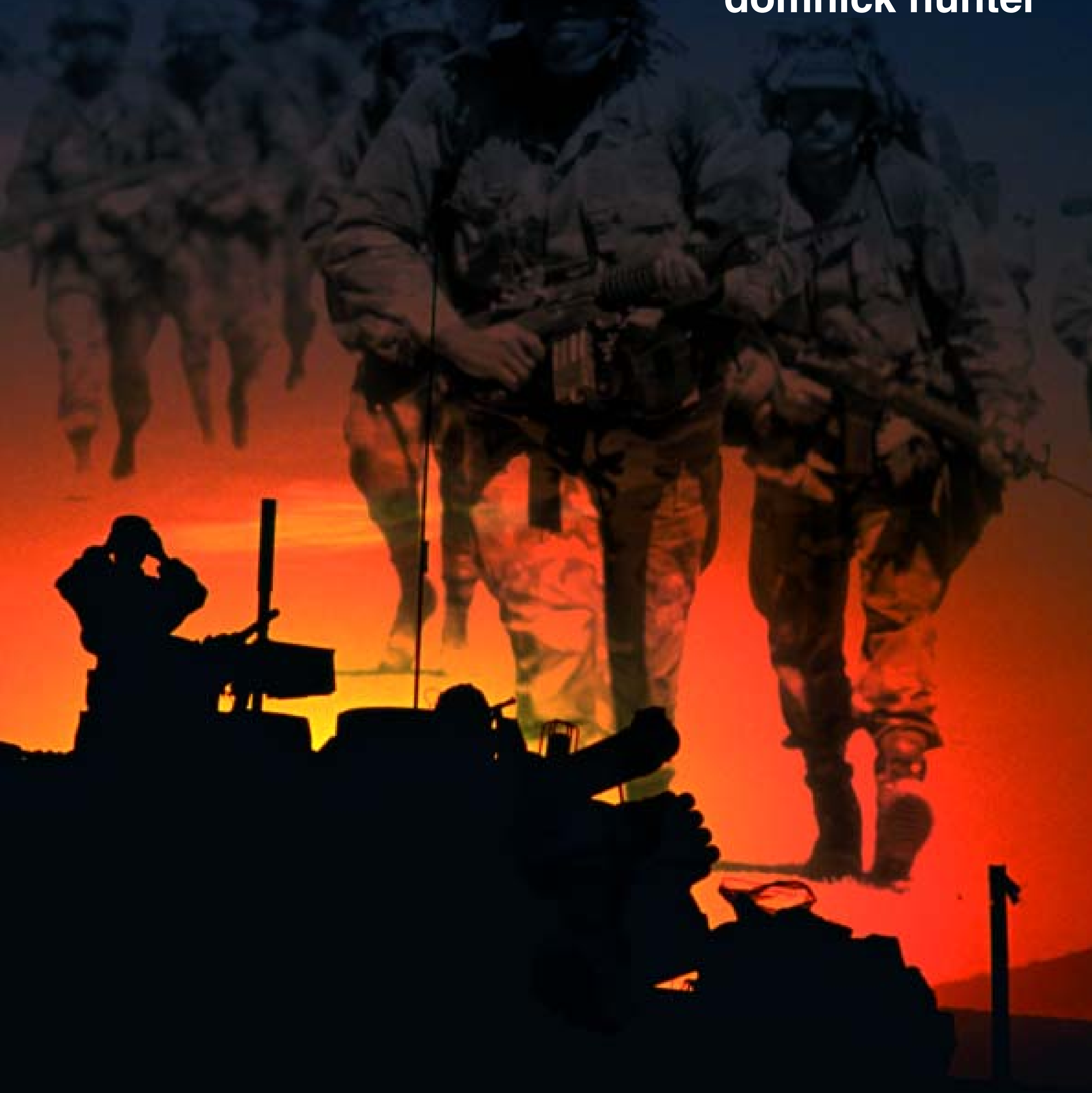
Patented Technology

domnick hunter



The World's First Regenerative NBC Protection Systems

domnick hunter Ltd.

Validation of Continuous Protection from Nuclear, Biological and Chemical Agents using in-situ Regenerative Pressure and Temperature Swing Adsorption Systems.

By Professor Rob M. Fielding
Director – Protective Systems

Introduction

The need for improved protection from Chemical weapons was identified long before the Gulf War, when the logistical support of existing single pass NBC filters was difficult to achieve for a number of reasons. Deployment of new filters is necessary because the single pass activated carbon filters used today deteriorate after exposure to atmospheric water vapour. UK experts at CBD Porton Down determined the best alternative technology is based on pressure and temperature swing adsorption, and a programme of work to develop a cyclic regenerative filtration system, supported by three European Governments under a EUCLID (European Co-operation for Long Term in Defence) contract was agreed. domnick hunter was appointed project leader of the tri–nation Consortium to develop and prove the technology. The project was announced a complete success at its conclusion in November 1998 by the Management Group consisting of European experts in NBC issues.

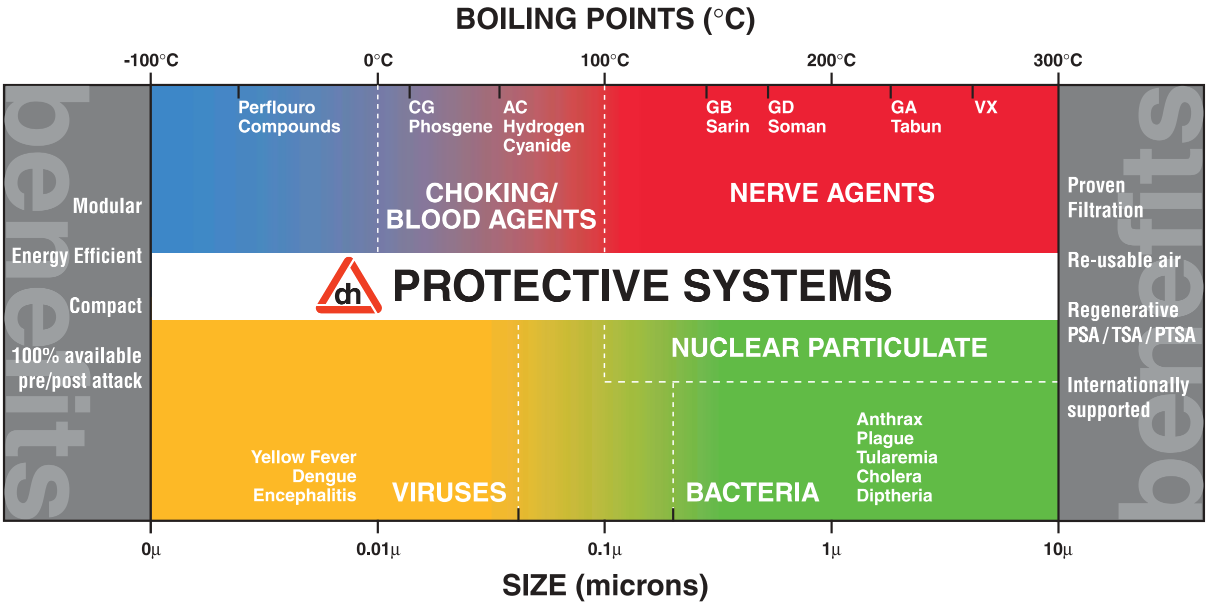
The technology is based on a core competency of domnick hunter – a physical adsorption process involving multiple gas phase separations, with internal heating to assist in the regeneration process. The use of a modular design enabled the engineering aspects of the technology to allow scaling for different platform applications.

To provide full protection, the filtration beds need to be integrated with a compressor or blower unit to provide overpressure to a crew enclosure, an air conditioning unit, and an independent control system. The air is fed into an enclosed space and maintained at just above atmospheric pressure to protect the occupants from the ingression of toxic chemicals present in the external environment. The system has to give full protection against all known CW agents, including blister, blood, and nerve agents, and the more recently developed perflouro compounds or so called 'carbon busters', against which single pass filters have no defence. Minimum protection factors must be better than those stated in the NATO Tryptych AC/225(Panel VII)/251.

During the EULID project, the technology was tested to the most arduous protocols than any system before, using Internationally accepted chemical simulants and live agents, with the conclusion that it showed zero penetration and > 98% regeneration, proving the technology and giving the customer a solution which was 100% available at any time, an answer to the logistic support problems, and the dependence on foreign supply issues, plus a reduced through life cost of ownership.

The programme further concluded that the pressure / temperature swing adsorption unit has the potential to be integrated into most COLPRO (collective protection) facilities. These include – armoured fighting vehicles, mobile field shelters, buildings and facilities, and surface naval vessels.

This paper looks at the issues relative to regenerative NBC filtration systems and outlines the design, validation and testing issues that domnick hunter Ltd has undertaken recently. The conclusion being that regenerative filtration offers significant capability improvement for lower cost than existing single pass technologies.



Nuclear Biological Chemical Defence
Airborne Contaminants

Chemical simulants

The following list of simulants which were recommended for use in the test programme, are Internationally accepted simulants for CW agents.

