

M505

Control of Hazardous Substances

Day 3

Today's Topics

- **Review of overnight questions**
- **Principles of containment**
- **Personal protective equipment**
- **Administrative elements**
- **Practical applications of control strategies**



Review of Overnight questions

Questions?

Principles of Containment

Definition

The terms “containment”, “isolation” and “segregation” are often used interchangeably to describe the equipment, systems or procedures which are employed to prevent or reduce exposure to hazardous substances

Containment

Describes any control measure which reduces exposure by using a barrier to prevent the escape of materials hazardous to health into the surrounding workplace

Simple Example of Containment



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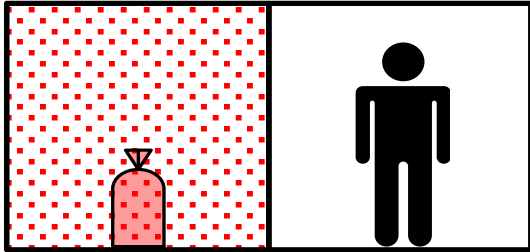
Containment as a Process Control

Containment may also be used as a process control

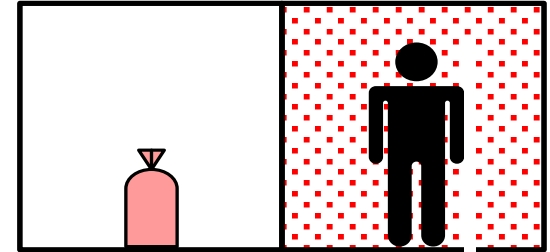
Containment can be used to prevent contamination or degradation of compounds by the environment:

eg: during electronic components or pharmaceuticals manufacture where a controlled manufacturing environment is required

Exposure & Process Containment



Containment as exposure control



Containment as process control

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Use Of Containment

Containment is used in manufacturing industries, particularly those handling and producing chemicals

Examples include chemical manufacture, agrochemicals, pharmaceuticals, petrochemical industry

Use Of Containment (cont)

Containment tends to be used as a control measure to reduce the level of risk from the following hazards:

- **Flammability**
- **Explosivity**
- **Toxicity**

Levels of Containment

- **Primary**
- **Secondary**



Primary Containment

- **The first level of containment**
- **An example is the use of an intermediate bulk container (IBC) or sealed drum to contain a liquid**



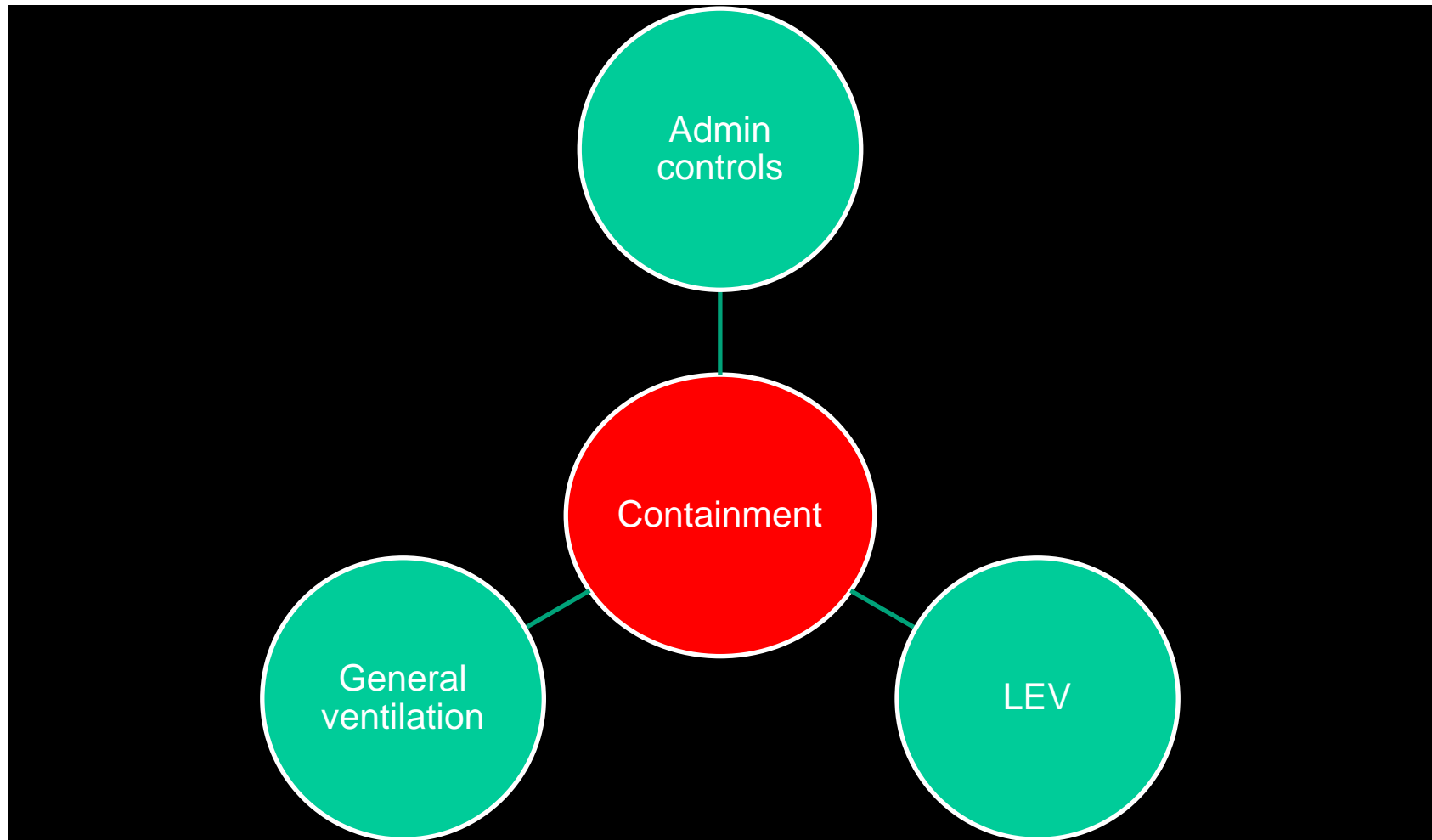
Secondary Containment

- **A control measure to prevent unplanned releases of toxic or hazardous compounds into uncontrolled work areas**
- **An example is use of a bund or drip tray to capture any releases from the drums or IBC**



Use of Multiple Containment Options

- **Often used in combination with other controls**



Barrier Devices

- **One or more barriers are placed between operator and exposure source**
- **An example is when the mixing of chemicals is carried out within a sealed vessel**

Combined Barrier-LEV Devices

- **Where the use of barriers/enclosures is combined with LEV controls**
- **For example a laboratory fume cupboard with an adjustable sash**

Modified Extraction Hood



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Integration of Containment with Process Design

- In many instances it is appropriate to integrate the design of containment with that of the process and as such the containment will influence the design of the process**

Integration of Containment with Process Design

- **Containment is much more difficult to apply as an add-on control measure than it is when considered at the start up stage**



Class Exercise

- **List the types of situations and processes where containment could be used to control exposure**



Transfer Operations Involving Solids

- **Dispensing operations**
- **Charging of vessels and equipment**
- **Unloading solid-liquid separation equipment**
- **Unloading dryers**
- **Milling and Blending**
- **Removal of solid impurities**



Transfer Operations Involving Liquids

- **Loading and unloading of road/rail tankers**
- **Drum and semi bulk container transfers**
- **Small container transfers**
- **Pressurised liquid transfers from cylinders**
- **Container filling**



Other Operations

- **Gaseous transfers**
- **Quality control sampling**
- **Process containment**
- **Plant cleaning**



Example-Manufacture of Chemicals

- **Weighing/dispensing of solid raw materials**
- **The addition of solid/liquid and /or gaseous reagents to reaction vessels**
- **The controlled reaction of chemicals with subsequent product and by product generation**



Manufacture of Chemicals (cont)

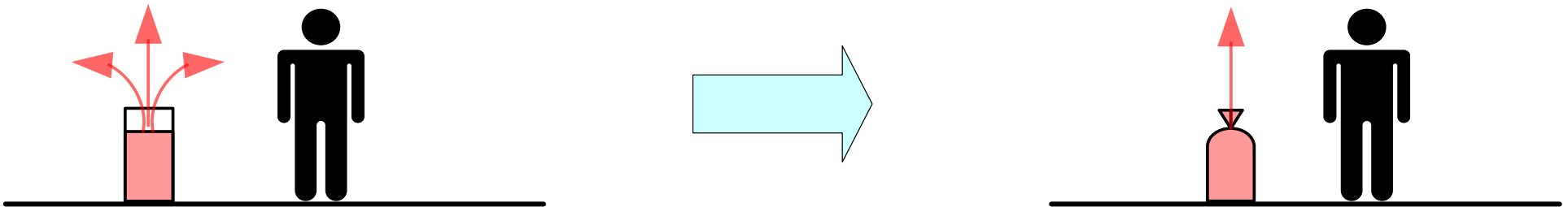
- **Purification steps which may involve the addition and removal of material**
- **Crystallisation of a solid product**
- **Separation of products from liquors**
- **Drying**
- **Removal of the product to containers**
- **Milling and Blending**

Types of Containment Equipment

- **Simple enclosures & screens**
- **Isolators**
- **Over-bagging**
- **Transfer devices**
- **Coupling devices**
- **Remote handling**

Simple Enclosures

Enclosing substances with sealed containers can prevent or minimise releases into the workplace



Source: Adrian Hirst – reproduced with permission

Bag and Poly bottle fitted
with passive sbv connectors

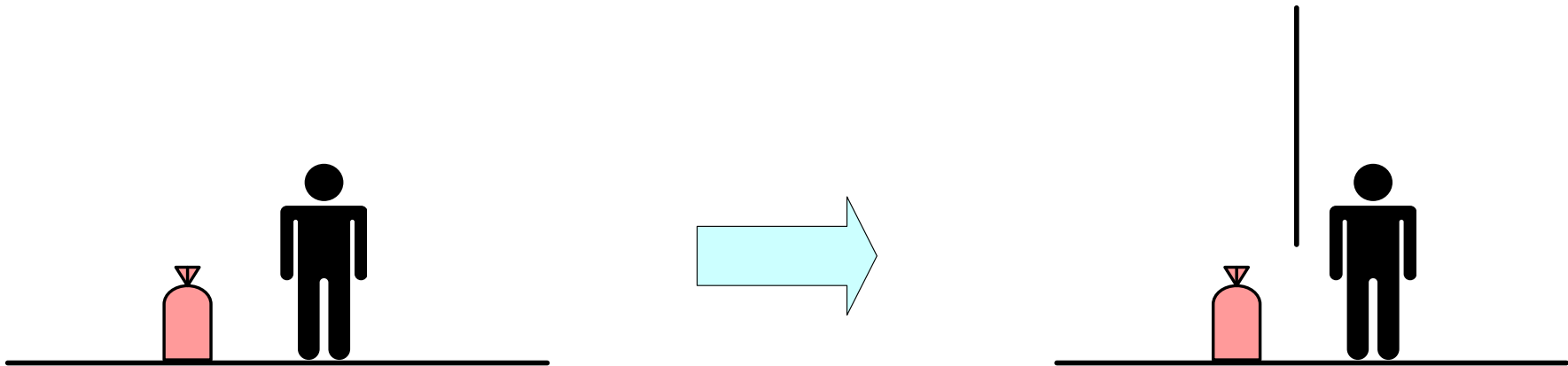


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Use of Screens

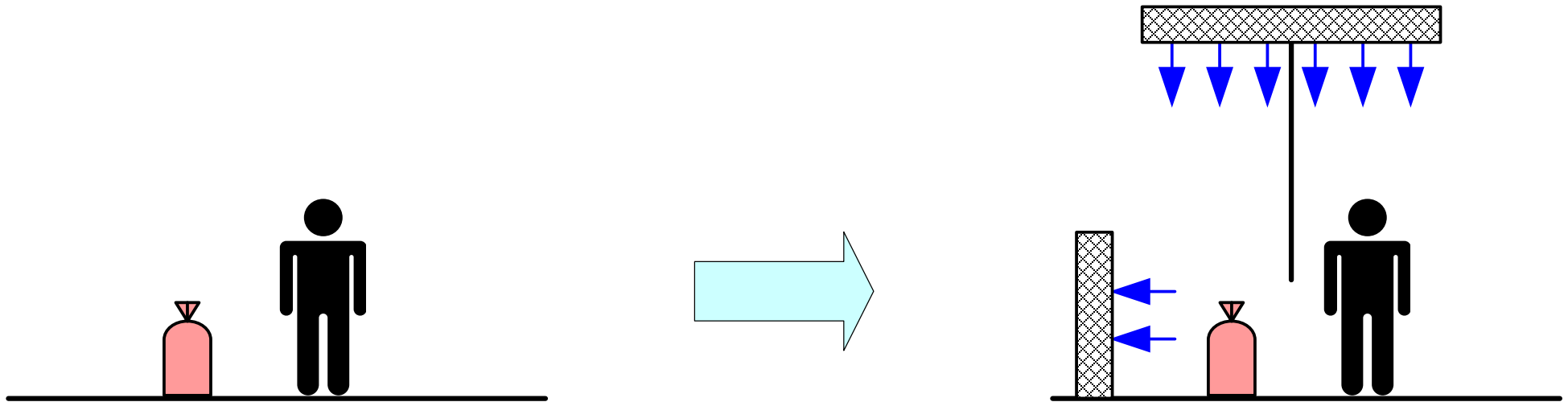
The use of a simple but incomplete barrier (screen) between the operator and the substance can also act as containment



