard (0.6m passed on each side) with 30 sec delay between each traverse

Inspection and tests BS EN 14175-3:2003 & 4:2004 (13)

BS EN 14175-3:2003 5.4 Robustness of containment typical illustration of arrangement
5.4.1 test equipment - 5.4.3 Positioning of test equipment – 5.4.4 test procedure

Inspection and tests BS EN 14175-3:2003 & 4:2004 (14)

BS EN 14175-3:2003 Containment outer plane robustness test example graph



Make 6 traverses (0.6m passed each end) at 1,0 m/s with a 30 second delay between each traverse at a distance of 0.4m from face of the fume cupboard

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Inspection and tests BS EN 14175-3:2003 & 4:2004 (16)

5.5 Air exchange efficiency

- With fume extract and supply air operating and sash closed to minimum opening using the outer plane test gas injectors to provide test gas flow rate such that the volume fraction of tracer gas at the fume cupboard connection to the extract system shall be in the range 5×10^{-6} to 8×10^{-6}.

- Position the gas analyser sampling probe in a straight section of exhaust duct at least 10 x duct diameters from fume cupboard. Measure tracer gas concentration then after 200 secs turn of the tracer gas continue to measure tracer gas concentration for a further 200 secs minimum

- Calculate the air change rate per hour, n, according to EN ISO 12569 from the gradient of a log-linear fit using the measured values in the range of 80 % to 20 % of the initial tracer gas concentration.

- Calculate the air exchange efficiency Ɛ in percent as quotient of measured and theoretical air exchange rate, rounding the result to the first decimal place, with equation

$$\varepsilon = \frac{100\,n}{Q / V_{fc}} = \frac{100\,n\;V_{fc}}{Q}$$

where Q is the extract volume flow rate and Vfc is the internal volume of the fume cupboard's workspace.

Inspection and tests BS EN 14175-3:2003 & 4:2004 (17)

BS EN 14175-3:2003 5.6 Pressure drop
At the rated volume flow and type test opening with a device capable of measuring air pressure differences with an uncertainty not exceeding ± 10 % of the reading, measure the fume cupboard pressure drop at its connection to the duct system.

BS EN 14175-3:2003 6.2 Sash displacement test
Measure the sash displacement force at three positions across sash edge for any possible direction of movement. Maximum permissible 30 N single sash and 50 N multiple sash's

BSEN 14175-3:2003 7 Air flow indicator tests
If the fume cupboard under type test is provided with an incorporated air flow indicator, then check to verify :-

- alarm activates when manufacturers specified or type test extract volume flow rates are failed;
- Visual prominence of alarm on silencing or muting of the audible alarm, if provided.

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Inspection and tests BS EN 14175-3:2003 & 4:2004 (18)

- BS EN14175 includes a calculation for 'Containment Factor' (CF) unfortunately when only CF evaluation is adopted a conclusion may be drawn that 'narrower width fume cupboards are more efficient than larger width fume cupboards'. This is a consequence of the CF calculation using exhaust volume flow. For example if a 1.2m and 1.8m fume cupboard were compared despite both having identical sash height, face velocity and containment performance the 1.2m fume cupboard CF index will be better than the 1.8m fume cupboard due to use of a lower volume flow.

- British Standards panel LBI/001/01 and CEN TC 332 WG4 Fume cupboards and associated ventilation propose inclusion of 'Protection Factor' (PF) which using tidal breathing rate and is considered more useful for containment performance assessments.

- Containment Factor and Protection Factor should be adopted in preference to the use of 'face velocity' when determining a fume cupboard containment compliance.

Note:
The fume cupboards 'Robustness of containment values' is an important factor when resultant extract volume flow provide face velocities < 0.35m/s.in the operational opening of the sash.

Inspection and tests BS EN 14175-3:2003 & 4:2004 (19)

CEN TC 332 WG4 March 2017 current review of EN 14175-3:2004 proposes inclusion of the following:-

containment factor (C_F)
ratio of the calculated volume concentration of tracer gas in the workspace of the fume cupboard to the measured concentration in the inner or outer measurement plane

NOTE : The containment factor is not a constant value but depends on the extract volume flow rate and the measured concentration of tracer gas.

protection factor (P_F)
ratio of the volume flow rate of the tracer gas to the measured volume flow rate of the tracer gas in the tidal breathing flow

tidal breathing flow
volume flow rate of air moved into (or out of) human lungs during sedentary breathing

NOTE For healthy adults, it is in the range of 6 l/min to 10 l/min. For the purposes of BS EN 14175, 10 l/min is used.

Fume cupboard SF6 tracer gas and UK ‘F-Gases emissions’

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SF6 as a tracer gas for fume cupboards 'pros' and 'cons'

Pros

- Non toxic *
- Non flammable and odourless
- Not naturally found in atmosphere **
- Unique signal so possible to measure low concentrations
- Contributes < 0.1% to UK SF6 Emissions (2011)***
- Overall contribution to global warming estimated to be less than 0.2% (2018)

Cons

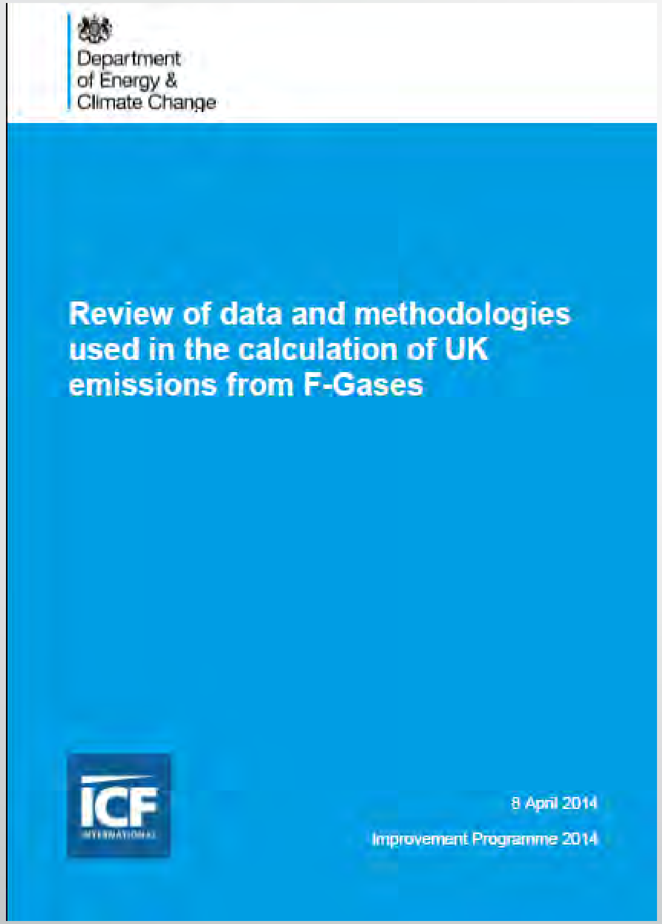
- Displaces oxygen
- Compressed gas
- Potent greenhouse gas with a global warming potential 23,900 times that of CO_2
- Atmospheric lifetime of 800–3200 years