Freon 23	which is trifluoromethane, a gas at normal pressures and temperatures.
Isobutene	(also known as 2 methyl propene or isobutylene, and which is a gas at normal pressures and temperatures).
Dimethylmethylphosphonate	(known as DMMP) which is a nerve agent simulant.
2 Chloroethylethyl ether	which is a simulant for mustard (blister agent).
Ethan 1,2 diol	(glycol) which is a simulant for mustard agent.
Triethyl phosphate	which is a simulant for nerve agent.
Methyl salicylate	which is a simulant for mustard agent.
Ethanol, Butanol and Octane	which are referred to as battlefield contaminants.

A survey of the background information indicates that the main consideration in selecting the simulants concerns the need to cover a reasonable range of boiling points. The background documents indicate that the filtration system should be capable of removing chemicals having boiling temperatures between -90°C and +200°C. The simulants were therefore selected with this in mind.

Air purity analysis was determined by gas chromatography, any further simulants which may be used should be detectable using the gas chromatography system. It must also be possible to calibrate the gas chromatography system using any additional simulants. The other analytical instrument available for use in the work was an FPD (flame photoionisation detector).

From the list of simulants, chemicals have been selected which cover the boiling range in an adequate fashion. Both of the gas simulants (trifluoromethane and isobutene - which is also known as 2 methyl propene) were used (there are only two gas simulants which are recommended for testing). The triflouromethane simulant boils at -82.2°C, and it is assumed that this is likely to represent the lowest boiling point of highly volatile chemicals which might be encountered. The isobutene simulant boils at -6.9°C.

Biological Simulants

The use of two biological materials which are normally used to test particulate filters were selected to challenge the NBC filtration.

domnick hunter manufacture filters which are designed to produce sterile air, for example in dental and other medical air applications. These filter types are tested using biological materials to determine their sterilising efficiency. They are tested using the biological materials Pseudemonas Diminuta and Bacillus Globigii. Neither of these materials are dangerous to use, and were used as simulants for biological materials in the test programme.

Testing with the biological materials involves producing an aqueous suspension containing each of the materials, and then dispersing them into the input flow to the filtration beds. The concentration is quantified by serial dilution. The output flow was sampled using a casella slit sampler. Samples from the impactor were then removed and cultured. Culturing shows the presence, and number, of organisms (or colony forming units, CFU's) which are present in the product flow which are viable (meaning they are still biologically active).

Design protocols

In order to allow a modular design, the system contains adsorbent filled cartridges that have been filled to their maximum packing density in layered format, and as such there will be minimal attrition and maximum utilization of the adsorbent inventory. The adsorption cartridges are filled using 'snowstorm' filling techniques which is a methodology that essentially imparts to each grain of adsorbent its' minimum potential energy hence maximum packing density, through the filling process. This develops a bed that significantly truncates the adsorption isotherm which develops in the adsorption bed during the process of establishing a dynamic equilibrium, allowing maximum use of the adsorbent inventory hence optimizing the bed dimensions. As the cartridges are filled with exactly the same amount of adsorbent inventory, then each cartridge presents the same flow resistance to a flowing gas stream. The electrical analogy is having equal resistors in parallel causing equal flow of current, hence even mass flow distribution is set up through the on-line beds.

Whichever size system is used, there is only one size of cartridge which effectively simplifies the logistics of stock and inventory control of the regenerative filters.

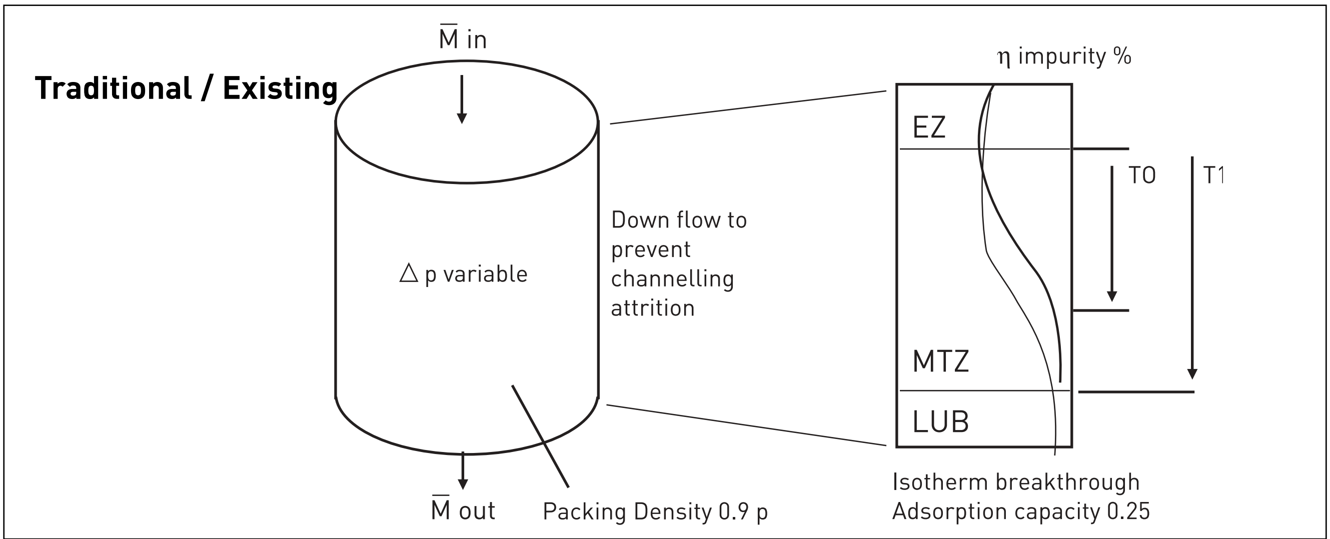
Packing densities of granular beds

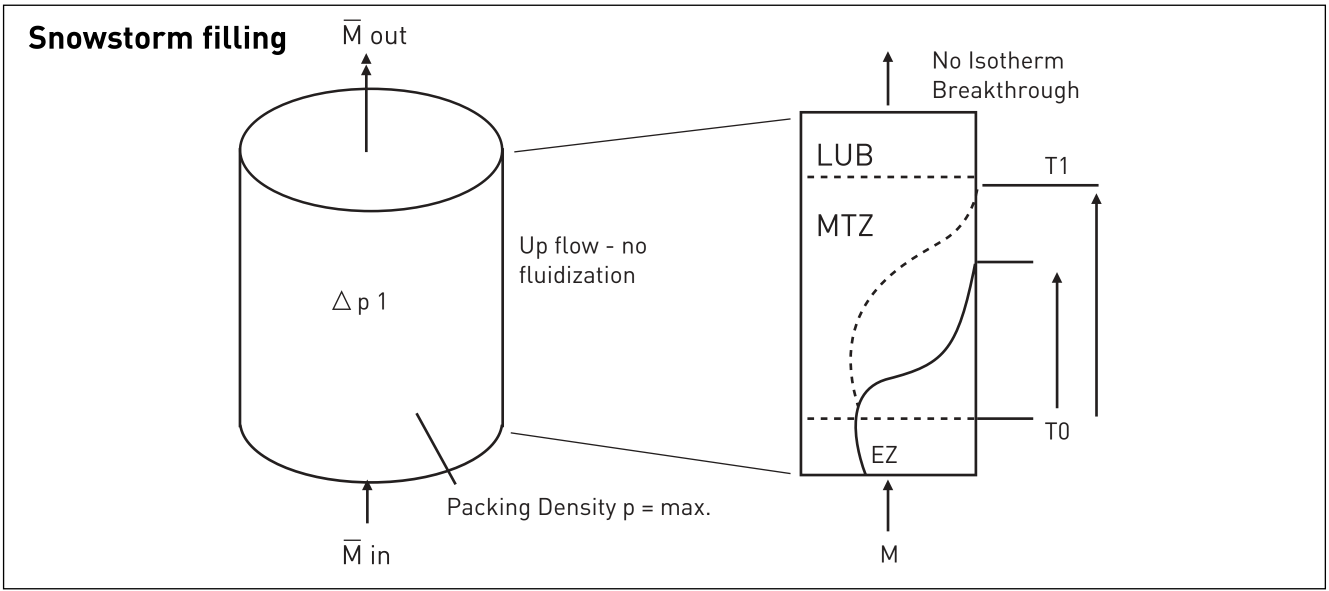
The traditional methods of filling an adsorption bed is where the adsorbent settles to its position of rest by gravity - typical densities are about 90% efficient and often need pulsing or vibration to try and improve on this. Another consequence of poor packing density is that the gas flow resistance figures for the bed are not consistent or reproducible. The adsorbent inventory is also non-uniform resulting in quality standards being difficult to apply to this method of design.

In any dynamic physical adsorption process there are three distinct sectors that form in the on-line bed. These are the Equilibrium Zone (EZ), Mass Transfer Zone (MTZ) and Length of Unused Bed (LUB). The important zone is the MTZ where the contaminant removal takes place. In this zone there is an adsorption isotherm established for each contaminant in the incoming gas and the shape or gradient of the isotherm is dependent on a number of factors. These factors are temperature, pressure, velocity of the gas, contaminant species, type of adsorbent and importantly packing density. The latter characteristic is the one most influenced by design.