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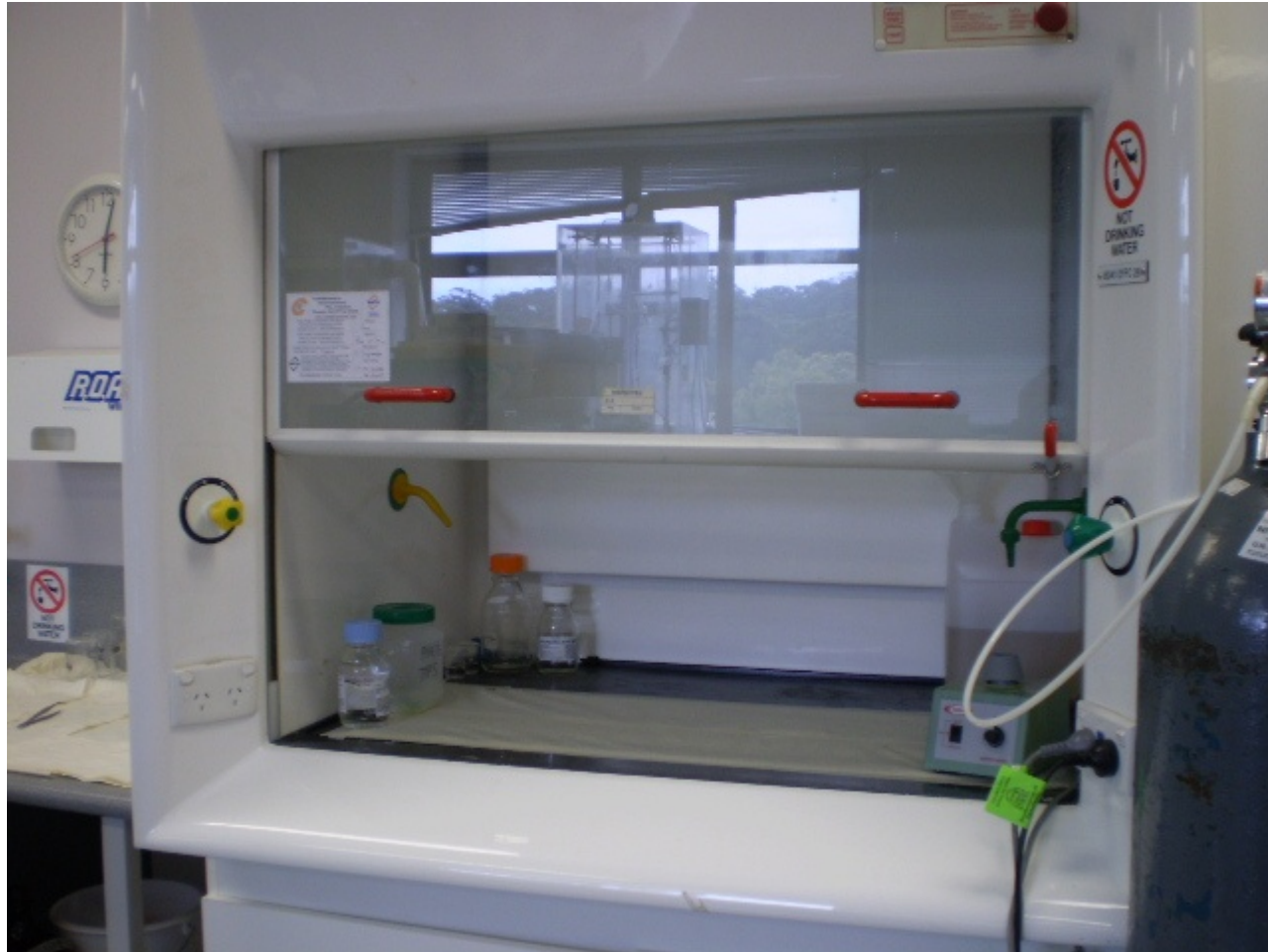
Screens Plus LEV

Screens can be combined with LEV to enhance the effects of both types of control e.g. sash in laboratory fume cupboard



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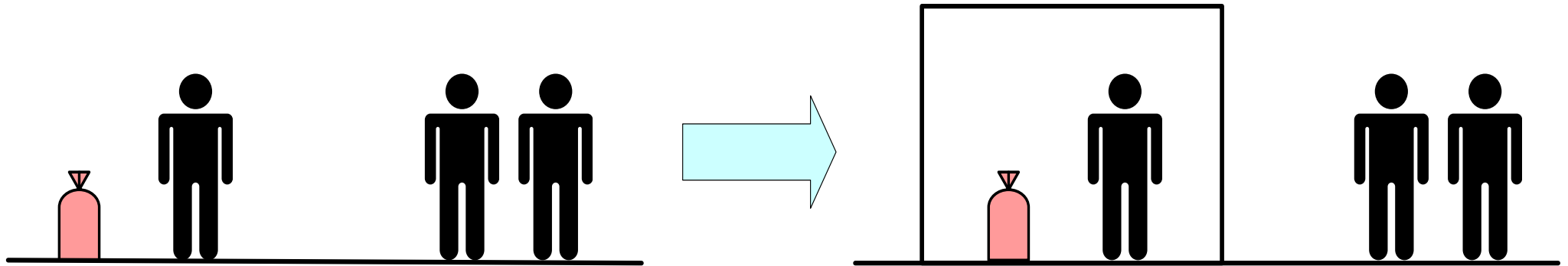
Screens Plus LEV



Source; University of Wollongong



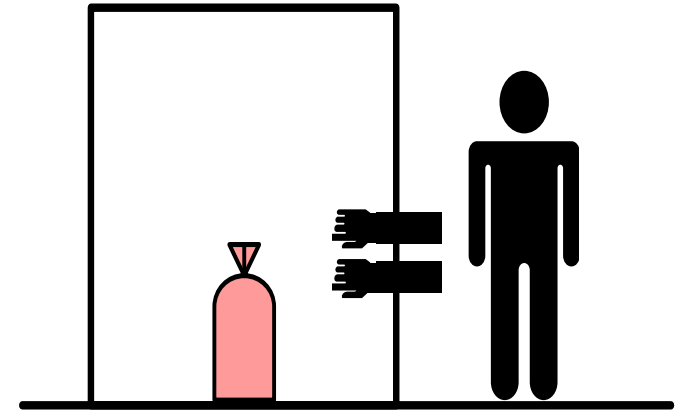
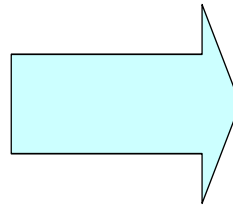
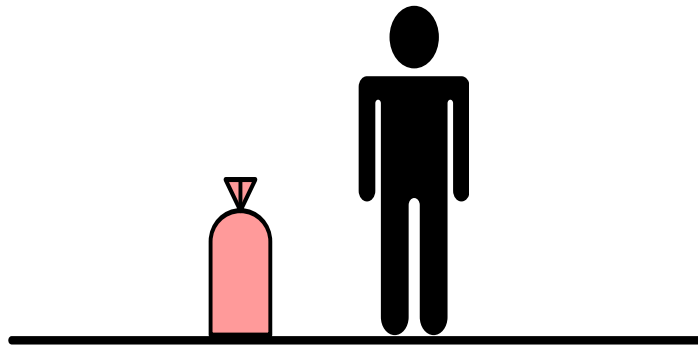
Segregation by Distance & Activity



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Isolators



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Glove Box



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Typical Isolator Used In Pharmaceutical Industry



Source: GSK – reproduced with permission

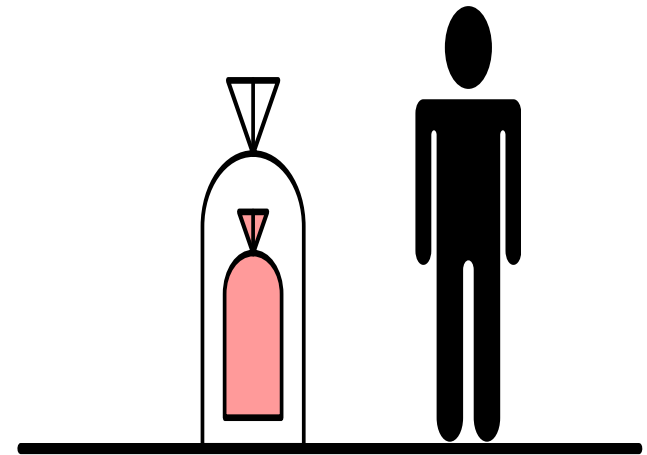
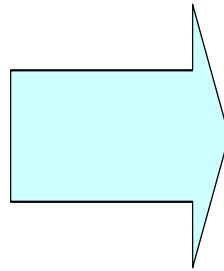
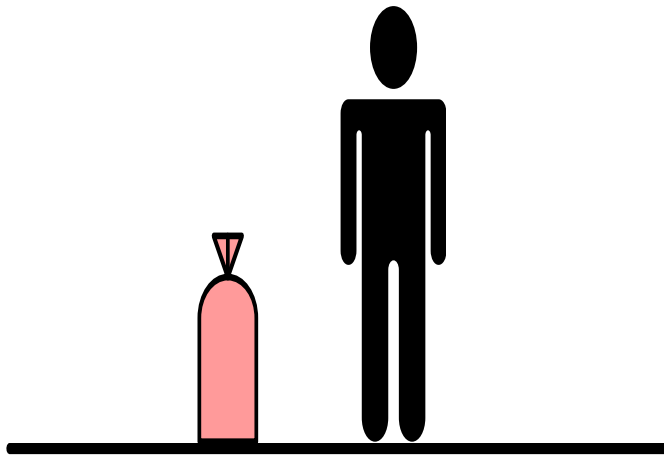
Half Suit Isolator



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Over-Bagging



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Asbestos Industry – Double Bagging



(Source: Gully Howard Technical Ltd)

Decanting Product into Plastic Liner Inside Drum

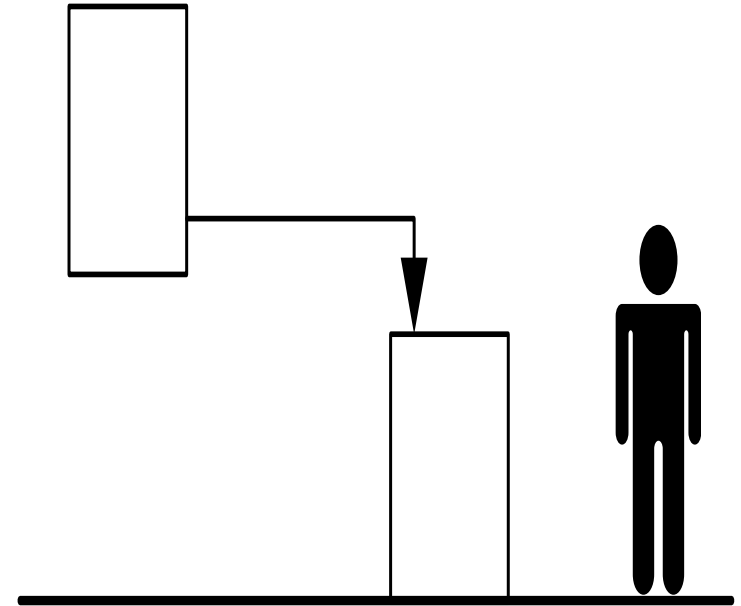
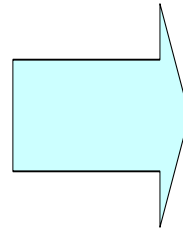
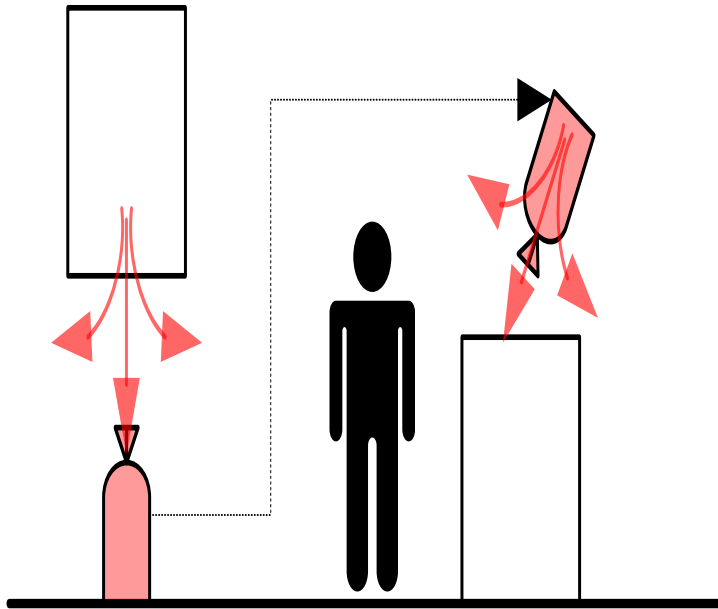


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Transfer Devices



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Bag Filling Unit



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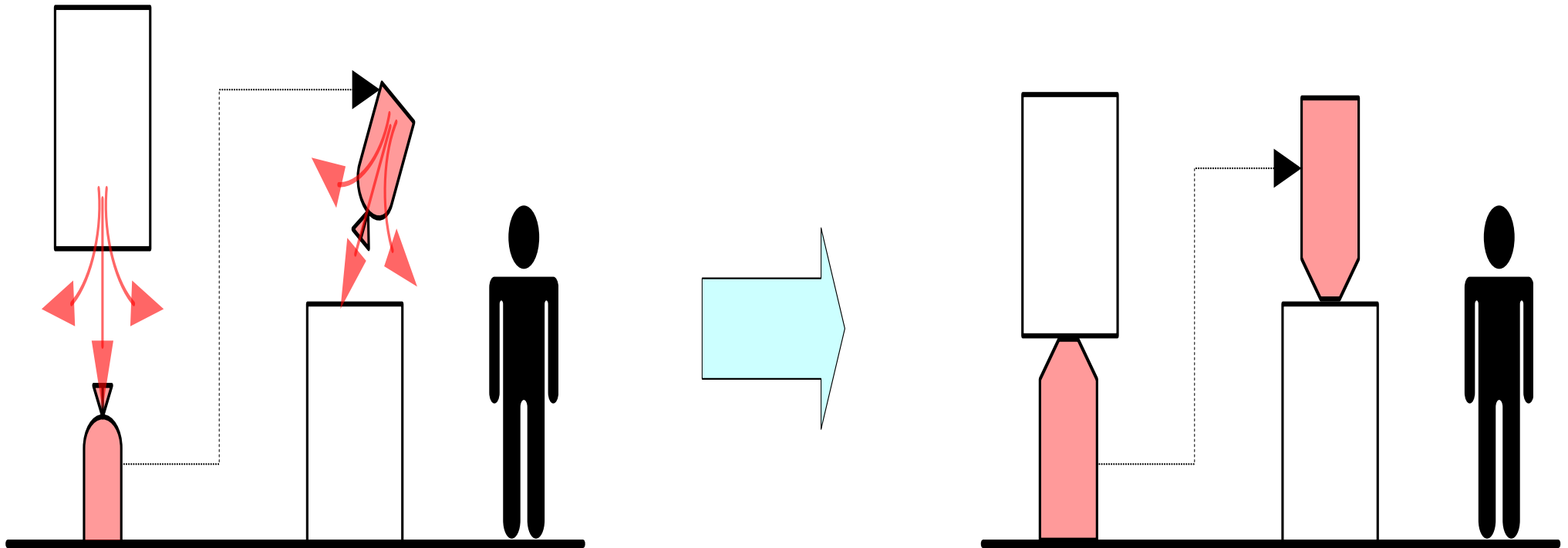
Ventilated Packaging System



Source: GSK – reproduced with permission



Coupling Devices



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Fixed Docking Port on Mixing Vessel



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Figure 7.12 shows the setup for dispensing and weighing of potent compounds. At the far end of the room is a downflow booth with clean air flowing down. A clear plastic sheet with integral gloves forms containment which augments the downflow booth.