* EH40 2005 (3rd edition 2108) - TWA 1000ppm – STE 1250ppm acknowledged asphyxia risk if high volume is inhaled)

** SF6 mixing ratio in the atmosphere is about 9 parts per trillion (February 2018)

*** Mathis, P., Scarbrough, T., Knoell, K., Acharya, B., Harris, D., Wagner, M., and Neuweg, I. (2014) Review of data and methodologies used in the calculation of UK emissions from F-Gases. Final Report to the Department of Energy and Climate Change. ICF International'

Review of data and methodologies used in the calculation of UK emissions from F-gases (1)

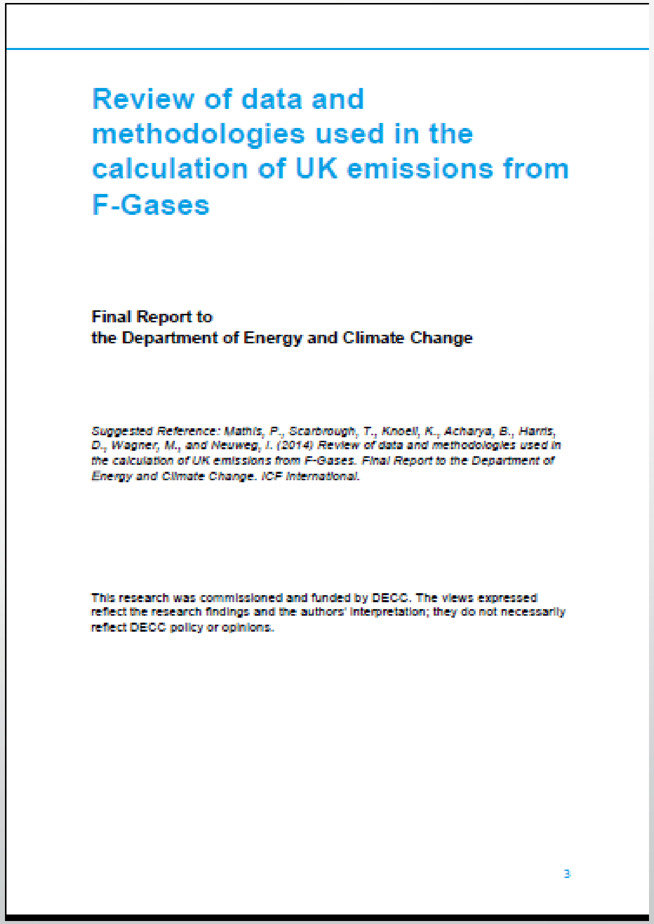

Department of Energy & Climate Change

Review of data and methodologies used in the calculation of UK emissions from F-Gases

ICF INTERNATIONAL

8 April 2014

Improvement Programme 2014


Review of data and methodologies used in the calculation of UK emissions from F-Gases

Final Report to
the Department of Energy and Climate Change

Suggested Reference: Mathis, P., Scarbrough, T., Knoell, K., Acharya, B., Harris, D., Wagner, M., and Neuweg, I. (2014) Review of data and methodologies used in the calculation of UK emissions from F-Gases. Final Report to the Department of Energy and Climate Change. ICF International.

This research was commissioned and funded by DECC. The views expressed reflect the research findings and the authors' interpretation; they do not necessarily reflect DECC policy or opinions.

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'Mathis, P., Scarbrough, T., Knoell, K., Acharya, B., Harris, D., Wagner, M., and Neuweg, I. (2014) Review of data and methodologies used in the calculation of UK emissions from F-Gases. Final Report to the Department of Energy and Climate Change. ICF International'

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Review of data and methodologies used in the calculation of UK emissions from F-gases (2)

Table 16: Comparison of total F-Gas emissions for 2011

Source	Emissions ($ktCO_2eq$)	Sector Status	% gas type	% all F-Gas
HFCs				
Refrigeration and Air Conditioning Equipment	11,220	Existing	76.4%	71.2%
MDI and Aerosols	2,721	Existing	18.5%	17.3%
Foams	312	Existing	2.1%	2.0%
Fire Protection	245	Updated	1.7%	1.5%
HFC and HCFC-22 Manufacture	72.6	Existing	0.5%	0.5%
Refrigerant Containers	43.2	New	0.3%	0.3%
Solvents	37.3	Updated	0.3%	0.2%
Magnesium Production and Processing	29.4	Updated	0.2%	0.2%
Electronics Manufacture	12.0	Updated	0.1%	0.1%
One Component Foams	0.0	Updated	0.0%	0.0%
Total HFCs	**14,692**			**92.7%**
PFCs				
Aluminium	162.4	Existing	45.2%	1.0%
Electronics Manufacture	109.9	Updated	30.6%	0.7%
PFC Manufacture	87.4	Existing	24.3%	0.6%
Trainers	0.0	Existing	0.0%	0.0%
Total PFCs	**359.7**			**2.3%**
SF_6				
Electrical Transmission and Distribution	502.6	Existing	70.1%	3.2%
Magnesium Production and Processing	118.3	Updated	16.5%	0.8%
Military AWACS	84.4	New	11.8%	0.5%
Trainers (included in ETD sector)	0.0	Existing	0.0%	0.0%
Electronics	5.9	Updated	0.8%	0.0%
Particle Accelerators	4.7	New	0.7%	0.0%
Tracer Testing	0.6	New	0.1%	0.0%
Total SF_6	**716.5**			**4.5%**
Total F-Gas	**15,768**			**100%**

Source	Emissions ($ktCO_2eq$)	Sector Status	% gas type	% all F-Gas
SF_6				
Electrical Transmission and Distribution	502.6	Existing	70.1%	3.2%
Magnesium Production and Processing	118.3	Updated	16.5%	0.8%
Military AWACS	84.4	New	11.8%	0.5%
Trainers (included in ETD sector)	0.0	Existing	0.0%	0.0%
Electronics	5.9	Updated	0.8%	0.0%
Particle Accelerators	4.7	New	0.7%	0.0%
Tracer Testing	0.6	New	0.1%	0.0%
Total SF_6	**716.5**			**4.5%**
Total F-Gas	**15,768**			**100%**