From a design viewpoint, the more truncated the isotherm profile is, the better the utilization of the adsorbent inventory and hence efficiency of the filtration process.

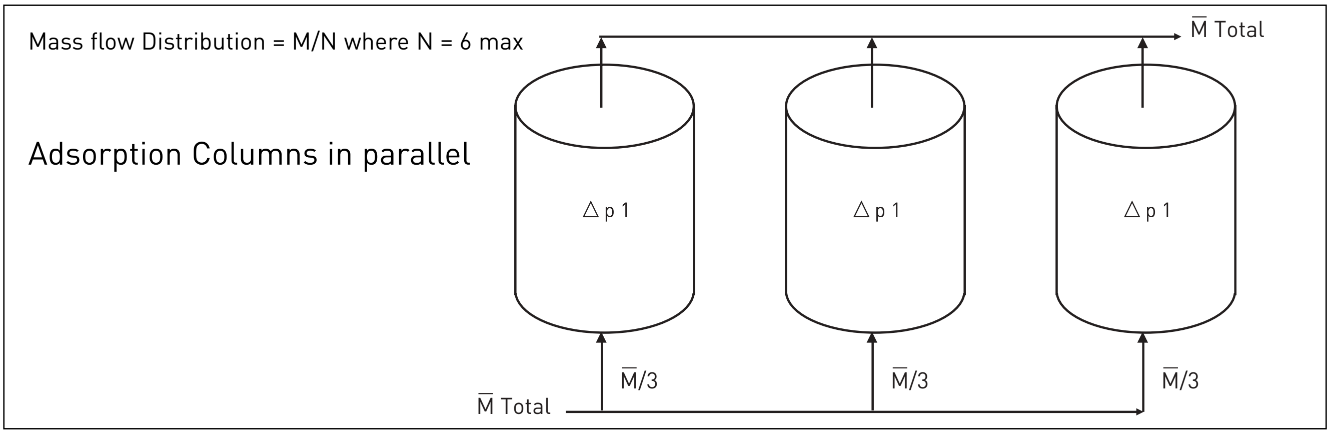
The greater the length of unused bed determines the overall adsorption capacity of the filter is and so determines the useful on-line protection against CW agents the filtration system will afford.





Snowstorm filling

This is a technique of manufacture introduced to the domnick hunter product range a number of years ago which allowed competitive advantage to be gained over existing designs by adopting a modular design concept. This resulted in a patented product in which the filling technique gives optimum packing densities hence a reproducible and consistent adsorption bed, which in practice gives full utilization of the adsorbent inventory and much improved adsorption isotherm profiles, independent of the type of contaminant or gas carrier.



The benefits of snowstorm filled containers can be summarized as follows:

- Maximum packing density achieved
- No fluidization of adsorbent - allows up flow configuration
- Consistent and reproducible container weights
- No flow attrition of granules hence minimum dust generation
- Improved life of downstream particle filtration
- Truncated adsorption isotherm - maximizes utilization of adsorbent
- Increases capacity of filter, weight for weight
- No flow channelling - hence no by-pass
- Beds offer same and consistent resistance to gas flow - allows parallel disposition of filter elements for different gas mass flows

Testing

In order to quantify the adsorbents performance, two basic tools are used. One is Gravimetric Analysis, which identifies the amount of adsorption capacity an individual adsorbent has for a specific gas species and produces adsorption isotherms for adsorbent / adsorbate combinations. The second is the use of a Gas Chromatography to identify the amount of breakthrough an adsorbent bed has for a single contaminant or a mixture of contaminants.

Gravimetric Analysis

The adsorption and desorption isotherms are measured using an Intelligent Gravimetric Analyser (IGA). The IGA is basically a very sensitive micro-balance, which is used to monitor very small changes in the mass of the adsorbent, which is on test. The balance is held at constant temperature within a cabinet to ensure that the obtained results are accurate. A small, weighed, sample of the adsorbent under test is loaded into a basket that is suspended beneath the balance, and this is then sealed into a controlled atmosphere. The adsorbent is then challenged by vapor / gas under either static or flowing conditions. Under vapor isotherm conditions liquid is added to the systems reservoir. The system pressure is dropped below the vapor pressure of the liquid, which allows vapor to be released from the liquid, this is adsorbed by the sample under test. For flowing isotherms, gas mixtures are flowed through the adsorbent sample chamber and are adsorbed. The gas flows through the IGA are accurately controlled using a Mass Flow Controller (MFC) and the temperature of the test is accurately controlled in one of two ways:

i. Using a fast response furnace (from ambient up to 300°C)

ii. Using a thermal-stirring device that enables the temperature at which the adsorption takes place to be lowered below ambient temperatures

Breakthrough Testing / Gas Chromatography

The other main area of testing is to use a gas chromatograph (GC) to monitor the adsorption performance of the adsorbent bed layers. A GC, operating in Mass Spectrometry mode (GC-MS) is used to detect and quantify the chemical and simulant 'challenge' to the test bed.

This technique combines gas chromatography and ion trap mass spectrometry. The basis of chromatography is the separation of components of a sample due to their differences in adsorption (or solubility) in a stationary bed of material, a molecular sieve or capillary tube in this case. As the sample is a gas and the stationary phase a solid, for these tests, the technique is termed gas-solid chromatography. The method of separation employed in this case is elution. In this method, the samples under test are introduced to the carrier gas as vapors / gases. Samples of the analyte are pumped through packed adsorption columns (stationary phase), which are maintained, at a specific temperature, where any separation of the components in the carrier air stream is carried out. Components of the analyte travel through the stationary phase at different speeds, then into the detector block, where individual components are identified.