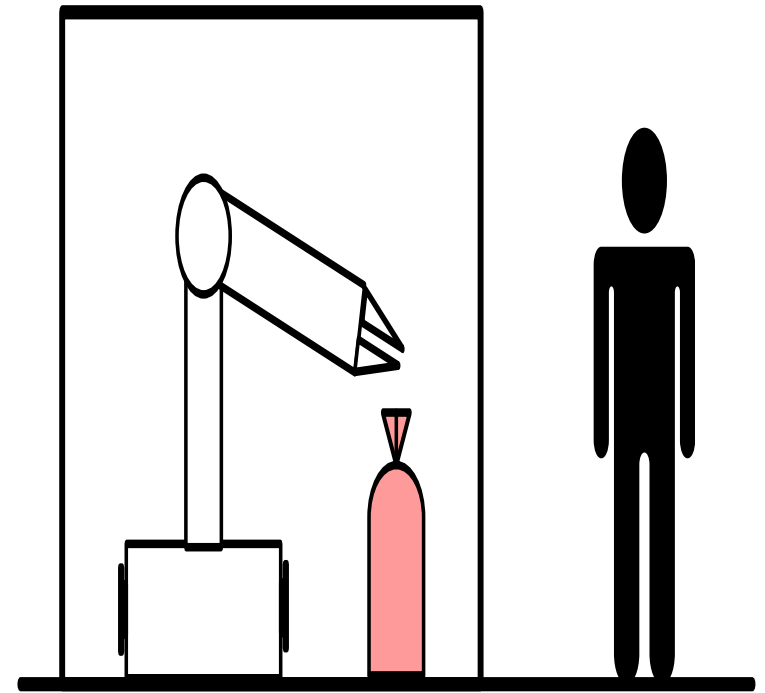
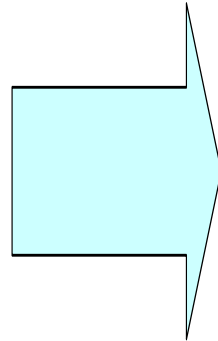
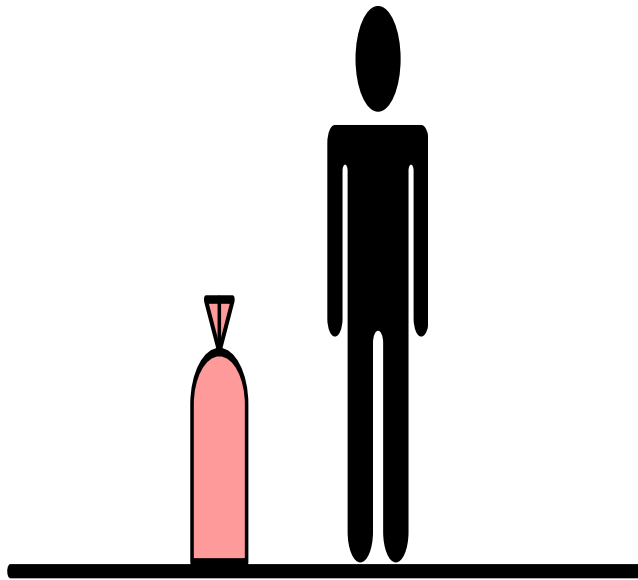
Coupling Devices



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Remote Handling



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Design of Containment Systems

- **Requires thorough understanding of hazardous substances involved & the processes which they are used**

Design of Containment Systems

- **Use of models, full scale “mock ups” and 3D imagery allows evaluation of all potential issues e.g. ergonomics**

Design of Containment Systems

- **Control banding can be used to determine the level of containment required**

High Level Containment Systems

- **High levels of containment tend to be used when potent materials are used which have low exposure limits or where larger quantities of more dusty or volatile materials are present**
- **Examples**
 - **Storage of flammable liquids**
 - **Biological laboratories**
 - **Nuclear industry**

High Level Containment Systems (cont)

- **The level of containment achieved at this level is refined by using increasingly more complex forms of engineering**
- **Example**
 - **three different levels of containment used for shutting off the supply of powder when filling containers by gravity feed**

Stage 1

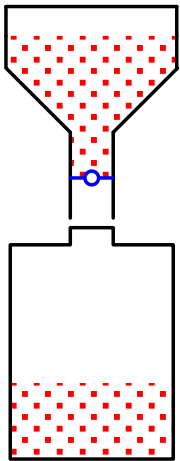
- **At the first stage a simple butterfly valve cuts off the gravity feed of powder from above**
- **This prevents mass leakage of the material but leaves the container open some residue at the mouth of the butterfly valve**

Stage 2

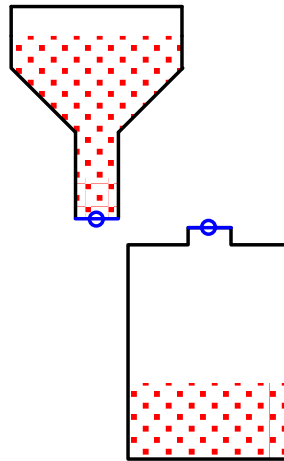
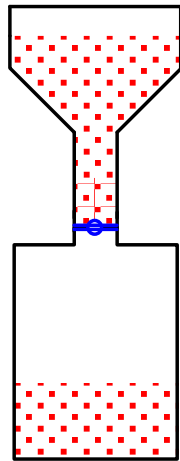
- **At the second stage the container is physically connected to the dispensing unit and a split butterfly valve is fitted**
- **The split butterfly valve seals both the supply and the container but leaves the possibility that small quantities of material are left at the point where the two valves meet**

Stage 3

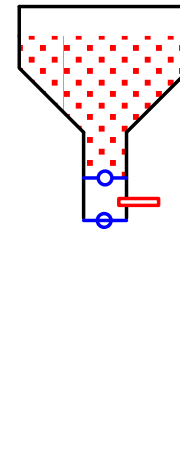
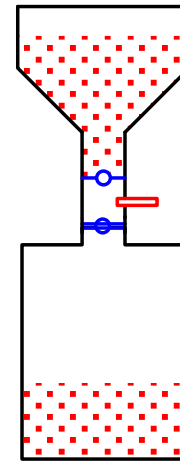
At the third stage a split butterfly valve is used but a compressed air supply is also used to blow residue off the valve before it is closed



Stage 1



Stage 2



Stage 3

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Types of Equipment used in High Level Containment

- **Isolators**
- **Clean room technology**
- **In process cleaning – washing & cleaning facilities to clean equipment in situ**
- **In process maintenance – Designs which allow activities such as glove or filter changing on an isolator without having to clean whole apparatus**

Types of Equipment used in High Level Containment (cont)

- **Split butterfly valves**
- **Docking systems**
- **Pass boxes – antechambers to isolators which allow controlled conditions for materials to enter & exit the isolator**

System for Weighing & Dispensing Potent Compounds



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Other Considerations

- **Control of Waste and Emissions**
 - **Any materials which are removed from a containment system, whether they are products or waste products have the potential to be contaminated with hazardous materials**
 - **Any form of containment will therefore require appropriate consideration to be given to the treatment of materials as they are removed from it**

Wastes from Containment Systems

- **Empty sacks, drums and liners etc will contain traces of the materials which were held within them**
- **The handling of these materials can give rise to significant exposures e.g.: the rolling of an empty sack for disposal**

Containment of Filter Elements & Media

- **It will be necessary to change consumable items such as filter media which will then need to be disposed of**
- **This can result in exposure as well as a temporary failure of the containment system**

Contaminated Clothing

- **Clothing and other forms of PPE/RPE may be contaminated and will require specific controls in order to ensure their safe handling, cleaning and/or disposal**

Exhaust Gases Containing Hazardous Vapours or Particulates

- **These may be generated by the process or induced as part of the containment equipment**
- **The subsequent cleaning and discharge of the gases will need to be considered**
- **Where high levels of containment are needed then the level of filtration will need to be high – e.g. use of HEPA filtration on isolators in the pharmaceutical industry**

Contaminated Drainage & Cleaning Liquids

- **Liquids will invariably need to be used for cleaning purposes**
- **These pose very different considerations when it comes to potential exposure and eventual disposal**

Explosion Prevention and Control

- **The build up of high concentrations of dust, flammable gases and vapours can give rise to the potential of explosion**
- **The act of containment means that substances are held in a smaller space which in turn means the localised concentrations are higher**
- **This means that introducing the concept of containment can increase the likelihood as well as severity of explosion**

Explosion Prevention and Control (cont)

- **The design of any containment system which involves potentially explosive atmospheres should incorporate design features which prevent the occurrence of an explosion as well as mitigate the effects in the event of one taking place**

Explosion Prevention

This may be achieved using a variety of techniques such as:

- The elimination of ignition sources: electrical sources, heat, static electricity etc.**
- The prevention of explosive concentrations**

Mitigation Measures

- **Explosion suppression – the use of sensors and fire extinguishants to react quickly and put out explosions as they start**
- **Compartmentalisation – the division of a containment into smaller units to prevent the spread of an explosion to other parts of the system**

Operation and Maintenance of Containment Devices

- **As with all forms of exposure control the correct operation and maintenance of containment devices is essential if they are to be effective**
 - **Information, instruction and training on correct use of device - Operating procedures.**

Operation and Maintenance of Containment Devices (cont)

- Regular checks and thorough examination.
In the UK the COSHH regulations require that all forms of control measure are inspected and tested on a regular basis**

Operation and Maintenance of Containment Devices (cont)

- The maintenance and repair of containment devices may present greater potential for exposure than their actual use. The cleaning of devices and activities such as changing consumable parts should be considered at the design stage as much as the normal operation of the devices**

Limitations of Containment Systems

- **Containment systems have inherent weaknesses which stem from the nature of their design**
 - **Transfer points: potential for release of substances**
 - **Seals: potential leaks**
 - **Cleaning**
 - **Quality assurance sampling: possible break in containment**
 - **Ergonomic issues: may influence way work is performed**

Future Developments

There are a number of factors which mean that in the future containment is likely to become an increasingly important method of controlling exposure

The trend of continually reducing exposures as legislative requirements become more stringent means that containment will need to be used instead of less effective or less desirable methods of control; eg: reducing reliance on RPE

Future Developments (cont)

The development of more potent compounds in the pharmaceutical and chemical industries means that improved levels of control will be required as active ingredients are developed which have lower exposure limits

The emergence and growth of nanotechnology presents a new array of hazards which can only be confidently controlled by using containment

Testing and Validation of Containment

- **It is important to ensure that any control measure which is introduced is working effectively**
- **The act of demonstrating the efficacy of a containment solution is termed “Validation” and consists of the visual examination of the controls as well as undertaking objective tests such as air monitoring, leak testing and the use of dust lamps**

Testing and Validation of Containment (cont)

- **Specific validation may be required for a number of reasons:**
 - **It may not be possible to visually determine that containment is effective e.g. where potent compounds with low OEL's are used such as in the pharmaceutical industry**
 - **Containment may need to be validated to ensure that it is protecting the product (process control) as well of the operator (exposure control)**

Some Specific Examples of Containment

- **Petrochemical Industry examples**
 - **Enclosed transfers designed to prevent leaks e.g. self-draining transfer lines**
 - **High integrity methods of material loading and unloading (e.g. dry lock couplings, vapour capture and recovery)**
 - **High integrity (low emission) valve packings and flange seals**

Petrochemical Industry Examples (cont)

- Plant designed to facilitate the draining and flushing of plant equipment items prior to maintenance, with recycle and/or suitable disposal of wastes**
- In-line process controls and/or contained systems for process sampling**
- Low emission pumps e.g. canned, magnetic, mechanical seals**
- Routine monitoring and inspection for leaks to reduce fugitive emissions**

Petrol Station Example

- **The fuel filler nozzle fits your car and has a device to cut off the delivery when it is full**
- **There is a sheath around the top of the nozzle which helps to reduce splash back and disperse vapours**
- **The underground storage tanks have linked tanks and are fitted with filters to equalize pressures and reduce emissions as they are filled and emptied**

Fine Chemicals Industry Examples

- **Material transfers via enclosed systems (e.g. semi-bulk containers such as IBC's)**
- **Enclosed and vented charging systems (e.g. bag slitters with integral package disposal)**
- **Discharging arrangements designed to minimise emissions (e.g. into drums/kegs via pneumatic filling heads and continuous liners; vented booths with exhaust scrubbing)**

Fine Chemicals Industry Examples (cont)

- **Plant designed to facilitate the draining and flushing (and detoxification) of equipment items prior to maintenance**
- **Maximal use made of automated process control systems to minimise manual interventions**
- **Contained process sample systems (e.g. vented cabinets or sample bombs)**

Pharmaceutical Industry Examples

- **Engineered Airflow Device**
- **Ventilated enclosures e.g. laminar flow/powder containment booth**
- **Vertical process trains**
- **Specialised valving such as split butterfly valves**

Pharmaceutical Industry Examples (cont)

- **Vacuum transfer of materials**
- **Intermediate bulk containers**
- **Isolation technology eg: isolators**
- **Soft Wall Isolators (Glove bags)**

Personal Protective Equipment

Personal Protective Equipment

- **Last line of defense**
- **Careful selection required**



Source: DuPont Personal Protection – reproduced with permission



Class exercise

- **What should be included in a PPE programme?**



PPE Programmes

- **Basis for selection of PPE**
- **Medical screening if required**
- **Training program**
- **Limitations**
- **Proper fitting**
- **Cleaning, maintenance & storage**
- **Evaluation of program**

We Need to Avoid Situations Like This!