'Mathis, P., Scarbrough, T., Knoell, K., Acharya, B., Harris, D., Wagner, M., and Neuweg, I. (2014) Review of data and methodologies used in the calculation of UK emissions from F-Gases. Final Report to the Department of Energy and Climate Change. ICF International'

Sulphur hexafluoride (SF6) use as a tracer gas for fume cupboard containment evaluation

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SF6 used in fume cupboard tracer gas testing

- Published National regulations limit and control use of SF6 with specified exemptions and permitted exclusions which are interpreted as permitting the controlled use of SF6 tracer gas in fume cupboard testing (excludes Denmark).
- Importantly, UK emissions of SF6 from fume cupboard tracer gas testing are extremely low and considered negligible when compared with total SF6 and 'F' gas emissions within the UK.
- When considering SF6 used in fume cupboard tracer testing be aware that the volume and concentration of SF6 used will depend on the standard applied BS EN 14175 or ASHRAE 110 -2016 and procedure specified for each test.

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SF6 volume comparison illustration
BS EN 14175 & ASHRAE 110-2016

Comparison of SF6 tracer gas used in BS EN 14175 and ASHRAE 110-2016 test *

ASHRAE 110-2016	SF6 Conc	Flow	Time	Positions	SF6 Volume
Static evaluation	100%	4 lt/min	5 mins	3	60 litres
Dynamic evaluation	100%	4 lt/min	2 mins	3	24 litres
					84 litres

BS EN 14175 Part 3	SF6 Conc	Flow	Time	Positions	SF6 Volume
Static & Dynamic evaluation	10%	0.5 lt/min	13 mins	9	5.85 litres
					5.85 litres

*Tables provides a comparison of closest like for like evaluation based on BS EN 14175 'outer plane'. ASHRAE 110-2016 has no directly comparable test procedures o those described in BS EN 14175 for Inner plane containment; Robustness of containment; Air exchange efficiency;

Alternatives to SF6
Progress and the future

Since 2013 there has been a number of research initiatives within the international community to identify a tracer gas or alternative test methods that can provide comparative data closely matching that of the current BS EN 14175 SF6 tracer gas test procedure.

Evaluations to date include N_2O (nitrous oxide) / CO_2 (carbon dioxide)/ Isobutylen / Helium / Alcohol IPA / DOP(Di-Octyl-Phthalate) & DEHS(Di-Ethyl-Hexyl-Sebacate, a colourless oil) Aerosol / Salt / Powder /Novectm 649 (Fluoroketone)

There is no direct government funding and the work is funded by private and commercial companies.

These research initiatives continue and it would be a significant financial and operational burden on the manufacturing, medical and scientific community if in the absence of a proven alternative to SF6, fume cupboards tracer gas testing to BS EN 14175 was prohibited because of withdrawal of SF6 tracer gas.

References (1)

BS EN 14175-1: 2003 - Part 1 - Vocabulary

BS EN 14175-2: 2003 - Part 2 Safety and performance requirement

BS EN 14175-3: 2003 - Part 3 Type test methods

BS EN 14175-4: 2004 - Part 4 On-site test methods

DD CEN/TS 14175-5: 2006 - Part 5 Rec. for Installation & Maintenance

BS EN 14175-6: 2006 - Part 6: Variable air volume fume cupboards

BS EN 14175-7: 2012 Part 7: Fume cupboards high heat and acidic load

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References (2)

- ‘Controlling airborne contaminants at work - A guide to local exhaust ventilation (LEV) HSG 258’ - Health and Safety Executive publication.
- ANSI/ASHRAE (2016) - Method of Testing Performance of Laboratory Fume Hoods abbreviated as ASHRAE 110.
- Illustration by Dr. Ali Bicen of possible banding and performance tables for fume cupboards could be presented – Dr. Ali Bicen Invent UK Limited.
- Fume cupboard: Effect of loading on containment – John Saunders Health and Safety Laboratory - Crown Copyright
- EH40/2005 Workplace exposure limits 3rd edition published 2018
  Containing the list of workplace exposure limits for use with the Control of Substances Hazardous to Health Regulations 2002 (as amended)

References (3)

- EU F-Gas Regulation No. 517/2014
- EU F-gas regulation No. 517/2014 (Decree No.2015-1790)
- Department of Energy & Climate Change – Review of data and methodologies used in the calculation of UK emissions from F-Gases

  'Mathis, P., Scarbrough, T., Knoell, K., Acharya, B., Harris, D., Wagner, M., and Neuweg, I. (2014) Review of data and methodologies used in the calculation of UK emissions from F-Gases. Final Report to the Department of Energy and Climate Change. ICF International'

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Further this information should not be considered as professional advice. You are recommended to consult with and seek advice from competent persons before proceeding with designs, work or testing with implications for health and safety. This presentation shall not be read or considered in isolation.

It is hoped this presentation may:

- Encourage readers to further their knowledge of SF6 tracer gas use in the UK for fume cupboard validation, commissioning, testing and inspections.
- Provide awareness of investigations being pursued to develop a suitable and appropriate methods for fume cupboard containment evaluation that may assist in reducing global warming

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LEV

Extracting the Best Practices

Personal Exposure Monitoring Reports- What Should These Include?

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The Institute of Local Exhaust Ventilation Engineers ILEVE Improving workplace air quality

Outline of Presentation

Extracting the Best Practices

- COSHH Regulation 10
- What COSHH states is required in a monitoring report
- Available reporting guidance
- Structure of monitoring reports
- Example of a monitoring report
- Questions

COSHH Regulation 10

Extracting the Best Practices

Regulation 10 Monitoring exposure at the workplace

(1) Where the risk assessment indicates that –

(a) it is requisite for ensuring the maintenance of adequate control of the exposure of employees to substances hazardous to health; or

(b) it is otherwise requisite for protecting the health of employees,

the employer shall ensure that the exposure of employees to substances hazardous to health is monitored in accordance with a suitable procedure.

(2) Paragraph (1) shall not apply where the employer is able to demonstrate by another method of evaluation that the requirements of regulation 7(1) have been complied with.

(3) The monitoring referred to in paragraph (1) shall take place –

(a) at regular intervals (see 'frequency of monitoring' in ACOP); and

(b) when any change occurs which may affect that exposure.

(4) Where a substance or process is specified in Column 1 of Schedule 5, monitoring shall be carried out at least at the frequency specified in the corresponding entry in Column 2 of that Schedule.