A schematic of a typical test arrangement is shown below in figure 1

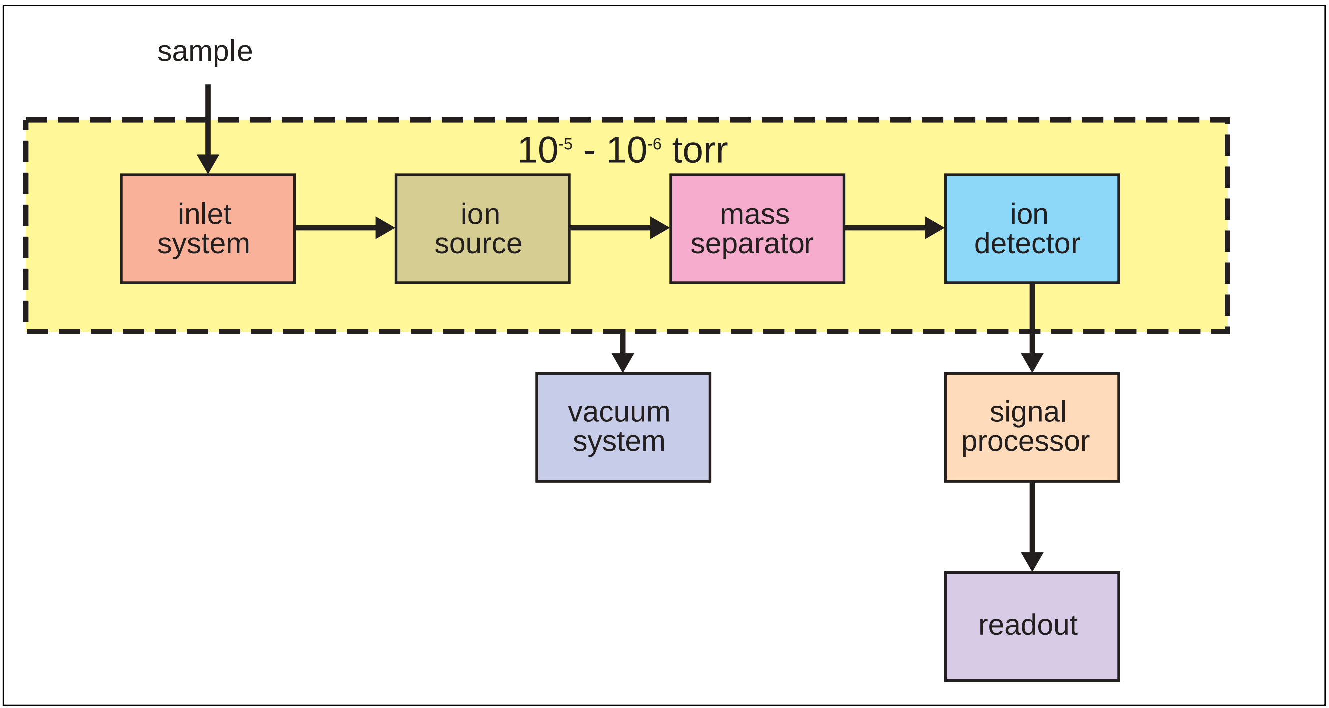


Figure 1: Typical Test Arrangement

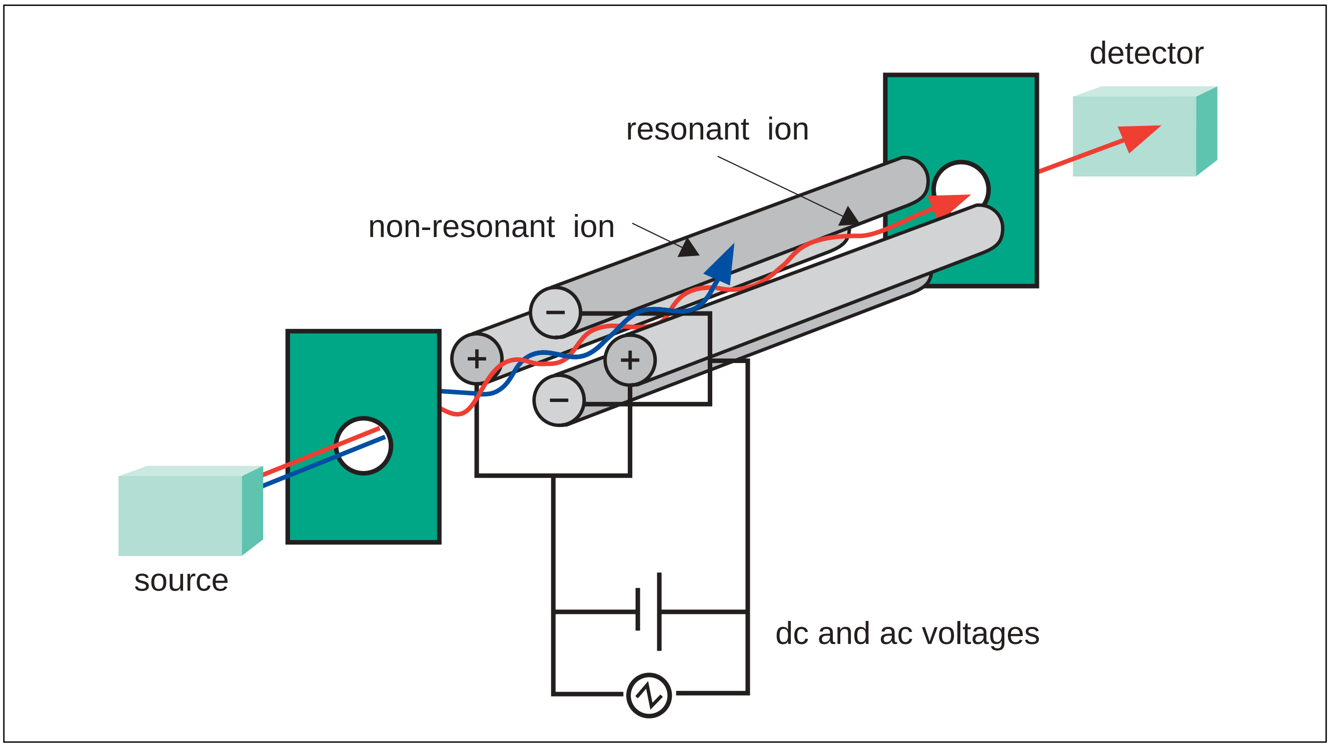


Figure 2: Mass Spectrometer detector

A mass spectrum of each component, as it is eluted from the column, is then generated. In Mass Spectrometry, the compound under investigation is ionized and fragmented in the instrument source. The ions are then selected by mass/charge ratio by passing them through magnetic and electrostatic sectors in order to generate a spectrum.

The spectrum typically contains peaks for the molecular ion and all of the fragments produced. Analysis of the fragmentation pattern can give important information about molecular structure.

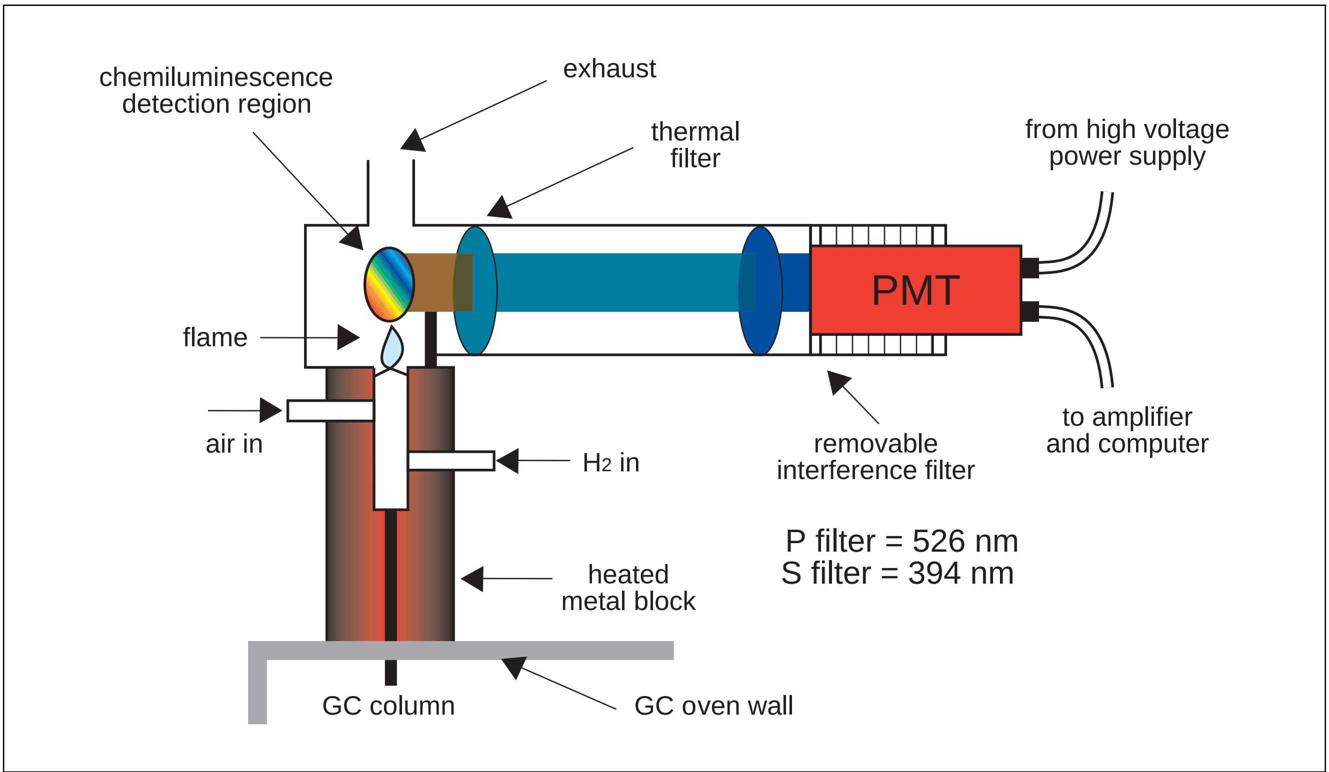


Figure 3: An FPD detector

A Flame Photoionisation Detector (FPD) instrument uses the chemiluminescent reactions of Sulfur and Phosphorus compounds in a hydrogen/air flame as the basis of its analysis. The emitting species for Sulfur compounds is excited S2. It has a lambda max for emission of excited S2 of about 394nm. In order to selectively detect a family of compounds as they elute from the GC column, an interference filter is used between the flame and the photo - multiplier tube to isolate the required emission band (see figure 3).

A system containing two separation columns was required to allow the inlet and outlet concentrations to be measured. Sampling of these flows requires the use of valves to introduce fixed volumes of gas onto the columns. Analysis of the signals produced by the flame detectors is by an integrating system which records, processes and stores data. The system produces graphical results, chromatograms, which give an indication of the amount of an individual component that is present in the sample, against the time it takes the component to travel through the stationary phase and enter the detector block (i.e. voltage against retention time).

Experimental Procedure

Adsorption and Desorption isotherms

To produce the required isotherms the IGA was set-up to produce a flowing isotherm.
The IGA equipment shown below in figure 4 was used to obtain isotherms. Basically, small samples of adsorbent of a known weight are loaded into a basket in the housing and the thermal stirrer jacket is raised to ensure that the temperature is held at 15°C.