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Global Harmonisation of PPE ?

Currently not in place or on near horizon

Standards from:

- **ISO**
- **National**
 - **AS/NZS, BS, EN, USA, Japan, Korea etc**
- **Often different – especially for respiratory**

Types of PPE

- Head protection
- Eye & Face protection
- Hearing protection
- Respiratory protection
- Hands / Gloves protection
- Body / Clothing protection
- Foot protection
- Protection against falling



Control of Hazardous Substances

- **Respiratory Protective Equipment (RPE)**
- **Chemical Protective Clothing (CPC)**
- **Gloves**
- **Eye & Face**

Respiratory Protective Equipment

- **Required when:**
 - **Deficiencies in oxygen**
 - **Contaminants in particulate form**
 - **Contaminants in gaseous or vapour form**



RPE - General Use Limitations

- Air purifying do NOT supply oxygen
- Do not use when:
 - IDLH (Immediately Dangerous to Life & Health)
 - Concentrations unknown
 - < 19% oxygen

Unless wearing SCBA or airline/escape SCBA

RPE - General Use Limitations (cont)

- **Do not abuse or misuse respirator**
- **Do not wear if facial seal cannot be made - beard, facial hair, etc**
- **Do not exceed maximum use concentrations set by regulatory authorities**

Types of Respirators

- **Air Purifying**
- **Air supplied**

Air Purifying Respirators

- **Particulates**
 - **Dusts, Fumes, Fibres, Mists**
- **Gases & Vapours**
- **Combination filters**

Air Purifying Respirators (cont)

- Non powered

“Disposable”



Half face piece



Full face piece



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Air Purifying Respirators (cont)

- **Powered**

PAPR



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Particulate Filters

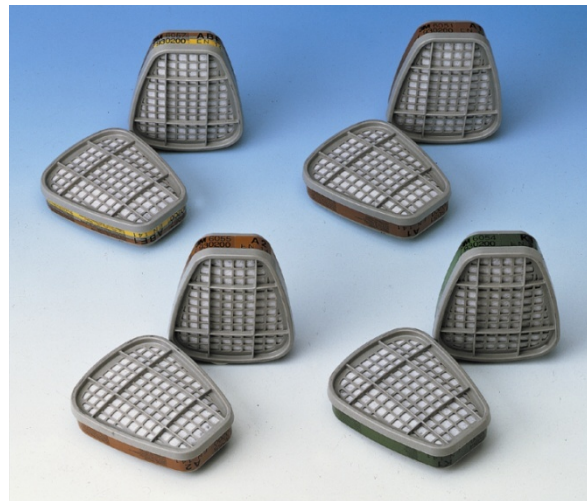
AS/NZS 1715	EN 529 / SA	NIOSH
P1	P1	
P2	P2	95 N, P, R 99 N, P, R
P3	P3	100

Substance Specific Classes e.g. asbestos, lead & Cr⁶⁺ in some countries

Gas & Vapour Filters (cartridges)

Examples – many other types

A	Certain organics
B	Certain inorganic & acid gases
E	Sulphur dioxide
K	Ammonia



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Classes of Gas Filters

Increasing capacity

- **Class Aus** **low (shorter than Class 1)**
- **Class 1** **low to medium absorption capacity**
- **Class 2** **medium absorption capacity**
- **Class 3** **high absorption capacity**

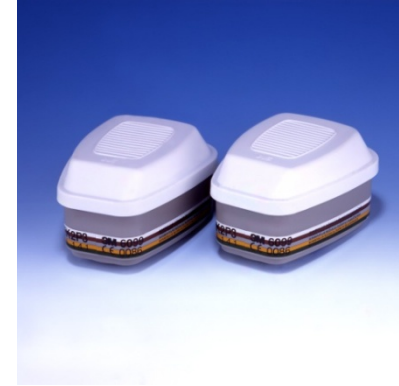
Different “Amounts & Types of Charcoal”



“Nuisance level organic”



Class A1



Class A2B2E2K2P2



PAPR A1B1E1P3

Source: 3M Australia Pty Limited – reproduced with permission

Combination Particulate & G & V Filter



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Substance Specific Filters

- **Some Countries**
 - **Vinyl chloride**
 - **Benzene**

Supplied Air Respirators

- Deliver “breathing quality” air to the wearer

Air hose respirator

Airline respirator

SCBA



Source: Dräger Safety Pacific Pty Ltd – reproduced with permission



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Breathing Air Quality

- **No objectionable odour**
- **Not less than 19.5% and not more than 22% by volume of oxygen**
- **Less than 10 ppm carbon monoxide**
- **Less than 800 ppm of carbon dioxide**
- **Less than 1 mg/m³ oil**

Protection Factor

“Ratio of outside concentration versus inside conc.”

$$\text{PF} = \frac{\text{Ambient Airborne Concentration}}{\text{Concentration Inhaled Inside the Respirator}}$$

Required Minimum Protection Factor

But what's “acceptable” inside the respirator ?

$$\text{Req Min PF} = \frac{\text{Ambient Airborne Concentration}}{\text{Acceptable Exp Level or Standard}}$$

Example

- **xyz dust**
 - **Concentration** **0.5 mg/m³**
 - **Exposure standard** **0.1 mg/m³**
 - **Required minimum PF = $0.5 / 0.1 = 5$**
 - **AS/NZS Tables Half face piece respirator (P1, P2 or P3 filter)**

Example (cont)

If however,

- **Concentration** **1.5 mg/m³**
- **Exposure standard** **0.1 mg/m³**
- **Required minimum PF = $1.5 / 0.1 = 15$**
- **A higher level of protection is now required**

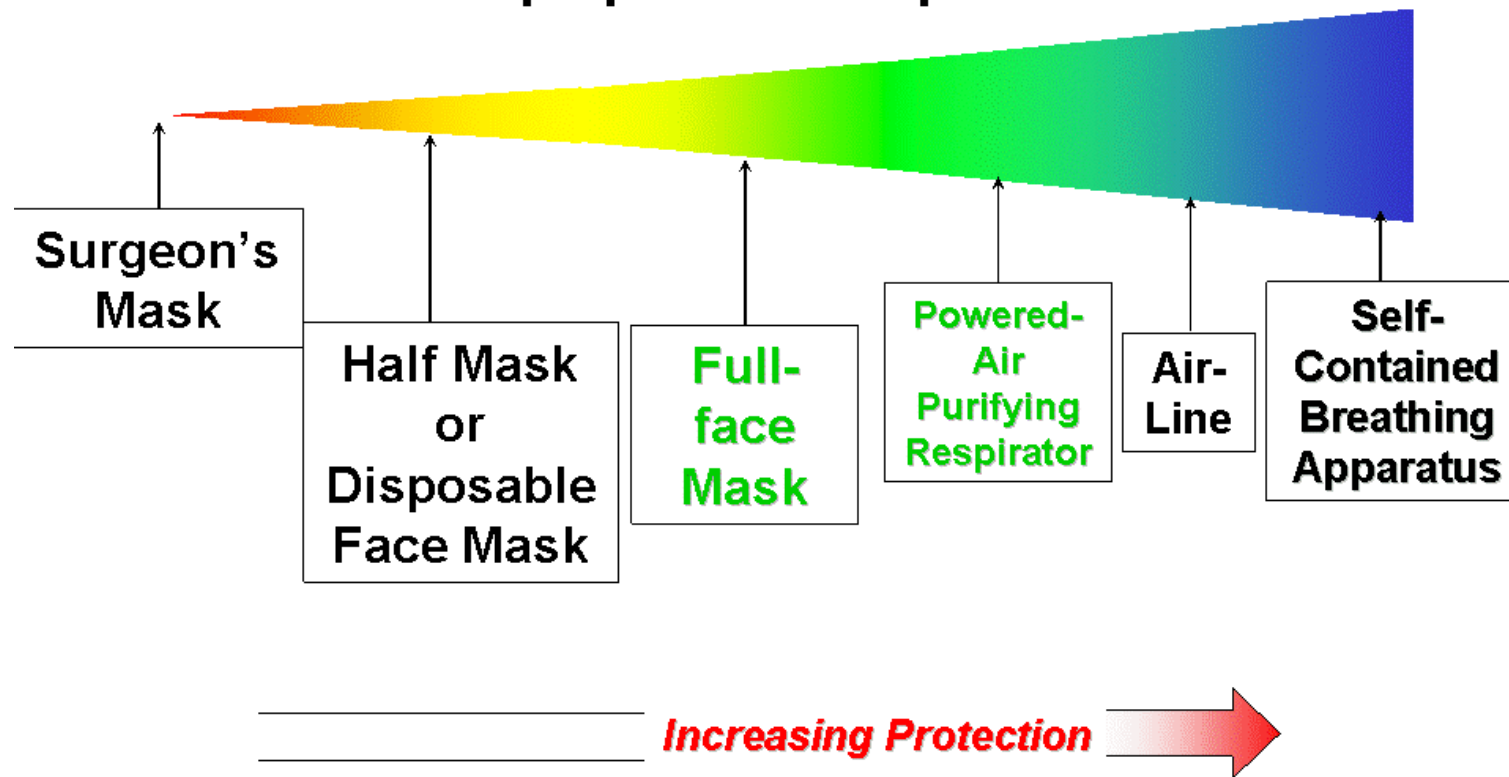
- **AS/NZS Tables** **Full face piece or PAPR**

Different “Factors”

- **NO Globalisation (yet) of Respirator Standards**
- **Differences & debates re “National Factors”**
 - **Required Minimum Protection Factor**
 - **Assigned Protection Factors**
 - **Nominal Protection Factors**
 - **Workplace Protection Factors**
- **Differences within types**
- **Differences between styles**

RPE Spectrum

Respiratory Protective Equipment Spectrum



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Contaminated Related Selection Factors

- **Is it a particulate, gas or vapour or both?**
- **What is concentration of contaminant(s)?**
- **Will respirator failure result in IDLH?**
- **Does contaminant have irritant eye properties?**

Task Related Selection Factors

- **The length of time the respirator will be worn**
- **Whether the respirator will be worn regularly**
- **The mobility required of the wearer**
- **The nature of the workplace, whether confined or restricted, thermal conditions**

Task Related Selection Factors (cont)

- **The need for communication and**
- **Other PPE which must be worn**
e.g. - safety helmet, ear muffs, safety glasses

Operator Related Selection Factors

- **Fitness of the wearer to withstand the extra physiological / psychological strain of working while wearing a respirator**
- **Ability of the person to accept the constriction of wearing the respirator**
- **Ability to obtain seal with facial hair**
- **Whether a person wears glasses which may affect the facial seal of the respirator**

Operator Related Selection Factors (cont)

- **Whether the person has facial features such as scars or acne or other aspects that may affect the facial seal of the respirator**
- **Gender considerations as women often have smaller sized faces and hence may need a smaller sized respirator**
- **Ethnic considerations as the shape of facial features varies and must be considered**

Training

- **Why the respirator is necessary and why the other hierarchy of control measures are not immediately feasible**
- **How the respirator provides protection**
- **Limitations of the respirator, including the service life of filters**

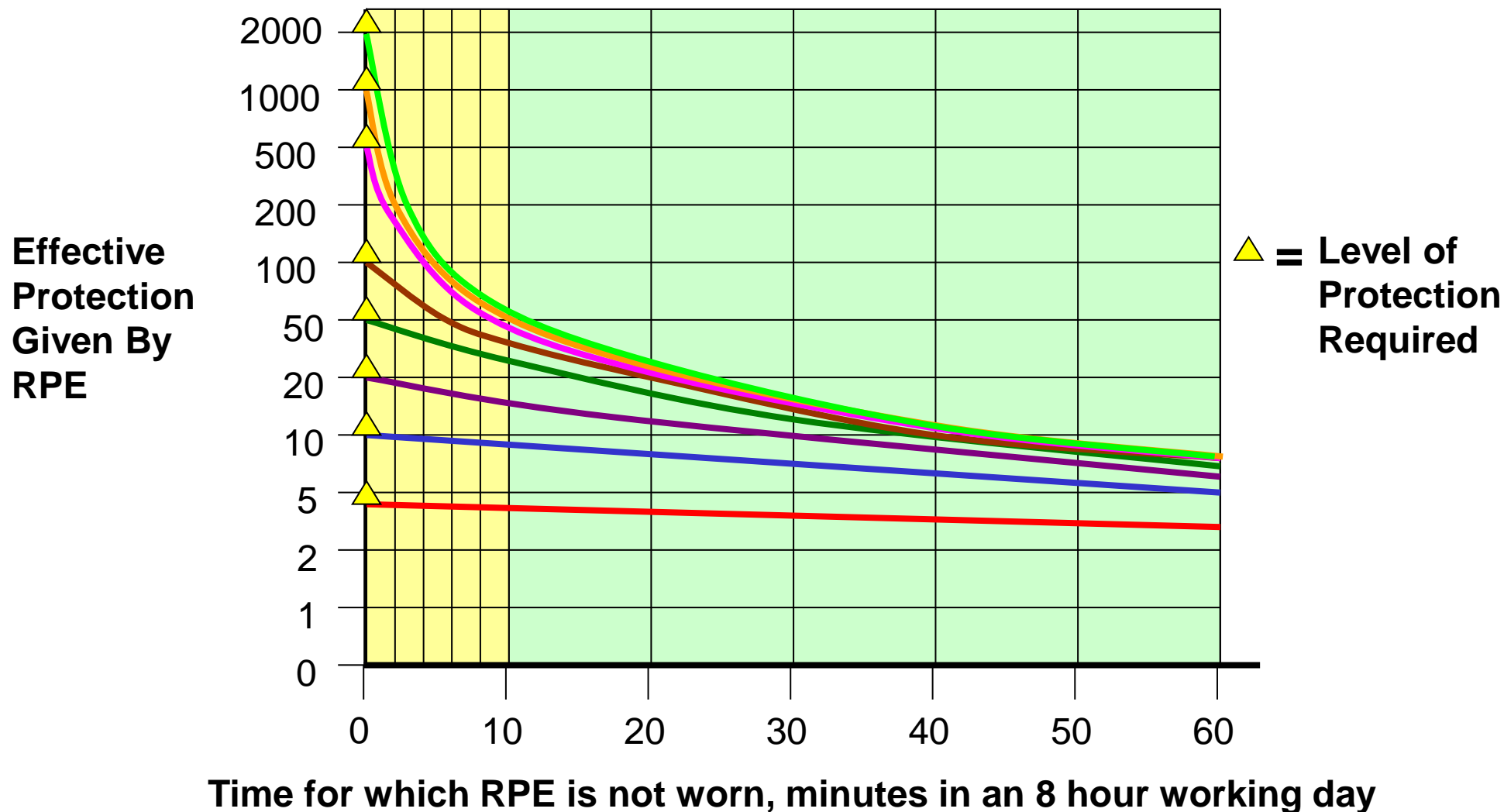
Training (cont)