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COSHH Regulation 10

Exposure monitoring is necessary :

- If an initial exploratory monitoring exercise is necessary to reach an informed and valid judgement about the risks;
- If failure or deterioration of the control measures could result in a serious health effect;
- If measurement is required to be sure that a WEL is not exceeded;
- If any change in the conditions affecting employees' exposure means that adequate control of exposure is no longer being maintained
- If it is needed as an additional check on the effectiveness of any control measures provided
- If it is needed to monitor for the presence of any biological agents outside the primary physical containment.

Source: SKC

Reporting Requirements- COSHH Regulations

Extracting the Best Practices

The information provided in exposure monitoring records should enable employers and others (eg employees, safety representatives, enforcement authorities) to understand and draw conclusions about the records' validity and the adequacy of control of employees' exposure to substances hazardous to health.

To be regarded as suitable, a record should contain the following details ….

- **traceability information**: including employer's name and address, name of the substance monitored, WEL, process/task description, date of monitoring, report author's name, dates of sampling and reporting;
- **sampling information**: including work activities during monitoring, type of sampling (breathing zone, fixed site…), sample identification reference, location details, sampling duration, activity duration, references to sampling, analytical and quantification procedures;
- **exposure control information**: including the types of controls in place. For each type of control, the information provided should enable an assessment of the adequacy of exposure control;
- **a summary:** providing sufficient detail for the employer to determine whether their employees' exposure is adequately controlled to comply with the requirements of regulation 7;
- **the report author's assurance**: including a written confirmation, as applicable, that the report author is competent to carry out sampling and analysis, write the report and interpret the results to help the employer assess the adequacy of exposure control.

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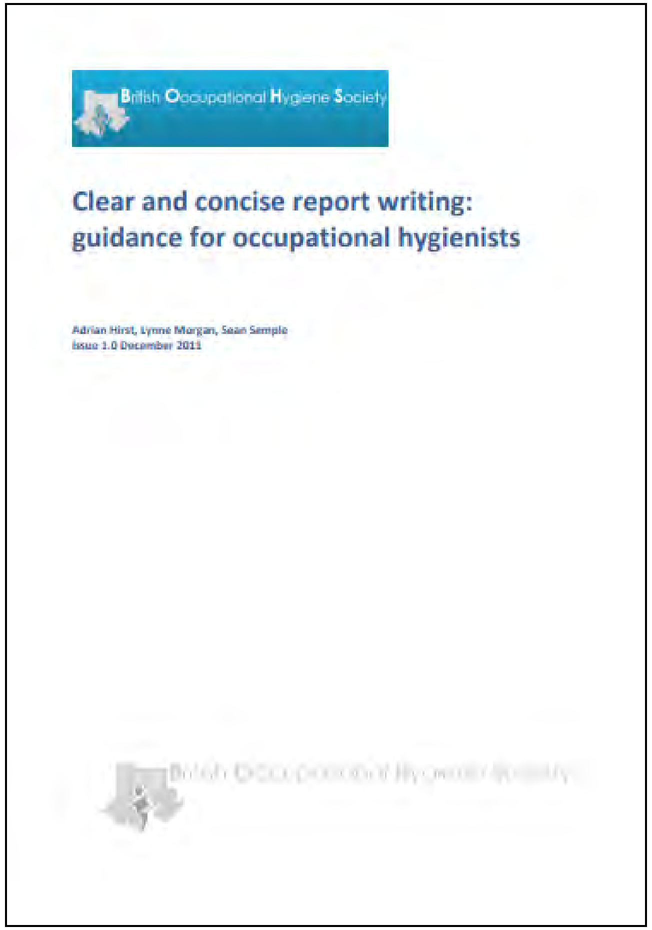
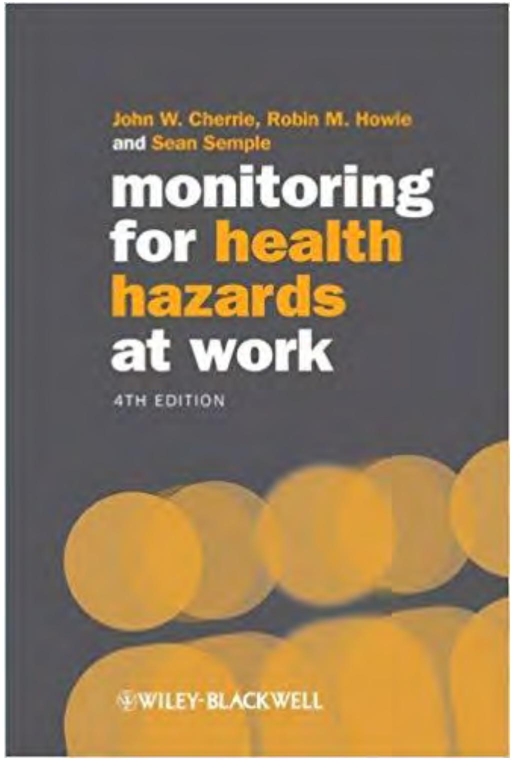
Available Guidance on Report Writing

LEV Extracting the Best Practices





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Structure of a Monitoring Report

LEV Extracting the Best Practices

1. Front Page
2. Executive Summary
3. Authors and Signatures
4. Contents page
5. Introduction
6. Aims and Objectives
7. Acknowledgements
8. Process Description
9. Description of Hazards
10. Relevant Legislation
11. Evaluation criteria
12. Strategy and Methods of sampling and analysis
13. Results
14. Discussion and Observations
15. Conclusions
16. Recommendations and suggested action plan
17. Tables, figures, maps, histograms, photographs
18. References
19. Appendices
20. Bibliography

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Core Elements of a Monitoring Report

Extracting the Best Practices

Data element	Detail
Sampling information	
Details of the workplace and premises where the survey was carried out.	Site address Dates of visits
Details of the process and tasks being carried out.	Duration. Continuous or episodic. Location of the worker in relation to potential exposure sources. Indication of how working conditions influence exposure e.g. higher than average production levels.
Specific location of any measurements.	Static or personal. Sketch plan of work area.
Names of employees sampled. Job title.	
Details of hazards present, products produced or processed.	References to other documents such as data sheets
Description of tools and equipment used.	
Any other co-workers or secondary sources of exposure	Info on process/chemical they are involved in, if relevant to contaminant of interest to present study
Method of measurement and where appropriate analysis-specific published method or in-house.	Pump , tube, badge, filer, filter holder, dosimeter numbers etc.
Sampling strategy.	Method of selection of workers. Timing and duration of sampling: representative or 'worst case'.
Sampling details.	Flow rate, calibration, who collected samples, who analysed samples.
Results. Concentrations.	Details of laboratory and field blank corrections.