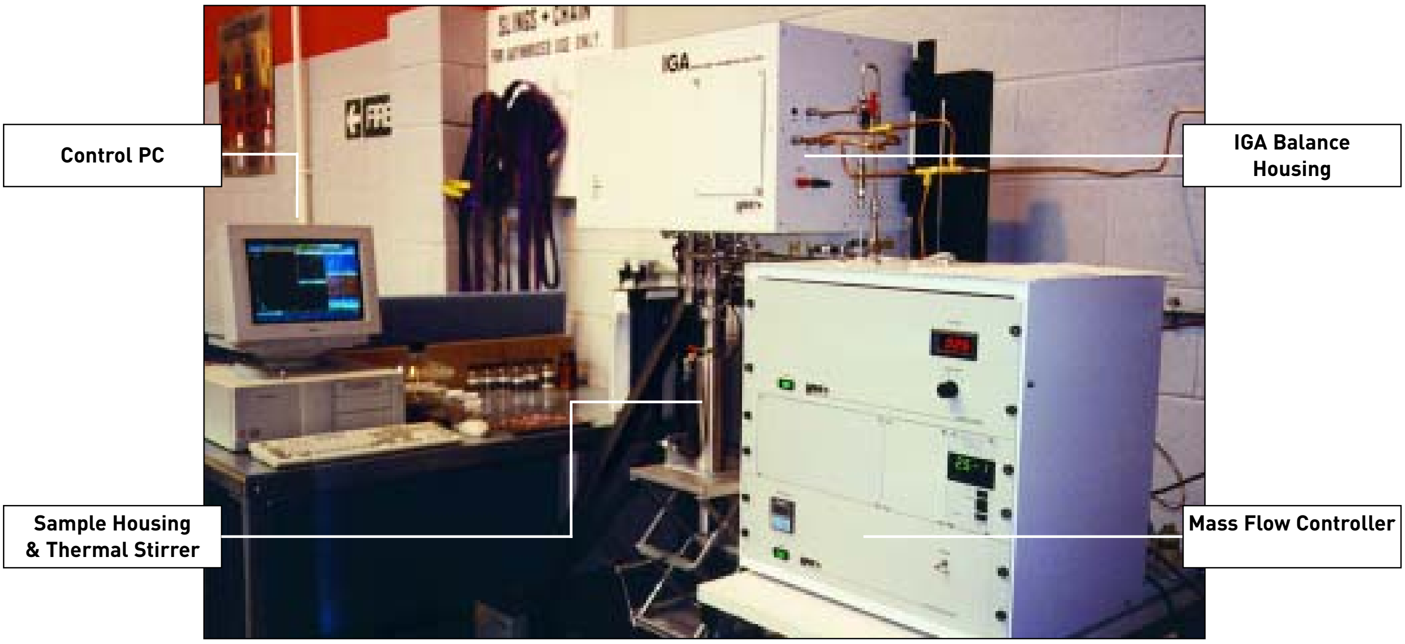


Figure 4: domnick hunter Gravimetric Analysis equipment

The IGA automatically increases the pressure from vacuum to 10 bara, using the supply of air mixed with one of the contaminant or simulant gases. The flow rate through the IGA is set at 20ml min-1, using the Mass Flow Controller (MFC).

The change in the mass of the adsorbent sample is monitored as the pressure is increased, and this changing mass value is used to give a measurement of the amount of adsorption taking place at the programmed pressure points.

This procedure produces adsorption/desorption isotherms for each of the adsorbent layers of the specific contaminant it is designed to remove. For all the isotherms, the representation of adsorption is given as 'mass adsorbed, kg/kg', this is the mass of gas adsorbed divided by the original weight of the adsorbent sample.

Breakthrough Testing/ Gas Chromatography

The breakthrough testing of the adsorbents was set-up as shown in figure 5. The inlet of the adsorbent bed under test was connected to a gas supply, and the outlet allowed to flow through the outlet flowmeter. The pressure of the adsorbent bed was controlled by use of the gas supply regulator valve and a valve placed at the outlet of the bed, before the flowmeter. Sample lines were taken at atmospheric pressure from the breakthrough rig and these are used to provide the analyte to the gas chromatograph.

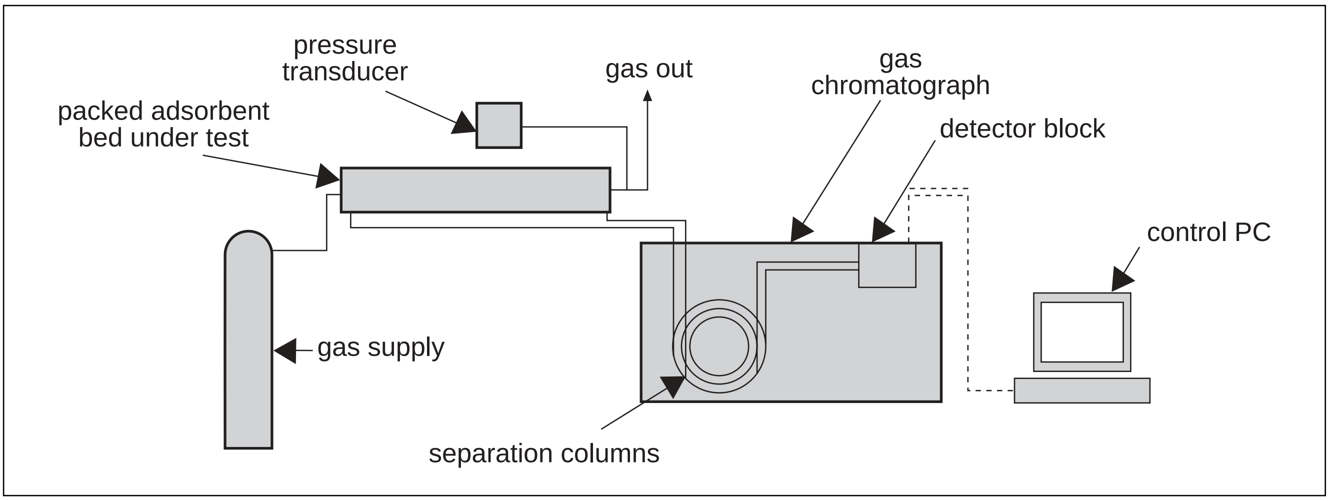


Figure 5: Schematic of Breakthrough Rig testing.

The test equipment used is shown in figure 6 below.

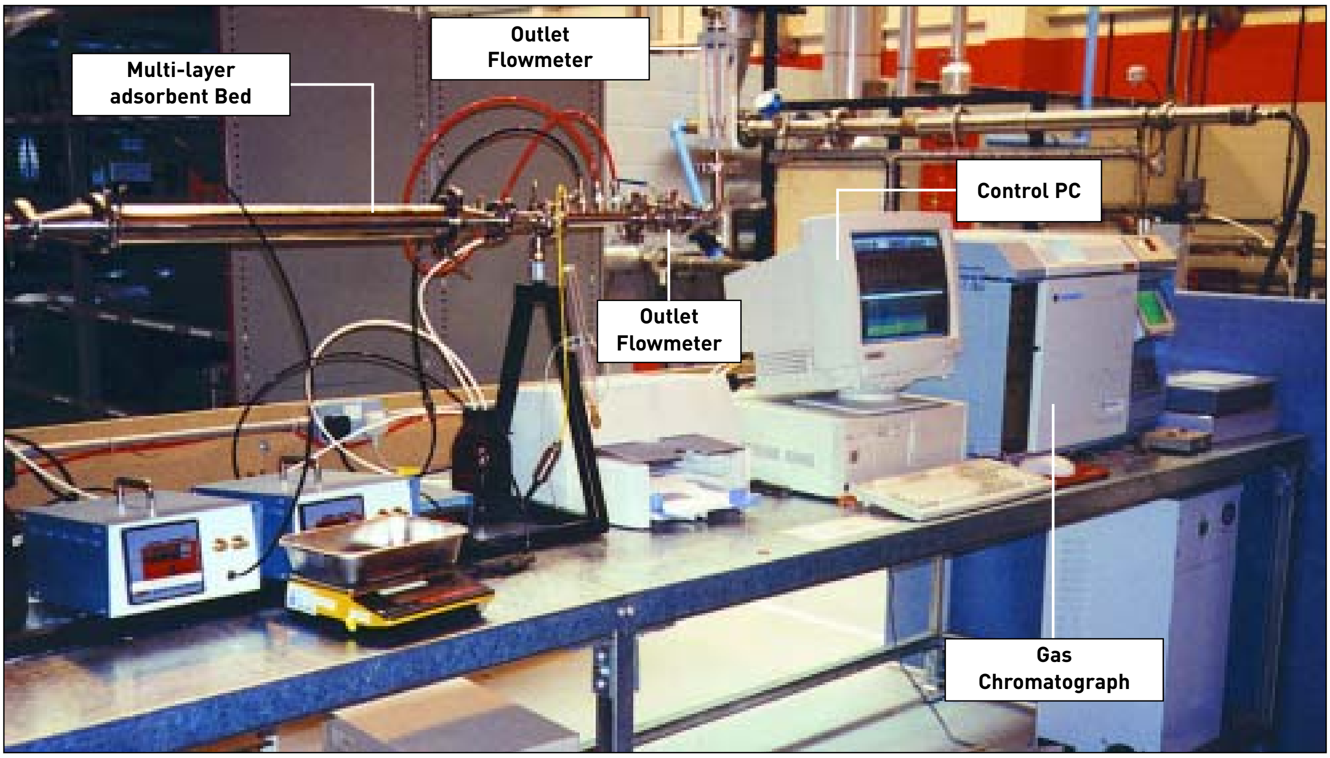


Figure 6: domnick hunter Breakthrough Test Rig

The regenerative adsorbent bed is tested using a scaled down multi layer bed, which is housed in the rig as shown in figure 6. The bed is challenged with air and the contaminant gases. The GC equipment monitors downstream of the adsorbent bed, and is used to detect any breakthrough.