- **How and why the respirator was selected**
- **Proper fitting of the respirator**
- **The importance of wear time**
- **Maintenance, cleaning and storage requirement**
- **Regular**

Respiratory Performance

- **Filter efficiency**
- **Proper Fit**
- **Proper maintenance**
- **Wear Time**

Effect of Non-wear Time



Source: 3M Australia Pty Limited – reproduced with permission

M505 – Control of Hazardous Substances

Qualitative Fit Testing

- Isoamyl acetate (banana oil)
- Saccharin mist
- Bitrex
- Irritant smoke



Source: 3M Australia Pty Limited – reproduced with permission

Quantitative Fit Testing

- Sodium chloride
- Oil mist
- Particle counters



Source: Kenelec Scientific Pty Ltd – reproduced with permission

Fit Checking



Source: 3M Australia Pty Limited – reproduced with permission

Cleaning

- **Frequency depends on extent of soiling**
- **Mild detergent & warm water**
- **Disinfected, rinsed & air dried**
- **Care if machine washed**
- **Follow manufacturers instructions**

Maintenance

- **Check before & after use & after cleaning**
- **Disposable style - check for physical damage, missing & damaged straps, deterioration of nose seal material**
- **Reusable style – check face piece for cracks, tears, distortion etc, dirt & residues, missing parts (eg valves, valve seats), worn or missing gaskets, missing or deteriorated straps**

Maintenance (cont)

- **Particulate filters**
 - **replace when damaged or breathing resistance is such that they are difficult to breathe through**
- **Gas & vapour filters**
 - **finite life – replace when smell, taste etc contaminant OR**
 - **Service Life Software - from filter manufacturer**
 - **Regardless of use replace after 6 months from opening**

Maintenance (cont)

- **PAPRs**

The head top, air hose, flow rates, pump and batteries must also be checked in accordance with the manufacturer's recommendations

- **SCBA**

Are a specialised piece of equipment typically used in IDLH and potentially life threatening situations. Only trained specialists should service this type of RPE

Storage

- **Close as practical to workplace**
- **Kept clean, dry in contaminant free area**
- **Away from direct sunlight**
- **Stored emergency use respirators – INSPECT**
- **Service life of gas & vapour filters when stored**

Medical Evaluation

- **Wearing respirator may place additional burden on respiratory & cardiac system**
- **Asthma, emphysema, or who suffer from chronic lung disease or those with circulatory or heart disease may be at risk from wearing a respirator**
- **Psychological factors**
 - **a feeling of isolation or**
 - **claustrophobia which limits their ability to work while wearing a respirator**

Poor Storage of Respirators



Note box of respirators stored with solvents etc

Source: University of Wollongong

Misuse of Respirators



Source: University of Wollongong

Misuse of Respirators (cont)



Source: University of Wollongong

Misuse of Respirators (cont)



Source: University of Wollongong

Misuse of Respirators (cont)



Source: University of Wollongong

Records

- **The process to select the appropriate respirator**
- **The training provided to the workers**
- **Maintenance and inspection programs for respirators**
- **Fit test conducted and results of those tests**
- **Medical assessment and surveillance (medical confidentiality guidelines)**

RPE Program Evaluation

- **The reasons for implementing the program remain valid, including a review of the concentration of the workplace contaminants**
- **The respirators are being worn in the workplace**
- **The respirators are being worn correctly in the workplace**

RPE Program Evaluation (cont)

- **The maintenance procedures are functioning correctly**
- **The program continues to meet its intended goals**

Chemical Protective Clothing

CPC can be obtained as one-piece fully encapsulating gas tight (“moon”) suits with attached gloves and boots or as multiple components (eg pants, jackets, hoods etc).



Source: DuPont Personal Protection – reproduced with permission

CPC – Where required

- **Emergency hazardous material response**
- **Environmental/contaminated site clean up**
- **Nuclear applications**
- **Pharmaceutical production**
- **Chemical waste management**
- **Spray painting**
- **Petrochemical manufacturing**

CPC – Where required (cont)

- **Chemical handling and transport**
- **Waste treatment**
- **Biological hazards and medical applications**
- **Asbestos removal**
- **Pesticide application**
- **Food processing**

Selection Factors

- **Chemical substances**
- **Exposure type**
- **Chemical protective type**
- **Garment design**
- **Sewing or construction methods**
- **Sizing**
- **Visibility**

Types of CPC

No Global Harmonisation

- **ISO / EN Classification**
- **US OSHA / EPA Guidelines**

ISO / EN

- **Type 1 Gas tight**
- **Type 2 Non gas tight**
- **Type 3 Liquid tight**
- **Type 4 Spray tight**

ISO / EN (cont)

- **Type 5 Against airborne solid particles**
- **Type 6 Limited protective performance against liquid chemicals**
- **Partial body chemical protective clothing**

USA OSHA / EPA

- **Type A Vapour or Gas Protection**
- **Type B Liquid Splash Protection**
- **Type C Particle or Liquid Splash Protection**
- **Type D No Hazard Protection**

Types of Materials

- Many including:

Tyvek®

Saranex®

Gore-Tex®

Nomex®

FEP

ProShield®

**Spun bound , woven, laminated, multilayered or
chemically coated etc etc**

Chemical Resistance of Materials

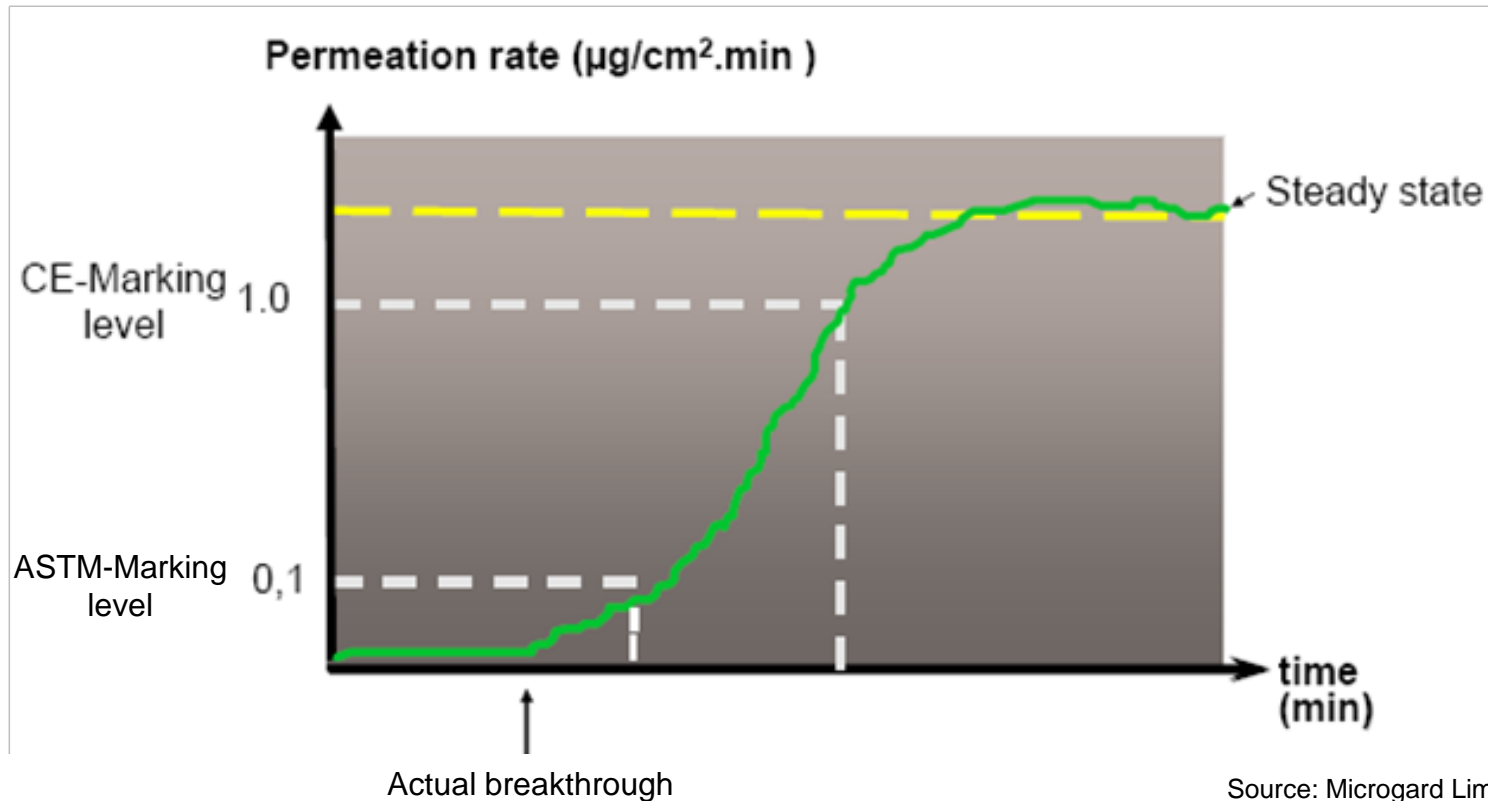
- **Penetration – movement of chemicals through zippers, seams or imperfections in the material**
- **Degradation – involves physical changes in a material as a result of exposure, use or ambient conditions – discolouration, swelling loss of strength or deterioration**
- **Permeation – process by which chemical dissolves in or moves across a material on a molecular basis**

ASTM Standard Chemical List

- **Cross section of different chemical classes and challenges for testing materials - 15 liquids & 6 gases**
- **Manufacturers typically have available test data on hundreds of other chemicals**

Permeation Tests

- Rate
- Breakthrough time
- Normalised breakthrough time



Source: Microgard Limited– reproduced with permission

M505 – Control of Hazardous Substances

Useful Sources of Information

- **NIOSH Pocket Guide to Chemical Hazards**
www.cdc.gov/niosh/ncpc/ncpc1.html
- **NIOSH Recommendations for CPC**
www.cdc.gov/niosh/ncpc/ncpc2.html
- **Manufacturers e.g.**
www.personalprotection.duPont.com
www.microgard.com

Seam Constructions



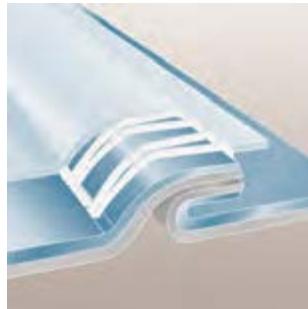
Serged or sewn



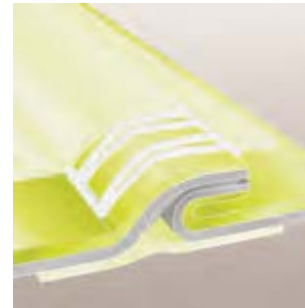
Bound



Welded or NSR



Taped thermobond



Double taped

Source: DuPont Personal Protection – reproduced with permission

Clothing Style & Size

- **Variety of styles, configurations & sizes**
- **Hoods, vests, aprons, coveralls to fully encapsulating suits**



Source: DuPont Personal Protection – reproduced with permission

Fully Encapsulating Suit



Source: DuPont Personal Protection – reproduced with permission

Standard CPC Test Procedures

- **ISO Standards**
- **EN Standards**
- **ASTM Standards**
- **NFPA Standards**

Chemical Resistance of Material Tests

- **Permeation resistance**
- **Resistance to penetration**
- **Particulate resistance**
- **Liquid penetration resistance**
- **Liquid repellency**

Whole Chemical Protective Clothing Integrity Tests

- **Leak tightness**
- **Inward leakage**
- **Liquid jet test**
- **Liquid spray test**
- **Particle aerosol inward leakage test**
- **Limited liquid spray test**

Use of CPC

- **Hot zone – the contaminated area where workers must wear the appropriate Type or Level of PPE**
- **Warm zone – where the equipment & personnel are decontaminated in transit from the hot to cold zone**
- **Cold zone – the clean area where no PPE is required**

Decontamination Plan

- **Minimise need for decontamination**
- **Develop a decontamination plan**
 - **Define the methods & equipment**
 - **Series of decontamination stations**
 - **Anticipate effects from the task at hand**
 - **What levels are acceptable**
 - **Disposal**

Decontamination



Source: Microgard Limited – reproduced with permission

Inspection & Storage

- **Inspection of equipment**
 - **When received**
 - **Before use**
 - **After use**
 - **Periodically if stored - especially if for emergency use**
- **Storage**
 - **Proper to storage to prevent damage or exposure to damaging conditions**
 - **Refer to manufacturers instructions**

CPC Limitations

- **In addition to material selection, garment design etc**
- **Heat Stress**
 - **Decrease in evaporative cooling effect**
 - **Often compounded by higher metabolic work rates**
- **Design can impair vision, mobility & manual dexterity**
- **Communication can also be impaired**

Training

- **Training & education required for users**
 - **Nature & extent of hazard**
 - **When required to be worn**
 - **What clothing is necessary**
 - **Use & limitations**

Training (cont)