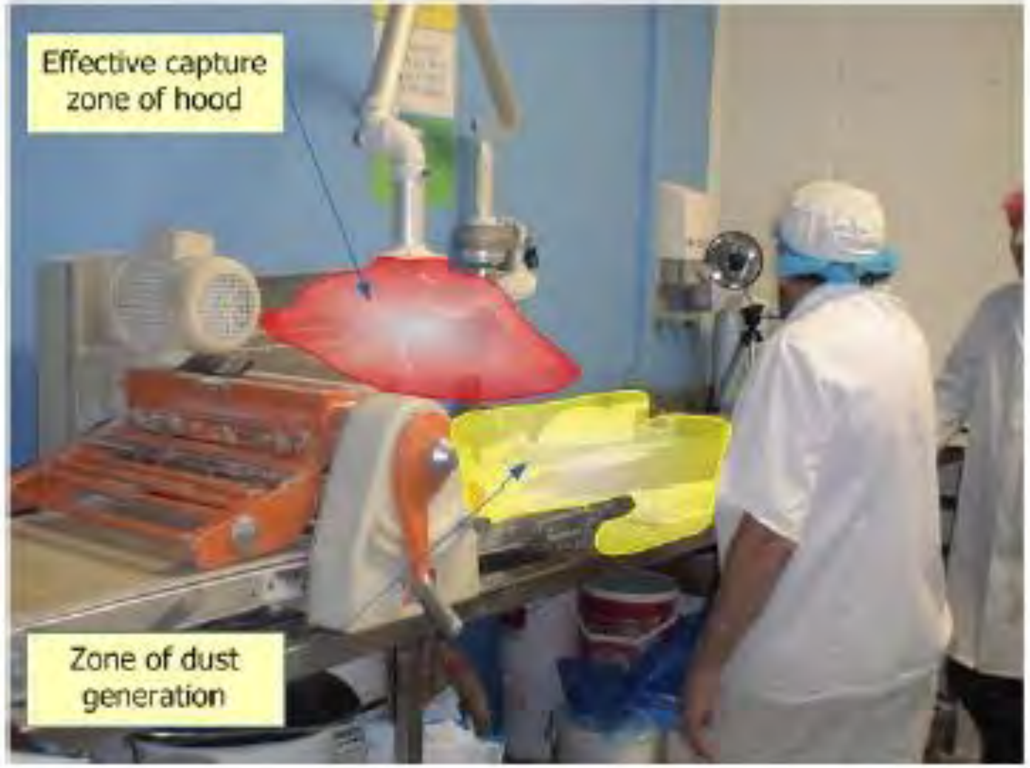
Contextual information	
Details on properties of materials	e.g. quantities of material involved; fine powder or coarse granules; percentage active pharmaceutical ingredient (API); moisture content
How materials were handled	e.g. sealed unit transfer or vigorous tipping from a height in to an open container; observations on 'careful' or 'rough' work practices
Data element	**Detail**
Presence and effectiveness of local control measures and procedures	Summary of controls: • LEV (type) and other engineering controls. • PPE. • Administrative controls. • Suitability and effectiveness of the controls. • Human factors and their influence on controls.
Inside/outside building.	Approximate room size in cubic meters.
Level of general ventilation.	Mechanical (info on air changes per hours (ACH) or natural.
Use of personal protective equipment.	Type, make, model, manufacturer. Duration of use. Maintenance and storage of PPE. Suitability and effectiveness.

Source: Clear and concise report writing: guidance for occupational hygienists

Example Content

LEV

Extracting the Best Practices



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Source: Clear and concise report writing: guidance for occupational hygienists

Checklist for reviewing an Occupational Hygiene report

LEV Extracting the Best Practices

Section of Report	Yes	No
Report Title		
Does the title accurately describe the contents of the report?		
Is the title specific enough (i.e., give enough information)?		
Is the title concise enough (i.e., not give too much information)?		
Does the title enable easy electronic and manual filing, referencing and indexing?		
Executive Summary/ Summary		
Is it shorter than one page in length?		
Does it contain a statement of the problem if there is one		
Does it contain information on who was monitored and where?		
Does it contain a statement of the methods used?		
Does it contain the most important results relative to applicable occupational exposure or other limits?		
Does it contain a statement of the conclusion(s) if found to be necessary?		
Does it contain the essential recommendation(s)?		
Introduction		
Is the problem clearly stated?		
Are the aims/objectives of the survey/report clearly stated?		
Is the history/ background included, and in sufficient detail?		
Does it reflect who did it, where and how it was done, and what workers were monitored?		
Does it include a summary of the operations and/or processes conducted during the survey?		

Materials and Methods		
Are materials and equipment described in sufficient detail necessary?		
Are methods described in sufficient detail for repetition, if necessary?		
If a laboratory manual was used as a reference, was it paraphrased and properly cited?		
Is the laboratory utilised identified?		
Are methods of statistical analysis included here?		
Is this section free of results or discussion?		
Results		
Have all of the results been described in the text of the results section?		
Have only the most relevant data been selected and reported in the tables and figures?		
Have all figures and tables been cited in the text of the results section?		
Have the most effective graphical or tabular formats been chosen to present important data?		
Can all figures and tables be understood without having to refer to the text?		
Are figures properly titled and captioned (below figure)?		
Are tables properly titled and captioned (above table)?		
Where applicable, does the dependent variable appear on the vertical axis and the Independent variable on the horizontal axis?		
Are tables and figures numbered independently, and are they numbered according to the sequence in which they are cited in the text?		

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Source: Clear and concise report writing: guidance for occupational hygienists

Checklist for reviewing an Occupational Hygiene report

LEV
Extracting the Best Practices

Section of Report	Yes	No
Have appropriate statistics been reported, and are they correct?		
Is the results section free of methodology or interpretation?		
Is the results section well-organised?		
Discussion		
Have all possible conclusions been drawn from the data, i.e., have all of the implications of the data been discussed?		
Where applicable, have anomalies been reported and addressed?		
Have assumptions been identified and justified?		
Where applicable, has the relationship between these and previous findings been discussed?		
What would be the implications of non-compliance with the report in terms of potential health and legal endpoints?		
Are control measures, and the efficiency of these control measures and any deficiencies in control measures discussed in this section?		
Is compliance with legal requirements highlighted in this section?		
Is the discussion section well-organised?		
Recommendations		
Are preventive measures included if employee exposures require to be reduced?		
Are required sampling strategies and programmes or additional required measurements listed?		
Are required actions to improve preventive measures and the persons responsible for carrying them out recorded along with action dates?		
Is the recommendations section well-organised?		