The breakthrough rig schematic shown in figure 7, details the apparatus used to house the adsorbents under test.

Note: the adsorption column is in the horizontal position, showing *no* by pass of the bed due to adsorbent settling. Horizontal adsorption beds have been used extensively by domnick hunter in several ardous product applications.

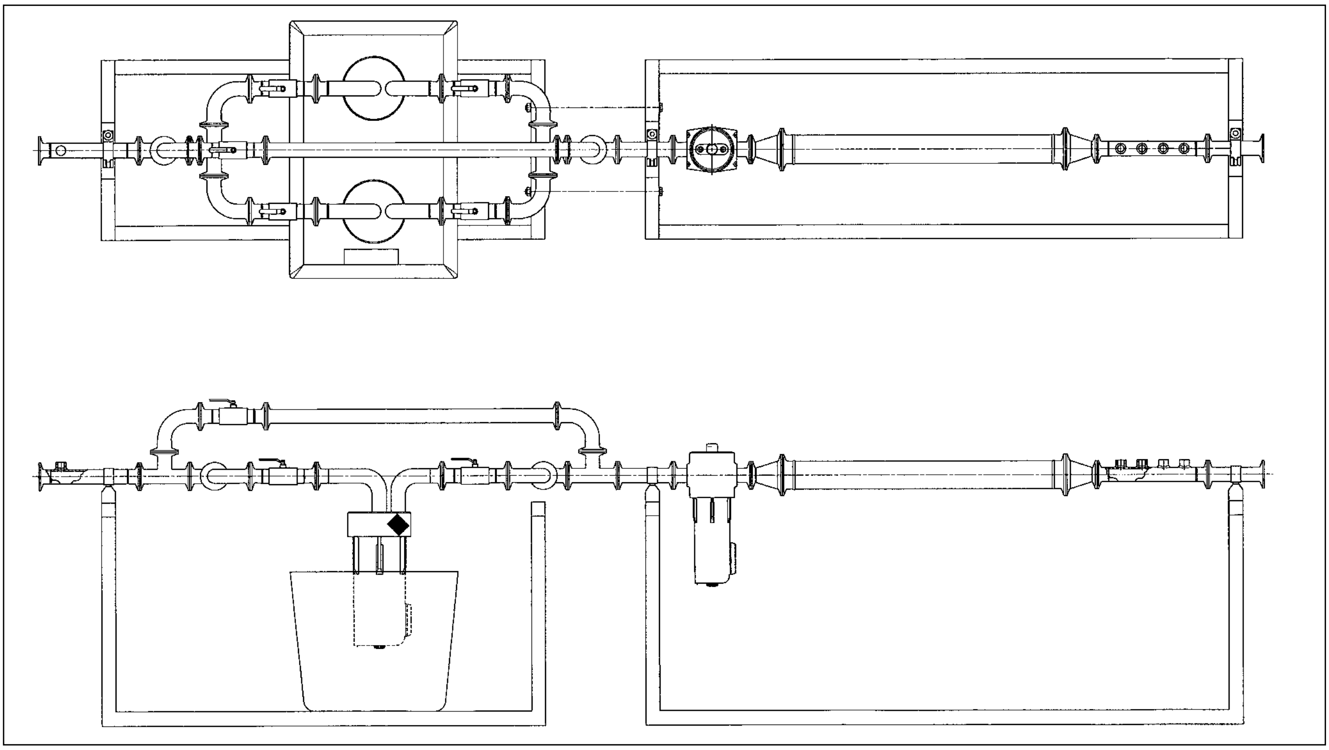


Figure 7: Breakthrough Test Rig Schematic

Regenerative filter – System description

The domnick hunter NBC-RR (Nuclear, Biological, Chemical Regenerative Re-circulatory Protection system) represents the latest technology in COLPRO systems.

Wherever protection from battlefield contaminants is needed, the NBC-RR system has the modularity and capacity to be integrated into virtually all COLPRO facilities, including AFV's.

Under a 'no threat' environment, the system will draw ambient air in through a first stage air/air heat exchanger made from highly efficient aluminium profiles. The warmed air will then be introduced to a stainless steel pre-separation chamber where the air is accelerated using static vanes. These impart a tangential component to the air velocity causing separation of particles, aerosols, dirt and sand down to about 10 micron aerodynamic particle diameters.

This pre-cleaned air then passes through a highly efficient particulate air filter which is capable of particle retention down to 0.01 micron in size. Any fine aerosols of chemical mist are also removed at this point and coalesced to the base of the chamber where they are ejected from the system using an automatic draining mechanism. The filter is manufactured from microfibre glass with an extremely high voids volume to allow operation with very low pressure drop characteristic. The filter rating is >99.9999% @ 0.3 micron removal, allowing effectively cold sterilisation of the air from any airborne bacterial, viral or spore based attack. This filter will show log reduction values of > 7 when challenged with a bacterial simulant such as Bacillus Globigii.

This air is then drawn in through a blower system and passes through an environmental control stage. This conditions the air prior to it being fed into the crew enclosure. Under a no-threat scenario, a small proportion of the air is re-circulated whilst the majority of air taken from the ambient atmosphere is dispersed under the positive pressure of the enclosure by platform leaks etc.

In the event of an attack, or movement into a high risk environment, the NBC-RR system automatically or manually reverts to a full protection mode where the NBC bypass is sealed and the air is diverted through a regenerative Pressure Temperature Swing Adsorption Filter. The adsorbent beds contained within the PTSA will give full protection against all known CW agents. The PTSA filter contains multiple beds to ensure full protection is given, while through a process of pressure swing and heat, the off-line beds will automatically scrub themselves clean of the pre-adsorbed chemicals and a purge system dispels them safely back into the externally contaminated environment.

During the re-circulation mode, the proportion of air being pulled in from the atmosphere is reduced to typically 40% of the full requirement hence the remaining 60% (leak rate dependent) is re-circulated from the crew enclosure. This has the immediate effect of significantly reducing the chemical loading on the PTSA system, hence allowing it to be sized optimally for an AFV application. It also has the following benefits over current technology:

Carbon dioxide removal:- Air that is exhaled by the crew members will contain up to 6% carbon dioxide. This gas is scrubbed from the enclosure when the re-circulated air passes through the PTSA filter. As it is fully regenerative, there is no need to replace filters.

Oxygen replenishment:- The oxygen used up in the breathing process is normally replenished by some form of on-board generation process which is generally considered to be hazardous. In the NBC-RR process, the proportion of air from the atmosphere contains 21% oxygen, and once the PTSA removes any CW agent, that proportion of air is mixed with the re-circulated air therefore eliminating the need for oxygen generation.

The enclosure temperature is regulated by the Environmental Control System to that determined by the crew members.

Overpressure in the enclosure is regulated from a pressure switch linked to the electronic drive on the blower motor – this is via an electronically commutated DC motor with speed control voltage. This will maintain a constant overpressure in the enclosure and give excellent energy savings at low leakage conditions.

The domnick hunter NBC-RR system has been tested to the most arduous protocols ever determined by CBDE Porton Down in terms of chemical loading, including so called carbon busters against which existing technologies have no defence. Regenerative PTSA has been proven through the EUCLID programme to be the only technology to demonstrate better than 98% regenererability against all CW agents.

Temperature Swing Adsorption (TSA) regenerative filtration system suitable for integration into a vehicle (Armoured or Diplomatic) or shelter platform (mobile or fixed).

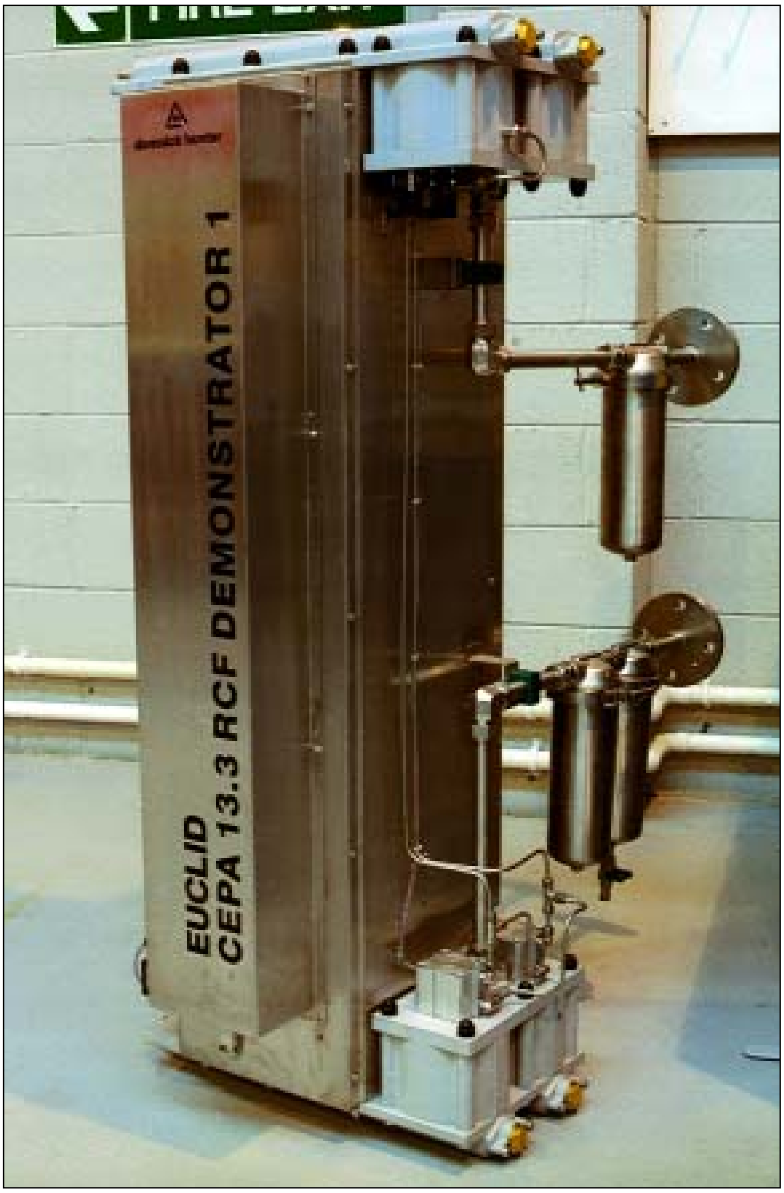
Pressure and Temperature Swing Adsorption (PTSA) regenerative filtration system suitable for the protection of buildings or other fixed facilities.