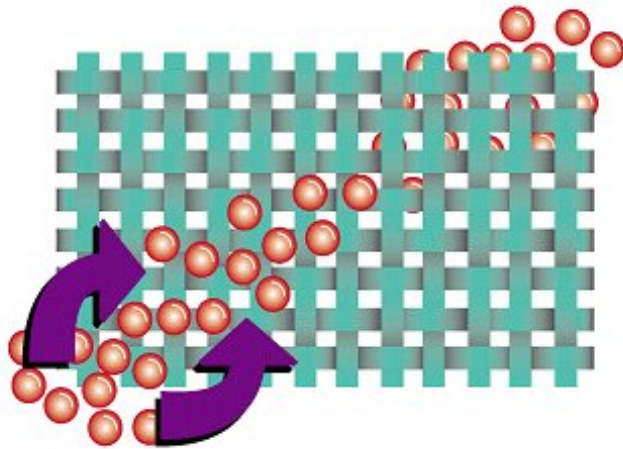
- **Training & education required for users**
 - **How to inspect, don, doff, adjust & wear**
 - **Decontamination procedures if required**
 - **Signs & symptoms of over exposure**
 - **First aid & emergency procedures**
 - **Proper storage, useful life, care & disposal**

Gloves

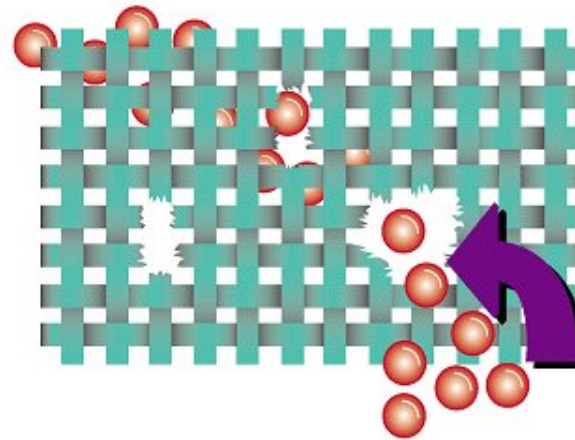
- **Standards: General requirements**
 - **Ergonomics**
 - **Glove construction**
 - **Innocuousness**
 - **Cleaning**
 - **Comfort & efficiency**
 - **Marking & identification**

Protection Against Chemicals

- Permeation
- Degradation
- Penetration



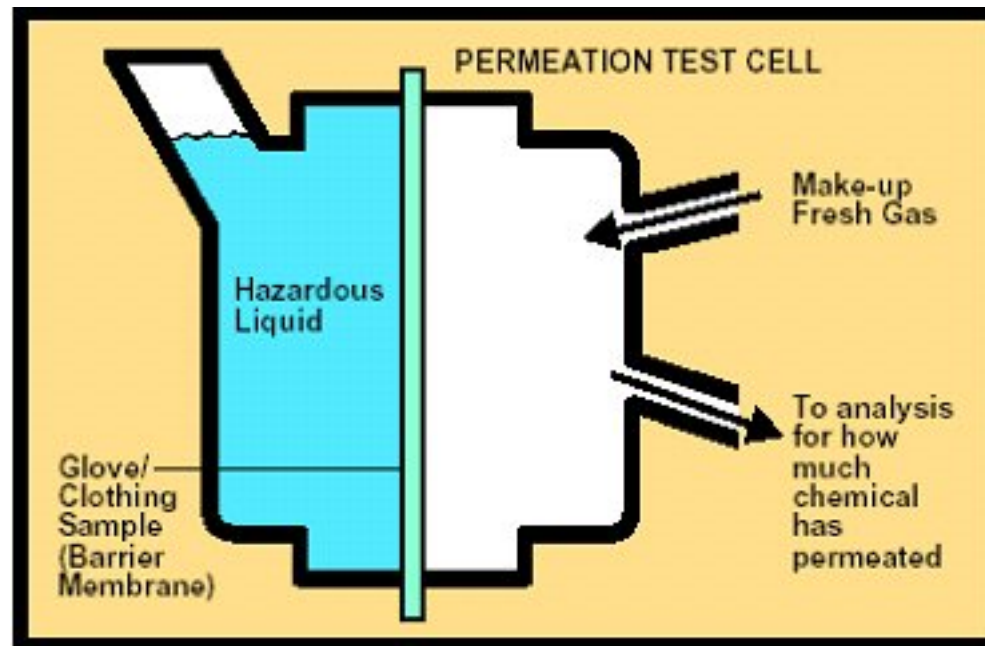
Permeation



Degradation

Source: Ansell Limited – reproduced with permission

Permeation Test Cell



Source: Ansell Limited – reproduced with permission

Glove materials

- Many types of materials used including:

Natural rubber

Neoprene

Butyl rubber

PVA

PVC

Viton

Nitrile

Laminates

Glove materials (cont)

- **Leather, cotton and canvas are not chemically protective**
- **They can prevent mechanical stress & minor physical injury**
- **They typically retain the chemical and continue the exposure after use of the chemical**

Sources of Information

The manufactures have useful web sites eg

- **CHEMREST used by Best Gloves**
- **SpecWare used by Ansell-Edmont**
- **North Safety Glove Products**

Overall Selection Process

- **Glove material selection**
- **Glove construction**
- **Glove options**

Limitations

- **Protect the wearer - do not remove the contaminant**
- **Can interfere with a person works**
- **Can cause loss of touch, feel & dexterity**
- **Protection depends on selection of glove material, a good fit & proper use**

Reuse & Laundering

Problems can include:

- **Small holes may not be detected**
- **Contaminants move to inside glove during washing**
- **Washing process may physically damage the glove**
- **Washing may not remove material that has started to migrate through the glove**

Eye & Face Protection

- **Standards:**
 - **Selected & tested against National or International Standards for:**
 - Flying particles**
 - Molten metal**
 - Liquid chemicals**
 - Acids or caustic solutions**
 - Chemical gases or vapours**

Hazardous Substances

- Glasses, goggles or face shields typically made from Polycarbonates or poly-methyl methacrylate (PMMA or acrylic)



Source; BOC Australia Limited – reproduced with permission

Traumatic Injury

- **Protection may be provided by same face shields and goggles that provide chemical protection**
- **Safety glasses (preferably with side shields) provide very little protection against chemical particulates or chemical liquid splashes & no protection against eye irritating gases and vapours**



Group Exercise

- **Glove Selection**

Administrative Elements

Administrative Elements

- **Broadest sense – management involvement in the training of employees, rotation of employees, air or biological monitoring, medical surveillance or housekeeping**
- **Narrower sense – meaning to reduce the dose of a hazardous agent by limiting duration ie more time in lower or no exposure**

Administrative Elements (cont)

Can also be considered as:

- **Changes in work procedures (written safety policies, rules, supervision, schedules) & training with the goal of reducing:**
 - **Duration**
 - **Frequency**
 - **Severity of exposure to hazardous substances or situations**

Legislative Requirements

- **OH&S Acts & Regulations, Codes of Practices, Industry Standards etc in all countries**
 - **Control of Hazardous Substances**
 - **COSHH**
 - **REACH**
 - **Others**

Reducing Periods of Exposure

- **Worker rotation**
 - **Team of welders**
 - **Multi skilling**
- **Worker replacement**
 - **Biological monitoring**

Lead levels

Maximum radiation dose in a time period

Scheduling of Work

It may be possible to reschedule high risk work:

- **Spray isocyanate based paints on A/Shift not D/S**
- **Remove asbestos on weekend not during the week**
- **Pour foundry metal on A/S rather than D/S**
- **Fumigate the building with pesticides on the weekend**
- **Perform maintenance out of hours**

Maintenance & Housekeeping

- **Insufficient maintenance can result in catastrophic releases from ruptured ductwork systems**
- **Fugitive releases from slowly increasing rates of leaks from flanges, joints & access doors**
- **Poor maintenance work practices may results in release & escape of material when emission control plant is being serviced**

Maintenance & Housekeeping (cont)

- **Maintenance itself can cause the generation & release of excessive amounts of accumulated dust.**
- **Compressed air must NOT be used to blow down & clean dusty surfaces**
- **Escaped dust will settle & become a source secondary exposure from wind or traffic**
- **Where dust accumulates regular clean up is required**

Compressed Air Signage



Source: Safety Plus Signs-reproduced with permission

Maintenance & Housekeeping (cont)

- **Liquid spills must be cleaned up promptly before evaporation occurs**
- **Solvent laden rags & absorbents should be placed in sealed bins**
- **Importance of maintaining high standards of housekeeping:**
 - **Secondary sources of exposure**
 - **Promotes the wrong message that poor work habits are acceptable**

Poor Housekeeping



Source: University of Wollongong

Eating, Smoking & Drinking

In work area poor personal hygiene potential:

- **Inhalation exposure**
 - **Lead**
 - **Pesticides**
- **Accidental ingestion**
 - **Dirty hands**
 - **Drinking from contaminated sources**

Personal Hygiene



Source: Safety Plus Signs & University of Wollongong-
reproduced with permission

Change Facilities & Laundering

- **Miners have a clean & dirty side of the change room**
- **Similarly in lead & nuclear industries**
- **Dirty clothes need to be washed**
 - **At site or taken away under controlled circumstances**
 - **Cases of asbestos & beryllium related diseases from washing at home**

Clean & Dirty Change Rooms



(Source: D Moore – reproduced with permission)

Showers & Hand-basins

Personal hygiene important in controlling accidental exposures:

- **Contaminated hands – secondary exposures by inhalation if a smoker or ingestion if eating without first washing their hands**
- **After work employees should shower effectively with special attention paid to their hair**
- **Adequate facilities need to be provided**



Use of Creams & Lotions

- **As alternative to use of gloves !!**
- **Intended for use materials with irritant or low dermal toxicity BUT often misused**
- **Water repellant barrier creams for protection against water or water soluble agents**
- **Solvent resistant barrier creams for protection against oils & solvents**

Use of Creams & Lotions (cont)

- **Both rely on regular & periodic reapplication**
- **Must be applied evenly over entire exposed skin surface**
- **Do not use on damaged skin**
- **If used check with manufacturer to ensure suitability for type of chemical**
- **Not generally considered as effective replacement for correctly selected & properly worn gloves**

Control of Access to Hazardous Areas

- Sign posting
- Entry log book
- Swipe or access card system
- Security personnel



Source: Safety Plus Signs-reproduced with permission

Initiating Control Measures

Role of:

- **Assessment**
- **Measurement**
- **Monitoring**
- **Health Surveillance**

All play a part because a thorough knowledge of the hazard is required:

Initiating Control Measures (cont)

- **How the hazardous situation arises**
- **What the exposed people are doing when they are exposed**
- **What are the intended outcomes of the control**
- **What the impacts on other nearby people are**
- **What are the consequences if the controls are not adequate or fail to protect the worker**

Initiating Control Measures (cont)

- **These are ALL elements of an effective Occupational Hygiene Program**
- **For each area, process or occupation a workplace assessment is carried out**

Initiating Control Measures (cont)

- **Identifies potential chemical, physical & biological hazards**
- **Workplace exposure monitoring should contain information describing conditions that relate to:**
 - **Intensity**
 - **Duration**
 - **Likely exposure routes**

Initiating Control Measures (cont)

Evaluate this information & recommendations may:

- **Require further monitoring**
- **Biological monitoring**
- **Initiation of a health surveillance program**
- **Introduction of control measures**

Role of Written Procedures etc

Ways of instituting exposure reducing work practices:

- **Operating procedures**
- **Job method statements**
- **Permits to work**

If written down its clear to all personnel the hazards associated with the task & what controls are needed

Safe Working Practices

Are administrative requirements & procedures to ensure employees work in a safe manner

Should become an integral part of the process

What are some examples in your work area?

Role of Occupational Hygiene Programs

Once introduced Control systems need to be maintained:

- Ventilation systems**
- Are routine occ hyg, biological monitoring or medical surveillance programs required**
- Where RPE is used, check maintenance of SCBA, establish & audit cleaning procedures & respirator filter change schedules**
- Where CPC & gloves required check their use and adequacy**

Education, Instruction & Training

To use administrative elements workers need to know:

- Why the control is needed**
- How the control is to be achieved**
- The limitations of such procedures**
- The consequences of not adhering to the controls**

Emergency Procedures & First Aid

PPE is important in dealing with emergencies & provision of first aid in high risk areas

If stored it must be:

- **Readily available**
- **Not “borrowed” to be returned later !!**
- **In date - Shelf life, deterioration**
- **Batteries go flat**
- **SCBA is complex & requires training in its use**
- **Refresher training**

Worker Participation

Critical in implementation of controls

- **Promotes consultation**
- **Provides a sense of ownership & empowerment of decisions that have been involved with**
- **Job satisfaction – their opinions valued**
- **Their experience tells if the controls are practical & useful**



Practical Applications of Control Strategies

Topics to be Discussed

- **Addition of hydrated lime to cyanide tanks**
- **Respirable silica during sand blasting**
- **Ventilation in a laboratory sample room**
- **Mercury exposure in a gold room**

Topics to be Discussed (Cont)

- **Manufacture of phthalic anhydride**
- **Control of powders in the pharmaceutical industry**
- **Diesel particulate in underground coal mines**

Addition of Hydrated Lime to Cyanide Tanks

- **At a carbon-pulp gold processing plant in Equatorial Africa, the need arose to make routine additions of hydrated lime (Ca(OH)_2) to the cyanide extraction tanks in order to control pH**
- **To do this the mill decided to use bulk hydrated lime delivered to the site in 1000 kg bulk bags so as to minimise transportation costs**

Addition of Hydrated Lime

- **The pH in the tanks was monitored and when required a 1000 kg bag was lifted by crane above a chute which had an internal spear to pierce the bag and release the hydrated lime to the cyanide mixing tanks below**
- **This process generated significant levels of dust**

Process of Adding Hydrated Lime



Source: University of Wollongong

Properties of Hydrated Lime

- **Reference to the product MSDS indicated that the material was corrosive by inhalation, ingestion, skin and eyes**
- **Inhalation would result in severe mucous membrane irritation of the nose and throat and prolonged and repeated contact with the skin would result in a severe skin rash, dermatitis and possible chemical ulceration**

Initial Issues

- **When the process initially commenced, operators experienced respiratory irritation and due to the hot humid equatorial climate, severe skin irritation and in one case, ulceration**

Initial Control Measures

- **The response of the mill manager (an expatriate from North America) was to supply respiratory protection and impervious raincoats so that the product didn't contact the skin**
- **This was a practice that had previously been used during an emergency at a mill in a cold North American location**