Acknowledgements		
Where applicable, are persons who assisted with the survey work identified?		
Are sources of borrowed equipment and supplies identified?		
Where applicable, are contributors of donated services (i.e., reviewing and editing) identified?		
Literature Cited		
Do all references cited appear in the text?		
Are all citations consistently presented in the same format?		
Are citations presented in an established format, including Internet citations?		
General		
Is the report consistently written in the past tense?		
Have typing errors and misspellings been eliminated?		
Does the entire report exhibit stylistic consistency?		
Did the authors use citations rather than footnotes?		
Does the report include a table of contents?		
Does the report need a listing of tables and figures?		
Does the report need a list of abbreviations and acronyms or a glossary?		
Does the report have provision for the official review or signing off by the relevant person(s)?		
Is the version of the report correctly indicated? e.g. Draft or Final.		

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Source: Clear and concise report writing: guidance for occupational hygienists

Questions

Health and Safety
Executive

HSE

LEV Fire & Explosion
- case study and prosecution

Duncan Smith

Help Britain work well

The Potential for Dust Explosions in Dust Collection Systems

- Based upon a 2011 ‘guesstimate’, there are around 2000 dust explosions across Europe and around 50 in the UK every year.
- A major factor leading to the high number of dust fire and explosions was a lack of risk appreciation, particularly for relatively benign dusts.
- The likelihood of an explosion in dust collectors will increase as the dust becomes concentrated in the airstream and filtration equipment.
- In many cases the ignition source is an easily identifiable risk such as a flame, spark or heat from a process. In some instances this source is an unexpected part of the process or environment – the process could produce static electricity, or human intervention may be such that a spark or flame is created due to deviation from approved procedures or incorrect use of machinery.

MBA Polymers, California -

- Fatal explosion of toner in 2000 - cartridge dust in recycling facility.
- Electrostatic charge in a grinder ignited the toner dust.

United States Chemical Safety and Hazard Investigation Board

Incident Title		
Investigation Concludes Toner-Cartridge Dust Played Role in Fatal Explosion, $4-million Plus Damage		
Location		Date of Incident
Richmond, CA, United States		**10/26/2000- 2:00 AM**
CSB Incident Number	NRC Report Number	Board Ref. Number
2000-4991	**None Reported**	**None Reported**
Current Status		Date of Report Update
No CSB Action		**4/26/2001 - 6:54 PM**
Incident Types	Location Types	
- Explosion	**Fixed Facility**	
Evacuations	Injuries	Fatalities
None Reported	**None Reported**	**1**
Chemicals Involved		
- Butane - Toluene - Xylene		
Description or Latest Development		

Information Added: Thursday, April 26, 2001 - 6:54 PM

Investigators for the California Division of Occupational Safety and Health said that the explosion and fire that claimed one life was related to an accumulation of toner-cartridge dust. They said an electrostatic charge in a grinder at the company may have ignited the explosive toner dust used in copy machines, causing the fire that killed a 26-year-old fork lift operator.

Cal/OSHA fined the company more than $221,000 for, among other items, failing to prevent the dust from accumulating and failing to warn the employees of its fire hazards.

Sam Singer, a spokesman for the company, complained that some of the fines "are high" but said the company was working with Cal/OSHA to prevent similar fires.

MBA Polymers recycles plastic items such as computer cases, telephones and toner cartridges and is considered a pioneer in the field. But the company has cut its staff by half and reduced the amount of plastic it recycles each month from 700,000 pounds as it revises operations to improve safety, Singer said.

Hazard recognised

- References two explosions in Japan in 2008
- Typical particle size <10µm
- Concludes that fire explosion during toner recycling is foreseeable and a major hazard

- **Actually**
  - Low MIE – very ignitable
  - St2 – strongly explosible
  - LEL = BIA assumed of 60 g/m3

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Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 84 (2014) 273 – 279

Procedia Engineering

www.elsevier.com/locate/procedia

HSE

"2014 ISSST", 2014 International Symposium on Safety Science and Technology

Study and countermeasure of hazard of dust explosion of various toner cartridges

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Abstract

This paper aims to show experimental research results of dust explosion of toner cartridges, and then propose countermeasure way against such explosion. Toner is composed various materials, iron, carbon and other organic materials, and which sizes are mostly less than 10µm (in diameter). Dust explosions sometimes occurred during usage, manufacture and recycled of toner cartridges. And recently toner powder size becomes much smaller, and more danger of dust explosion. In Japan we experienced incidents of dust explosion at toner cartridge manufacture and recycle facilities and other places. Therefore author studied its danger of dust explosion using new and recycled toners with various dust explosion tests, such as the minimum ignition energy test and the 30L explosion bomb test. Based on data, we found toner is safer than those of similar size of Al or Mg powder, but have a potential like to most organic powder. To reduce ambient oxygen concentration at treatment equipment was one of effective ways to reduce potential of dust explosion of toner cartridges.

Peer-review under responsibility of scientific committee of Beijing Institute of Technology

Keywords: dust explosion; toner cartridge; Japan

Close the Loop, Kentucky

- 2018 explosion safely contained
- No injuries

Explosion, fire reported at warehouse in Boone County

By | May 3, 2018 at 4:37 PM EST - Updated August 14 at 2:00 AM

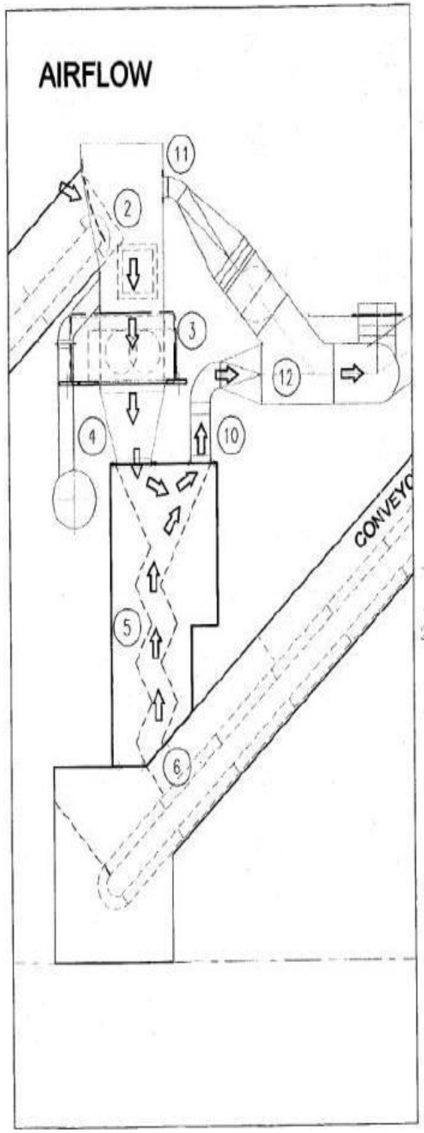
BOONE COUNTY, KY (FOX19) - Hebron fire officials said a company expects to have a stop on production for a day or so after a fire Thursday afternoon.