Chemical Agent Challenge testing of a Regenerative NBC Pressure Temperature Swing Adsorption Filter.

Format

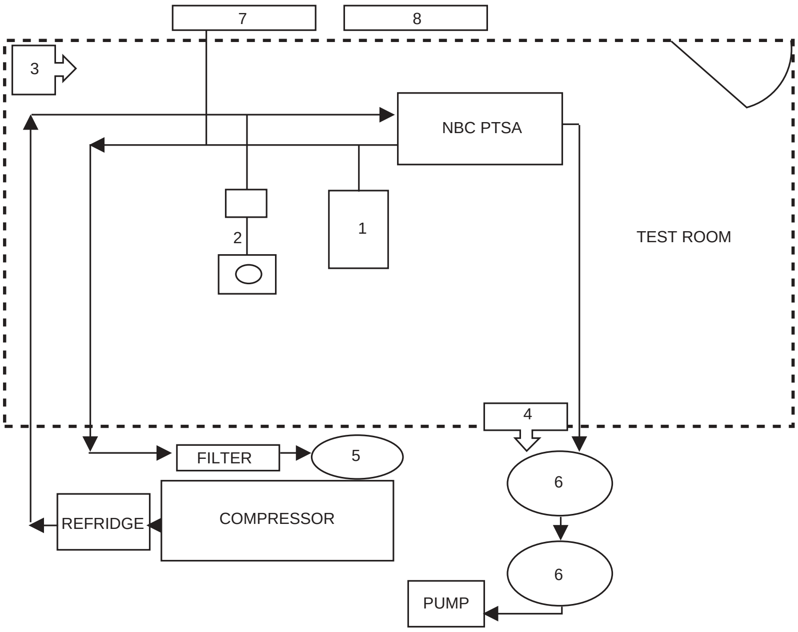
A regenerative PTSA unit was assembled to cope with the following specification.

Air flow 170m^3/hr delivered @ A1 / B2 inlet conditions.
Air pressure 3.5 barg



Regenerative PTSA Filter

PTSA test layout



Key:

1 Infrared spectrophotometer
2 Chemical agent injection equipment
3 Air vent in
4 Air vent out
5 Air receiver
6 PTSA exhaust filters
7 Infrared spectrophotometer
8 Computer monitoring

Methodology

Liquid injections

For liquid injections into the PTSA inlet a Gilson pump was used to directly inject droplets into the inlet port. Checks were made to determine signs of condensation. None were found, hence it was accepted that all of the product had totally evaporated into the PTSA inlet.

Gaseous injections

As product vapour pressures were greater than 3.5bara, it was possible to inject directly from the cylinders into the test cicuit, again directly into the inlet port of the PTSA filter.

The injected quantity was checked in the following manner:

- a Miran Infrared spectrophotometer was connected to the PTSA inlet to check the concentration.

- The cylinders were weighed (0.1g accuracy) in order to check the injected mass of the product.

Detection

Two instruments were used:

A Miran analyser was used to acquire product concentrations in the purge gas of the PTSA to determine completeness of regeneration.

- a Nicolet gas chromatograph was used to detect chemicals present in the outlet of the PTSA.

The challenge concentrations and order of challenge are detailed in the table below.

Agent	Time h	Gilson none	Mass g	Flow* m^3/h	Temp.* °C	Press.* Bar absolute	Flow** m^3/h	Conc.** g/m^3	Ct $mg.min/m^3$
POL	2h 56	95	575	196.5	10.8	3.49	202.8	0.967	
POL	8h 58	95	1765	196.0	11.2	3.50	202.2	0.973	964 000
POL	4h 28	96	905	194.8	11.3	3.51	200.9	1.008	
DMMP	4h 28	30/29	448	196.7	12.9	3.53	201.5	0.498	268 000
DMMP	4h 28	29	448	194.6	12.8	3.52	199.4	0.503	(211 000)***
n-Octane	4h 29	96	894	196.1	12.0	3.51	201.6	0.989	266 000
n-Octane	0h 15	480	250	193.6	11.3	3.51	199.5	4.985	75 000
Cyclohexan	4h 29	86	893	194.8	11.7	3.53	200.5	0.993	267 000
Cyclohexan	0h 15	435	251	194.8	11.1	3.51	200.1	5.017	75 000
HCN	4h 27	89	882	195.6	10.6	3.50	202.1	0.981	262 000
HCN	0h 15	445	247	193.5	8.7	3.50	201.3	4.908	73 500

* at PTSA inlet sensors (means)
** recalculated for 1bar and 20°C
*** after subtraction of liquid collected in purge

Results

HCN: No breakthrough was observed during the whole test (at $1g/m^3$ and $5g/m^3$).

POL: No breakthrough was observed during the whole POL test campaign (16 hours).

DMMP: These tests were carried out over a 9 hour period, no breakthrough was detected.

OCTANE: The octane tests were the same as the POL tests except for the duration, again no breakthrough was detected.

CYCLOHEXANE: For both the high and low challenge levels, no breakthrough was detected during the whole test campaign.

At no time during the test period was there any indication of displacement of pre-adsorbed chemicals, and the outlet dewpoint of the air from the PTSA unit did not get wetter than –58°C.

Conclusions

- Over the total test regime, 11.5 Kg of chemicals was injected directly into the PTSA filter with air between 80 to 90% humidity.
- The total time for the tests was over a period of 304 hours.
- The total amount of water vapour presented to the beds over this period was calculated as 78 Kg.
- No penetration of the beds occurred at any time.
- The bed regenerability was determined at > 98% within three cycles of the chemical injection.
- No displacement effects were observed.

The tests were independently carried out by staff at the Centre De Bouchet test facility in France and witnessed by personnel from Dstl Porton Down from the UK.

Chemical testing using low boiling point, highly volatile materials - TSA system

Introduction

As with any new technology, it must be shown that the system offers improved capability over existing systems. Testing in the UK, on the existing impregnated Activated Carbon filters has clearly demonstrated that single pass filtration offers no protection against the more volatile simulants such as Freon 23 and Freon 134A.

Indeed, as a condition to enter a recent Technology Demonstrator Programme, domnick hunter had to show that its filtration beds could remove significant amounts of Freon 23 at pressures approaching atmospheric pressure and show regeneration. This was successfully carried out by domnick hunter staff under the scrutiny of personnel from Dstl Porton Down.

These tests were carried out on scaled systems so there was still the need to test a full system with volatile simulants. Therefore, the following test programme was initiated.

Format

A full size TSA regenerative filter was assembled as part of the Engineered Tank System programme.

This consisted of a cyclonic separator, pre-evaporator and the NBC beds operating on a blower fan at a working pressure of 150 mbar. The following schematic describes the test arrangement.

The inlet flow to the NBC filter was set at 125% of rated flow (51 m^3/hr).

A humidification system was used to increase the inlet air temperature to that of A1 and B2 conditions.