Secondary Issues

- **Initial issues of respiratory & skin irritation were significantly reduced; however**
- **Almost immediately that the initial control procedures were introduced the number of heat stress cases presenting to the onsite clinic increased**

Results of Investigation

- **Upon investigation it was realised that the combination of impervious raincoats and a hot equatorial climate had resulted in the operators' core body temperature increasing to the point of heat stress onset**
- **This had not occurred in the North American location when the same approach was previously used, due to the cold climate**

Final Solution

- **Management response was to temporarily cease the addition of the hydrated lime in bulk bags until a series of fine water sprays could be installed inside the delivery chute**
- **Once the spray system was activated the fine dust arising from the opening of the bags was contained, eliminating the need for any personal protective equipment**

Key Learning's

- **Need to consider all aspects of the process when evaluating a control solution**
- **What works in one location may not be transferable to another**
- **Incorrect use of PPE can lead to a dangerous situation**

Respirable Silica Exposure During Sand Blasting

- **Sand blasting (or more correctly, grit blasting) is a common practice in industry to prepare steelwork for painting, welding or further processing**
- **The term “sand blasting” is derived from the period when river or beach sand was forced at high pressure through a nozzle so as to clean surfaces**

Sand Blasting

- **The high velocities involved in sand blasting results in the sand particles fracturing, thus reducing the particle size to the point that it could be respired by the operator.**
- **Many operators of such systems who were not adequately protected suffered silicosis and in some cases, death**

Modern Practice

- **To overcome the issue of silicosis, statutory authorities in many countries banned the use of sand, and low silica products such as garnet, ilmenite and copper slag were substituted**

Workplace Situation

- **An occupational hygienist was visiting a construction site and observed significant dust clouds arising from a grit blasting operation**
- **Upon closer investigation it was found that the material being used in the process was a fine dust containing 35% w/w crystalline silica as it was a cheap source of blasting material**

Workplace Situation (cont)



Source: University of Wollongong

Workplace Situation (cont)

- **The airline respirator being used by the operator was found to be in poor condition and the air compressor being used for the blasting process was also the air supply for the air supplied respirator**
- **No air quality monitoring results from the supplied air could be found**

Workplace Situation (cont)

- **Discussions with the operator's assistant indicated that it was not uncommon for the dust cloud from the blasting operation to drift over the position where he was shovelling the silica material into a supply hopper**
- **No respiratory protection had been supplied to this person**

Occupational Hygienist's Response

- **Process stopped immediately**
- **Substitution of sand with more appropriate product**
- **Independent air supply for airline respirator with regular air quality monitoring**
- **Introduction of a wind barrier to minimise wind drift**
- **Introduction of an educational programme for all employees**

Key Learning's

- **The need to understand the nature of products being used in a process and the effect the process may have in increasing the risk of a health hazard**
- **Consideration needs to be given to all potentially exposed workers not just those in the near area**
- **Maintenance of PPE is a priority if the expected level of protection is to be achieved.**

Ventilation in a Laboratory Sample Room

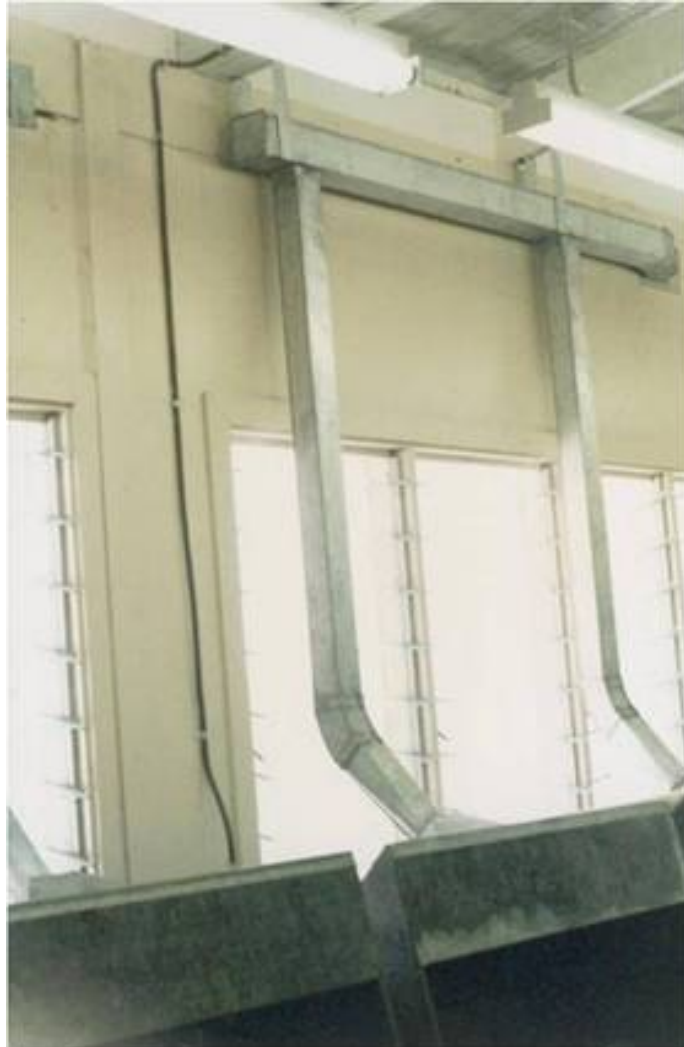
- **Following complaints from laboratory technicians working in a sample preparation room regarding high levels of noise and dust, an inspection was undertaken by an occupational hygienist**
- **Upon attendance, the occupational hygienist found the ventilation system to be somewhat of a “jigsaw puzzle” in that there were numerous branches off a main duct leading to grinding mills and furnaces all connected to the one fan**

Ventilation Ductwork Connected to Fan



Source: University of Wollongong

Homemade Extraction System



Source: University of Wollongong

Inappropriate Duct Design



Source: University of Wollongong

Inappropriate Duct Design (cont)



Source: University of Wollongong

Inspection of Ventilation System

- **Homemade ventilation system with numerous braches and poor duct design**
- **Only one fan installed for total system and in poor condition**
- **Fan capacity not matched to system requirement**
- **No balancing of system ever undertaken**

Performance Measurements

- **Some tube and air velocity measurements confirmed that air was traversing duct closest to fan and little airflow in other branches**
- **No maintenance or system performance records could be found**

Additions to System over Time

- **Apparent that as the laboratory had expanded, the ventilation system had been extended without due consideration of the size of the fan, duct design or the extensive duct branching**
- **Unfortunately, the situation above is not uncommon and serves to highlight that any ventilation system should be fit for purpose and simply adding another branch can upset the whole system**

Key Learning's

- **Ventilation systems need to be designed to meet the individual process needs**
- **Implementation of a ventilation system is not the end of the exercise. Good maintenance practices need to be observed**
- **System performance needs to be regularly monitored**

Mercury Exposure in a Gold Room

- **The final stage of extracting gold from ore using the carbon-in-pulp method is to smelt the recovered elemental gold so as to remove impurities**
- **The smelting process involves heating the raw gold in a natural gas furnace and creating a slag on the surface of the molten gold using various minerals**

Treatment of Impurities

- **Many impurities transfer from the gold to the slag under controlled metallurgical conditions but others (eg: mercury) are released to the atmosphere as a vapour.**
- **At the appropriate time the gold is poured, cooled, identified and sent to a specialist refinery for further processing**

Gold Pour



Source: University of Wollongong

Current Control Measures

- **The furnace is located under a canopy type hood which is linked to an extraction fan outside the building. The purpose of an extraction system is threefold**
 - **To remove any combustion gases**
 - **To remove any contaminants**
 - **To remove hot air**

The Issue

- **Following complaints from workers an examination of the gold room was undertaken**
- **Initial findings were that there were elevated levels of mercury present in the atmosphere (albeit below the exposure standard), capture velocities of the canopy hood were low and that there was minimal air movement within the gold room**

Ventilation System

- **Examination of the fan established that the belts between the drive motor and the fan impeller shaft were continually “slipping”, thus decreasing the degree of extraction**
- **Closer examination of the outer fan housing and ductwork found significant openings due to corrosion (the fan was not protected in the harsh equatorial climate) again reducing the efficiency of the system**

Actions Taken to Address Issues

- **Repairs were made to the ventilation system with a resultant improvement in capture velocities**
- **Mercury levels were no longer detected, and while the airflow in the gold room increased it was not at a level that was expected**

Actions Taken to Address Issues (cont)

- **Inspection of air intake vents for the air supply system established that many were blocked, thus limiting the amount of make-up air entering the gold room. Once these were cleared, air movement within the gold room increased**

Key Learning's

- **The process itself may produce contaminants that require control (e.g. mercury)**
- **All ventilation systems are prone to failure if not adequately maintained**
- **A simple check of the hood face velocity or the hood static pressure would have highlighted the ventilation system issues**

Manufacture of Phthalic Anhydride

- **Phthalic anhydride is an important bulk chemical and is used in the manufacture of phthalate ester plasticisers, polyester formulations for boat hulls, glass reinforced plastic applications and in alkyd resins for paints**

Production Process

- **Over 85% of commercial phthalic anhydride is produced from o-xylene by gas phase oxidation using vanadium pentoxide as a catalyst**
- **The final product is sold in bulk bags of 500 kg or 1,000 kg capacity, road tanker and 25 kg bags as a flaked solid. The product is also sold in the molten form and transported in insulated road tankers**

Properties & Health Effects

- **White solid at room temperature**
- **Melting point of 131°C**
- **Saturated vapour pressure of 1 mm Hg @ 96.5°C**
- **Phthalic anhydride is a known respiratory sensitiser with established workplace exposure limits.**

Workplace Situation

- **Concern was raised as to the potential exposure of workers during the filling of bulk bags with phthalic anhydride immediately after manufacture**

Initial Survey by Occupational Hygienist

- **24 hour production process**
- **Flaked solid main area of potential exposures**
- **Re-handling of processed product due to quality issues**
- **LEV system limited & subject to failure**

Initial Survey (cont)

- **LEV system not designed for capture & transport of phthalic anhydride & fume**
- **Bulk bag system designed for 1000kg bags but used for 500kg bags**
- **Increased exposure due to need for manual connection, disconnection & tie-off of bags**
- **All workers complying with PPE standards**

Preliminary Monitoring

- **Monitoring indicated that long term exposures ranged up to a maximum of 4.1 mg/m³ phthalic anhydride during bag filling operations.**
- **As the statutory exposure limit was 4.0 mg/m³ appropriate action was required to reduce employee exposures.**

Approach to Control Exposures

- **The approach to establish what exposures needed to be controlled and how they could be controlled was systematic, scientific and involved stakeholders**
- **Key actions included**
 - **Detailed task observation & measurement to identify exposure sources in bag filling system**

Poor Location of Tie-Off Increased Exposure



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Key Actions (cont)

- **The use of simple techniques such as the dust lamp (Tyndall beam) to identify phthalic anhydride fume loss from bags . Targeted workplace monitoring was also undertaken to confirm these observations**
- **Redesign of bags to include double seams**
- **Introduction of lined bags**
- **The repositioning of the tie point to avoid the need to lean under the extraction system to tie-off filled bags**

Use of Dust Lamp to Identify Fume Loss



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Key Actions (cont)

- **Modifications were made to the flaking process to produce solid sheets of solidified phthalic anhydride which were then turned into flake using a mechanical nibber**
- **This overcame the problem of solidification in the bulk bag and subsequent rehandling**
- **Introduction of new LEV system designed for process**

Testing New LEV System



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LEV During Bag Filling



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Re-sampling after Controls Introduced

- **Personal exposures reduced to 0.2-0.4 mg/m³ PA**
- **Little dust or fume leakage from bags**
- **Annual workplace monitoring introduced**
- **Health surveillance programme introduced with pre-employment screening**

Key Learning's

- **Visual observation and simple techniques can highlight potential employee exposures**
- **A systematic approach to developing suitable control strategies is very effective**
- **The involvement of stakeholders (including suppliers) can lead to significant improvements and lower exposures**
- **Process modifications may be necessary in order to control exposures**

Control of Powders in the Pharmaceutical Industry

- **In the pharmaceutical industry there is a constant need to transfer powders from one form of container to mixing or reaction vessels**
- **This case study details two situations where problems arose in the process of manually handling powders**

Situation A

- **In this situation an operator is removing pre-weighed bags (about 5 kg) of powder from a cardboard container before lifting and tipping the material into a chute connected to a mixing vessel**
- **The operator is wearing a Tyvek suit with a separate hood. The hood is fed with breathing air, taken from the local area by a battery operated pump and filtered**

Situation A



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Issues

- **Open work area allowing dust to travel & settle out on ledges & machinery**
- **Other persons working or walking through area potentially exposed during loading in not wearing PPE**
- **Some powders when airborne easy to ignite**

Issues (cont)

- **Dust layers can be disturbed and inhaled by others later who are not wearing protective equipment for supposed “safe” activities such as equipment checks (maintenance).**
- **They may react with moisture or other materials in the air to change their character sufficiently to pose additional risks (chemical burns).**
- **They may fall onto exposed skin or into eyes or may be transferred by hand to the mouth or other surfaces such as door handles and light switches**

Control Strategy Implemented

- **Use of pre-weighed containers that can “dock” with vessel**
 - **Easy flow powders in rigid containers**
 - **Not so easy flow powders in flexible containers**

Pre-weighed Containers



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Pre-weighed Container in Discharge Position



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Fixed Docking Port on Mixing Vessel



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Outcomes

- **Some material released during undocking but devices available to reduce exposures to $<1\mu\text{g}/\text{m}^3$**
- **Solution involves capital cost but docking bags are reusable and have a reasonable life**

Situation B

- **Similar to situation A except there is a requirement to load significantly larger quantities into a dissolving vessel**
- **Quantities can be up to 25 kg**

Situation B (cont)



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Situation B (cont)

- **In this case there is no chute around the man way which is used for loading but some local exhaust ventilation has been provided nearby**
- **The personal protective equipment is similar to that used by the worker in Situation A and the operating area is an open area of the workplace**

Situation B (cont)

- **If the approach adopted in Situation A was applied here, the greater volumes of material involved would mean repeated small loading operations, giving rise to potentially increased exposure (in the absence of other controls)**
- **If the other extreme was considered (ie: one large pre-weighed bag or container) it would be difficult to handle and give rise to substantial ergonomic issues**