According to dispatch, the incident happened at Close the Loop in the 2000 block of Meridian Place.

The company is an Australian-based company that recycles toner cartridges.

A company representative said a piece of metal sparked, creating a flash fire inside the building.

HSE


AIRFLOW
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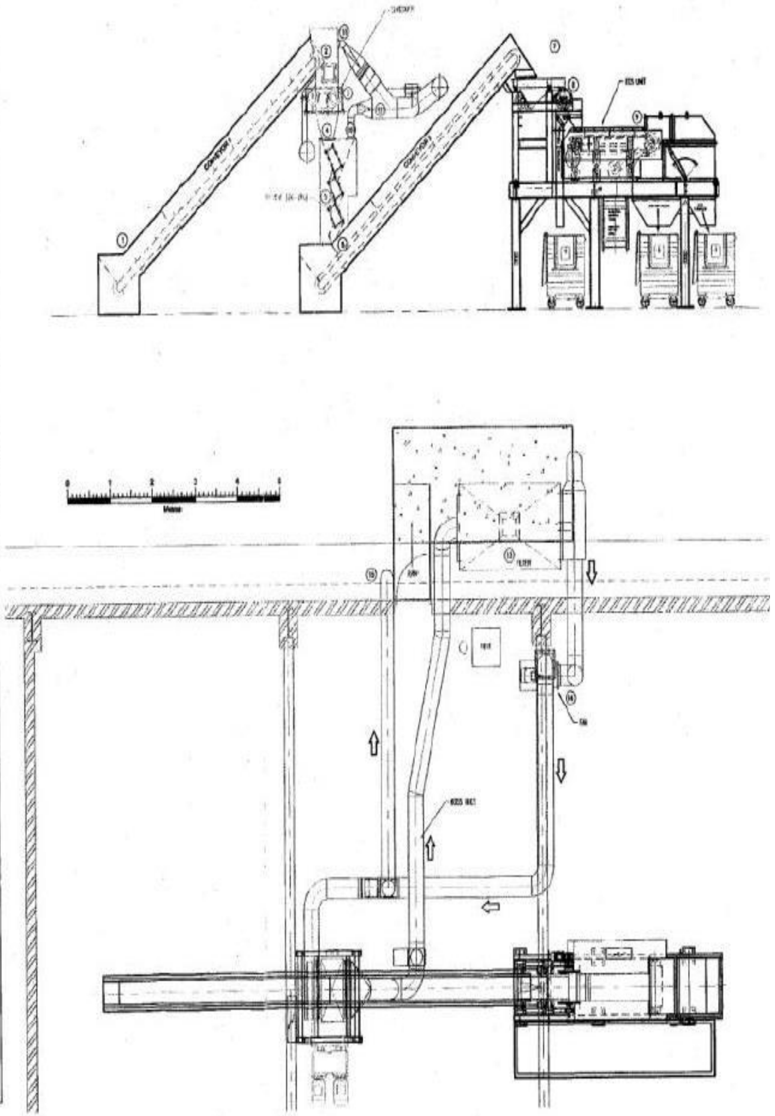