Control Strategy Implemented

- **The solution adopted was to install a drum lifter with an enclosure around the area above the discharge points**

Drum Lifter with Discharge Enclosure



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Other Factors

- **Glove posts installed for access to remove drum lid, open liners and cleaning etc**
- **Mock-up of wood & cardboard made of isolator to ensure all ergonomic factors considered**
- **Increased cost off-set by time saving & cost of PPE**

Key Learning's

- **Containment is an effective means of controlling employee exposures**
- **Implementation of any control strategy that involves the direct involvement of operators needs to take account of individual human factors if they are to be used by all personnel.**

Diesel Particulate in Underground Coal Mines

- **Diesel engines have been used in the underground mining industry for many years and have been a key factor in the increased productivity of such operations**
- **While the health effects of gaseous emissions were well understood from their initial introduction, little or no attention was paid to the control of the particulate fraction**

The Situation

- **This case study details how one industry researched, evaluated and ultimately initiated strategies for the control of diesel particulate in underground coal mines**
- **As with the control of any contaminant, it is important to have a clear understanding of the physical and chemical properties of the substance plus knowledge as to the potential health effects**

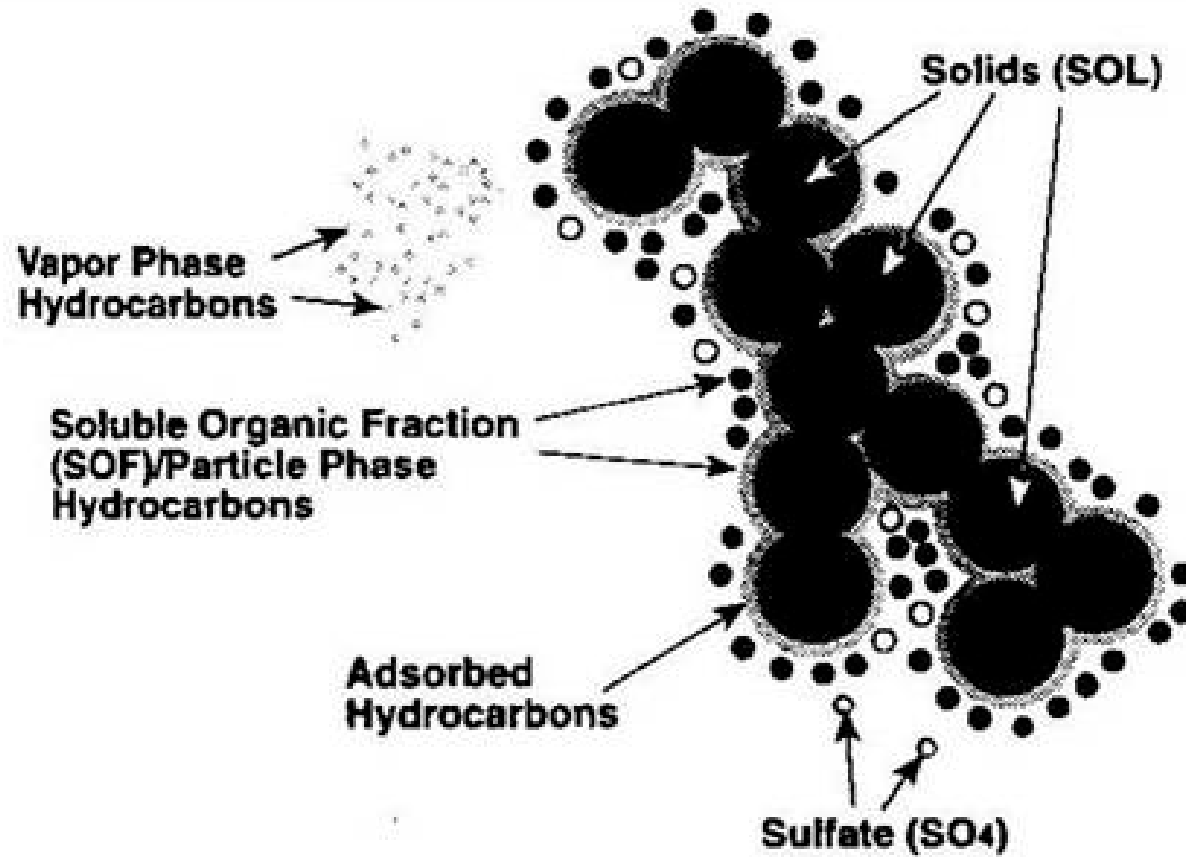
Properties of DP

- **Generated along with gaseous emissions in the exhaust of every diesel engine**
- **Small particles (15-130 nm) called spherules**
- **Agglomerate to form larger particles but still $<1\text{ }\mu\text{m}$ in diameter**

Properties of DP (cont)

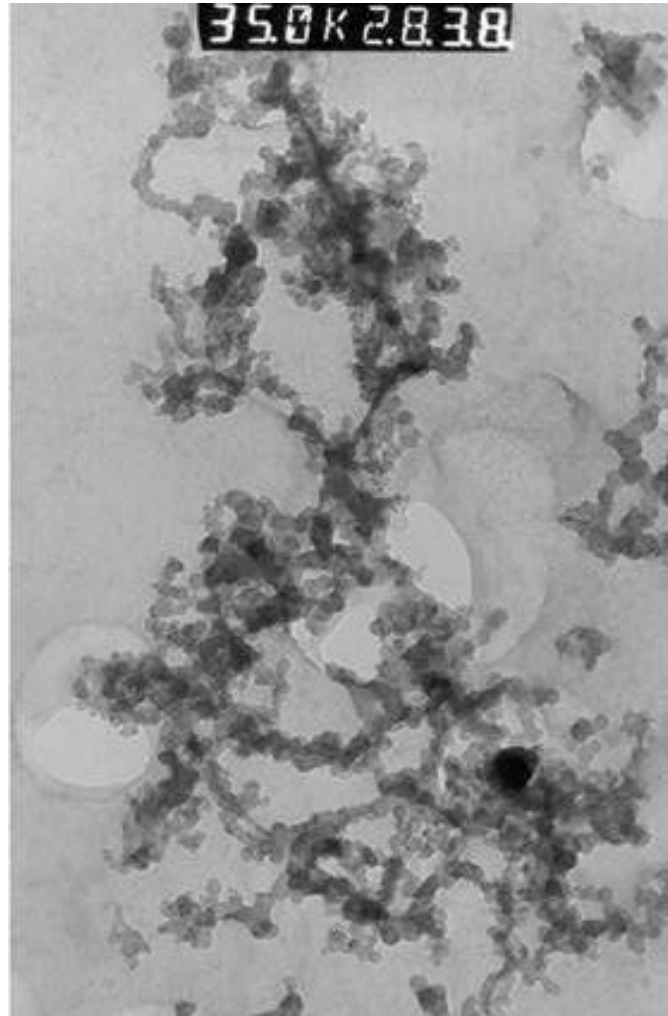
- **Absorb significant quantities of hydrocarbons and other organic compounds**
- **Contains traces of inorganic compounds**
- **Respirable by humans**
- **Has a central core of elemental carbon**

Schematic of Diesel Particulate



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Electromicrogram Showing Agglomeration of Small Diesel Particles



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Health Effects

- **Classified as carcinogenic by many authorities throughout the world**
- **Potency not well defined but significant**
- **Small particle size of diesel particulate has resulted in it being linked to non malignant health effects similar to $PM_{2.5}$**
- **Irritant (eyes, nasal and bronchial).**

Research on Control Strategies Indicated

- **No single simple strategy exists to cover all situations**
- **Individual operations using similar equipment could have significantly different exposure profiles due differences in ventilation patterns, work practices & maintenance**

Potential Control Options

- **Low emission diesel fuel**
- **Ventilation at levels commensurate with the size of the engine. In cases where ventilation is restricted (eg: mines) it may be appropriate to limit the number of diesel engines operating in an area**
- **Exhaust treatment devices such as catalytic converters, wet scrubber systems, regenerative ceramic filters, disposable exhaust filters, exhaust dilution-dispersal systems.**

Potential Control Options (cont)

- **New generation low emission engines**
- **Maintenance programmes targeted at minimising exhaust emissions**
- **Well-sealed and filtered air-conditioned operators' cabins**
- **Employee education**
- **Personal protective equipment**

Emissions Based Maintenance Programmes

- **While combinations of the potential control strategies have been found to be effective, one strategy has the potential to deliver higher productivity with reduced employee exposures**
- **The introduction of an emissions-based maintenance programme has been shown by various researchers to result in improved fleet availability, increased power and thus productivity and lower exhaust emissions**

What's the Problem?

- **While emissions based maintenance seems apparent, it is based on the premise that individual engines can be tested during maintenance procedures**
- **To do this, raw exhaust measurements for various gases and diesel particulate must be conducted & instrumentation must be available**

Initial Raw Exhaust Monitoring Equipment

- **Monitoring of raw exhaust gas emissions for control of workplace exposures has been in place for decades & has been very effective**
- **Measurement of DP in raw exhaust presents complex issues**
 - **Water vapour in exhaust effects laser based instruments**
 - **High DP concentrations flood ambient instrumentation**
 - **Composition of DP make consistent measurement difficult**

Initial Approach

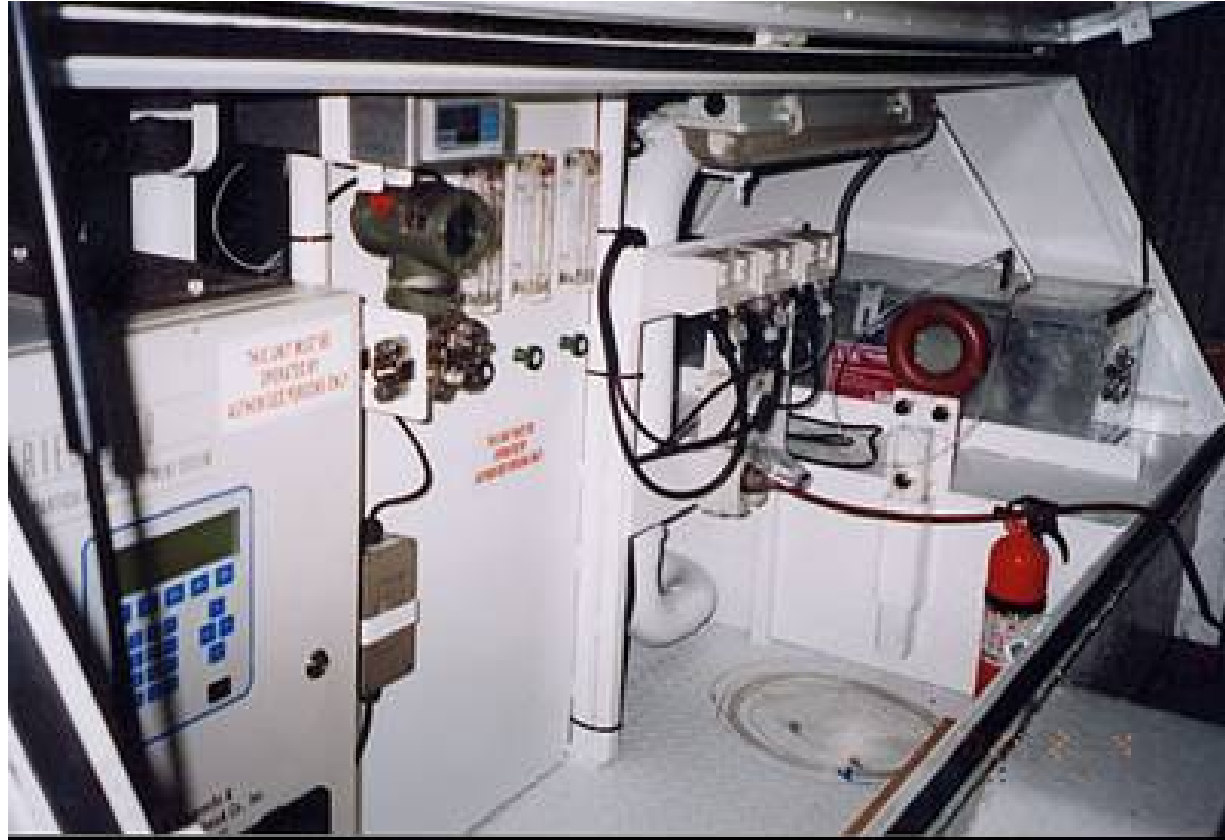
- **Focus on elemental carbon as surrogate for DP**
- **Use of laboratory analyser mounted in a mobile trailer to measure raw exhaust EC**
 - Gave good results but,
 - Difficult to operate
 - Expensive & not cost effective

Mobile Raw Exhaust Analyser



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Mobile Raw Exhaust Analyser (cont)



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Maintenance Trial

- **Mobile EC analyser used to measure the raw exhaust EC levels in a fleet of 66 engines**
- **Of the 66 engines initially tested 7 were found to be abnormal**
- **Simple maintenance resulted in significant reductions in raw exhaust EC levels & hence worker exposures**

Effect of Simple Maintenance

Vehicle	Pre maintenance EC (mg/m3)	Post Maintenance EC (mg/m3)	Maintenance Performed
1	139	46	New fuel pump and cleaned scrubber tank
2	131	40	New scrubber tank, new injectors, adjusted fuel
3	159	71	Replaced injectors
4	102	61	Replaced injectors, cleaned scrubber tank and intake air system

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Development of More Practical Instrumentation

- **Once this concept was proved by various researchers, more practical instrumentation has been developed based on new laser technology and more recently backpressure on an exposed filter**

Raw Exhaust Diesel Particulate Analyser



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Portable Raw Exhaust Analyser



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Key Learning's

- **No one simple solution exists. Each operation needs to evaluate which control technologies work best for their circumstances**
- **Control of diesel particulate requires a major commitment by all involved – equipment suppliers, mine operators, workers**

Key Learning's (cont)

- **Emissions-based maintenance programmes offer potential for major gains in emissions and through increased productivity. For this strategy to be effective, this required the development of a different approach to monitoring the contaminant at its source**
- **Attention to detail is necessary to sustain control technologies**



Review of Today's Topics

- **Review of overnight questions**
- **Principles of containment**
- **Personal protective equipment**
- **Administrative elements**
- **Practical applications of control strategies**