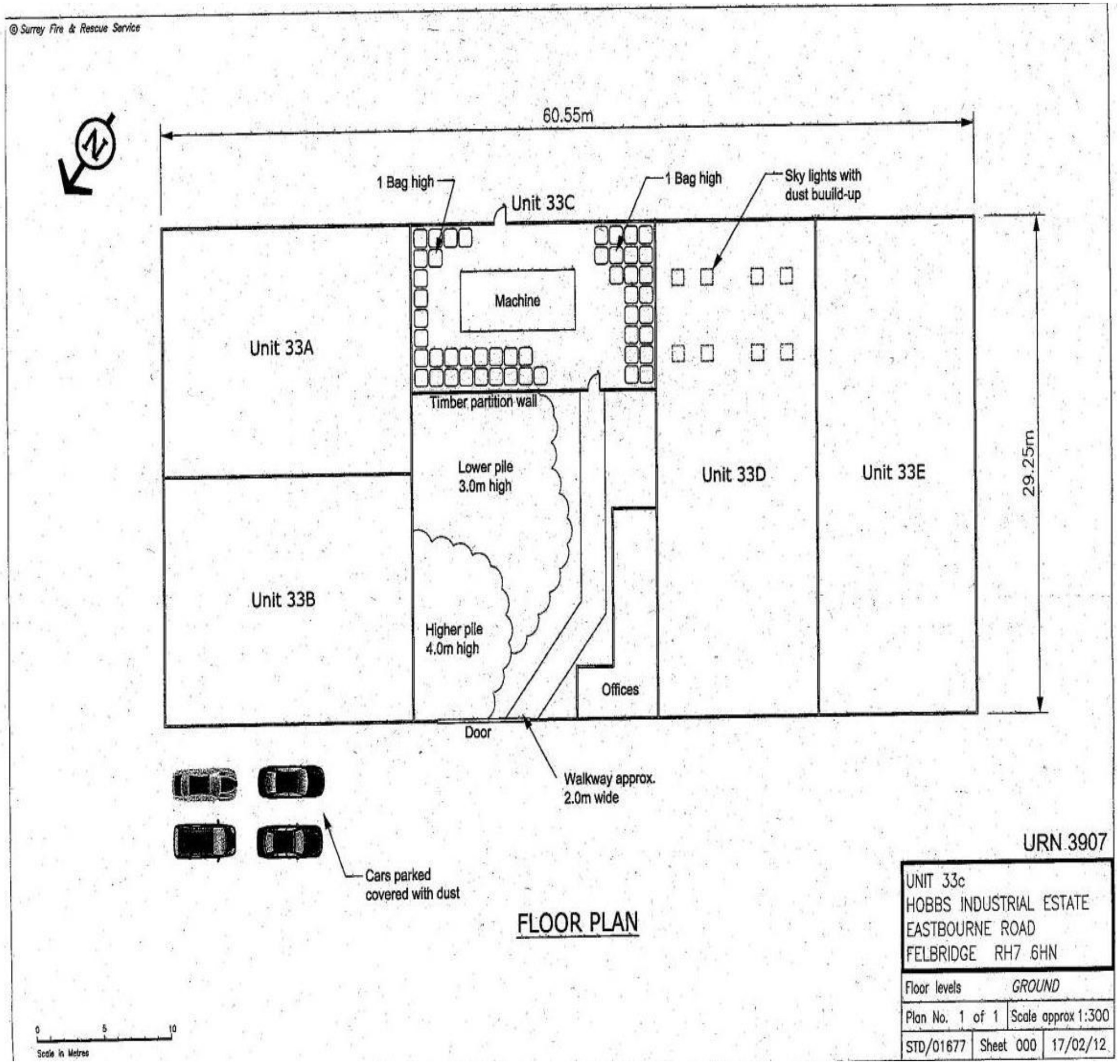

© Surrey Fire & Rescue Service
60.55m
N
1 Bag high
Unit 33C
1 Bag high
Sky lights with
dust buuild-up
Machine
Unit 33A
Timber partition wall
Lower pile
3.0m high
Unit 33D
Unit 33E
29.25m
Unit 33B
Higher pile
4.0m high
Offices
Door
Walkway approx.
2.0m wide
Cars parked
covered with dust
FLOOR PLAN
URN 3907
UNIT 33c
HOBBS INDUSTRIAL ESTATE
EASTBOURNE ROAD
FELBRIDGE RH7 6HN
Floor levels GROUND
Plan No. 1 of 1
Scale approx 1:300
STD/01677
Sheet 000
17/02/12
0 5 10
Scale in Metres

03/10/2011

Picture Source: BBC Website

Trevor XXXXXXX

- (who had only been working for eReco for a few days).
- His injuries required him to be placed into an induced coma.
- His treatment required general anaesthetic on at least 40 occasions and he was allowed home after approximately 3 months.

Stephen XXXX

- Suffered second degree burns over both arms, his head and his back.
- He suffered hearing loss and after 3 days in hospital was discharged but later re-admitted following a reaction to his medication.

Simon XXXXXXX

- Sustained burns to his left hand as well as his face and head where the mask he had worn melted as a resulted of the explosion.

Nigel XXXXX

- Was airlifted to Kings College Hospital and then taken to Chelsea and Westminster where he recovered consciousness.
- He had sustained burns to his face, head, both forearms and hands as well as parts of his back and buttocks.
- He needed a skin transplant on his hands which were later replaced with skin grafts.

Dominic XXXXXX

- Suffered burns as a result of his face mask catching fire.
- He sustained burns around his nose and mouth as well as burns to his right hand.
- He underwent outpatient treatment for the subsequent 10 days.

Recycling company fined after explosion

27th February 2018

A Sussex-based recycling company has been fined following an explosion and fire at their site in Surrey which left a worker in an induced coma.

Portsmouth Crown Court heard how a massive explosion occurred at Ereco EMEA Corporation Ltd site on 3 October 2011 at Hobbs Industrial Estate, Lingfield, Surrey, following the storage of print toner on site. Eight people were injured as a result of the explosion, five seriously. A 30-year-old worker was placed in an induced coma and remained in hospital for 15 weeks.

A joint investigation by the Health and Safety Executive (HSE) and Surrey Fire and Rescue Service (SFRS) found that Ereco failed to ensure there was a safe system of work in place to reduce the risk of dangerous substances; this could have been completed through carrying out suitable fire risk assessments and following guidelines in Dangerous Substances and Explosive Atmospheres Regulations 2002.

The investigation also found that Paramount Waste Extraction Ltd, the company who designed the machinery that was used to shred and process the toner cartridges, did not consider the likely misuse of the machine by overloading the processing of toner with more than a residual amount of toner powder left inside; it was found they relied on generic data to determine whether an explosive atmosphere may arise.

Judge's Sentencing Remarks – eReco failings

- Inadequate housekeeping, especially a failure to deal with the increased workload/quantities of consumables;
- Allowing an increased level of toner powder/dust – consequent upon the inadequate housekeeping;
- Failure to control possible sources of ignition, when it was known that the dust being generated was potentially explosive;

- Failure to install a downdraught bench to limit dust levels during cartridge emptying;
- Lack of control measures to limit the quantities of toner in the consumables being placed in the machine;
- Inadequate risk assessment, monitoring and supervision of the explosive dangers created by the systems of work being used and the inevitable generation of toner dust.

Judge’s Sentencing Remarks - Paramount failings

- Paramount was aware of the shredding of consumables containing more than residual quantities of toner powder during the installation process at eReco but took no action (or no adequate action including providing warnings) when armed with this knowledge;
- Failed to anticipate (and in fact knowing of) misuse of the machine and relied inappropriately on calculations in respect of explosive risks which as a result were redundant.

Extraction System Technical File

HSE

- Assumed 3g toner in the empty cartridges.
- Cartridge feed rate assumed to be one every 4 seconds (one every other flight).
- Top hopper charge box airflow = 1.44 m^3/s, charge box volume = 0.522 m3 ∴ 1 air change every 0.36 seconds.
- Conveyor belt speed of 300 mm/s and flights at 600 mm spacing, the dust concentration in the hopper is calculated as 3g/(4 x 1.44) = 0.52 g/m^3 (i.e. less than the LEL of 60 g/m3 - giving a safety factor of 115).

However…..

- The actual LEL of the dust had not been measured and a generic value had been used.
- The actual LEL for toner dust recovered from site was measured to be 15 g/m^3 - significantly lower than the assumed value of 60 g/m^3.
- This reduces the initial calculated safety factor of 115 by 75%.

And….

- The mass of toner powder in full cartridges ~ 600g and not all cartridges were empty.
- For example, the LEL would be exceeded if a cartridge containing 600g of toner was placed on every other flight. This would result in a dust concentration in the hopper = 600g/(4 x 1.44)= 104 g/m3 i.e. seven times the measured LEL of 15 g/m3.

And….

- The processing speed was likely to have been higher than a cartridge every other flight, due to misuse.

Post-Prosecution Comments

- Speaking after the hearing HSE inspector Michelle Canning said: “All the employees involved in this incident are extremely lucky this explosion didn’t prove fatal.
- “eReco failed to take the required precautions before starting a process of work with dangerous substances and this failure resulted in this serious, life threatening explosion.

- “Both designers and suppliers must ensure that the risks of using their equipment are eliminated through safe design, and this should include taking into account foreseeable misuse.”