The regenerative filter was allowed to condition for well in excess of 500hrs operating, at worst case conditions, with the following parameters being recorded:

Inlet and outlet pressures

Inlet and outlet temperatures

Flow rates

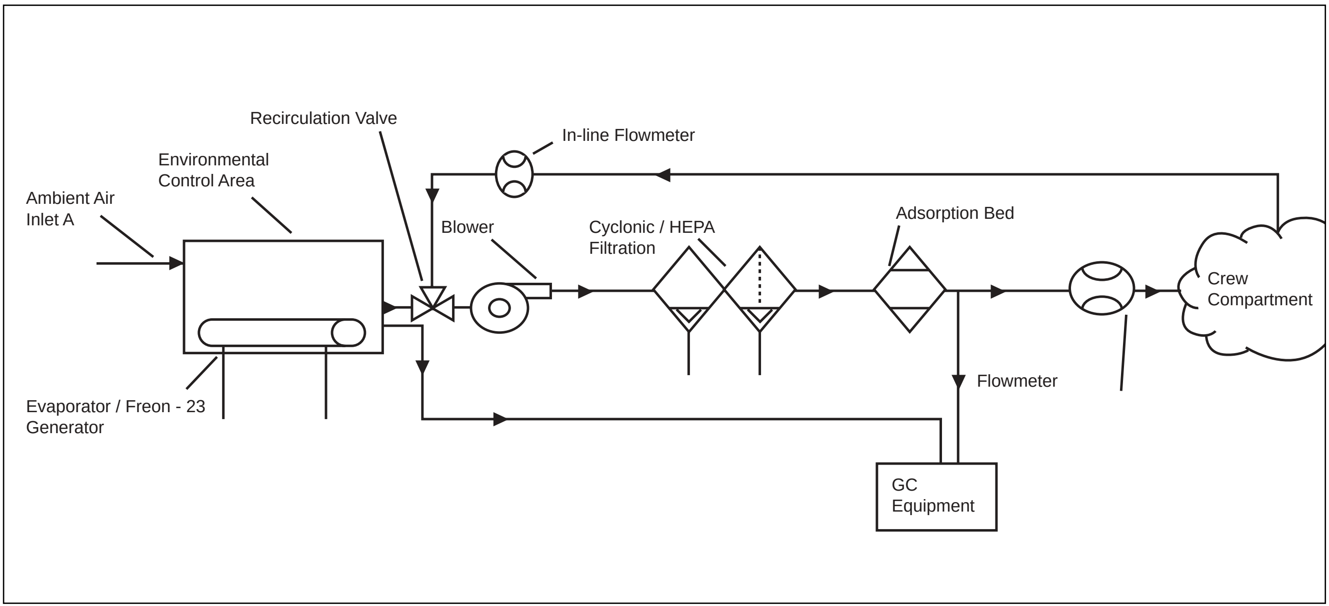
Power usage

Dewpoints

Differential pressures

Bed temperatures

Inlet and outlet chemical concentrations



Freon 23 was injected into the cyclonic filter inlet with the scavenge fan switched off so all of the chemical challenge was presented to the NBC beds. The inlet concentration* time was 15000 mg.min/m^3. For two minutes giving a total challenge of 30000 mg.min/m^3. The inlet concentration was determined by weighing a gas cylinder pre and post test, and by the taking of an inlet air sample by use of a Tedlar bag and analysing the contents on a pre-calibrated Gas Chromatograph (GC).

The downstream air samples were taken throughout the half cycle, either for the duration, or at regular intervals, to ensure that there was no Freon 23 or Freon 134A penetration or emissions during the whole cycle.

The purge gas was also sampled to determine the degree of regenerability that was being achieved over subsequent cycles.

All of the air analysis was done on a GC with full calibration details being available.

To ensure that the methodology and procedures were robust and valid, the test procedure has been witnessed by staff from Dstl and the Public Analyst who then issued a certificate of verification and compliance.

Actual test rig used for high volatility simulant tests

Results

The following graphs detail the actual results and show that the Regenerative TSA system to be fully effective against low boiling point, high volatility simulants.

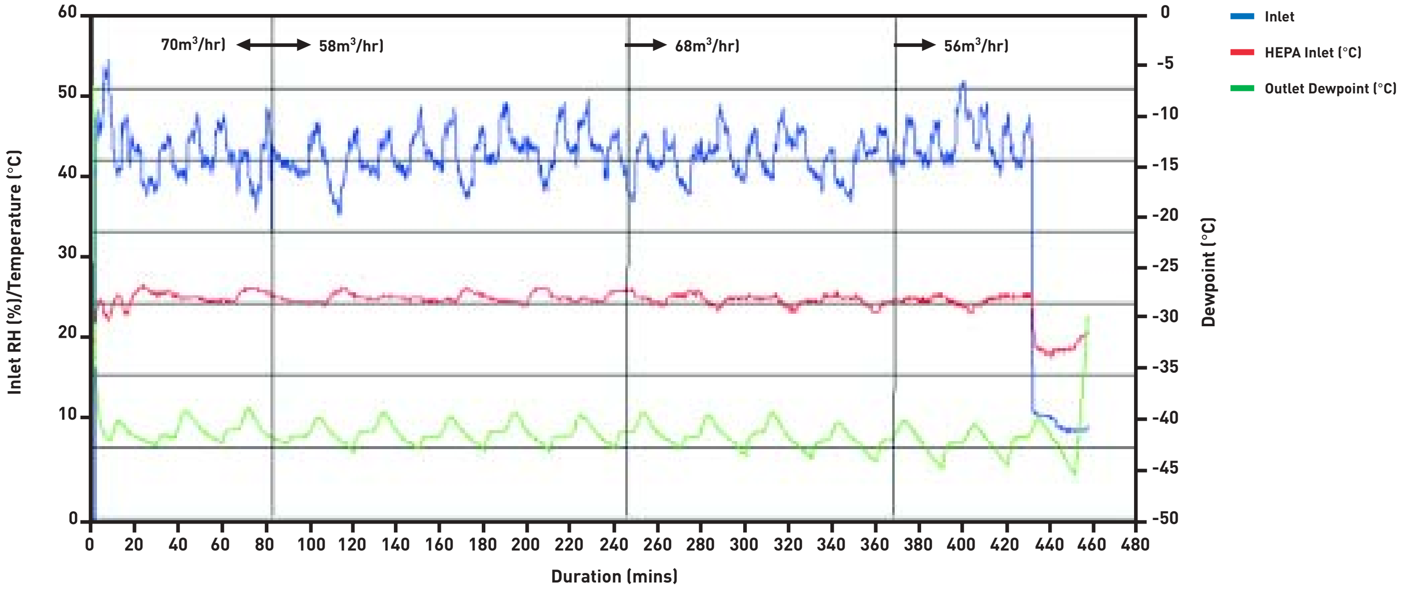
The filtration system was tested under worst case conditions, under independent scrutiny.

The TSA system was also found to be fully regenerated after three cycles with no residual freon being detected within the beds.

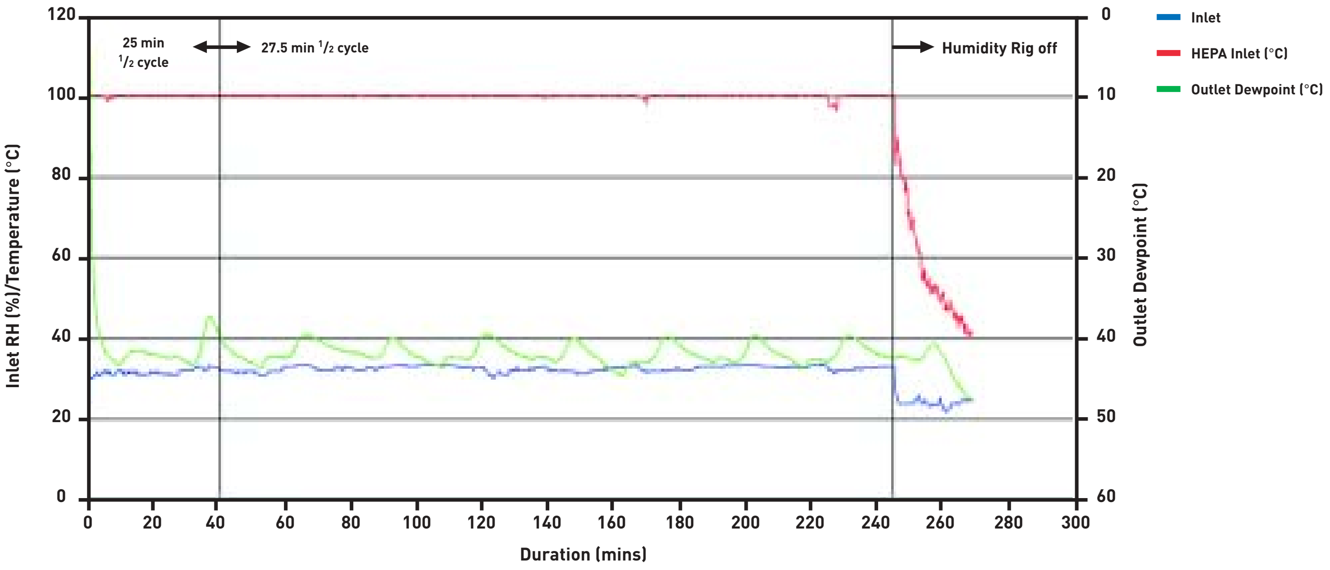
The outlet dewpoint was recorded continually and showed that typical levels of about –50°C were delivered to the crew enclosure thereby increasing user comfort considerably under high ambient temperatures and high humidity levels.

Use of the pre-evaporator also meant that the air temperature entering the toxic free area was at an optimal level for comfort.

Inlet RH %/Temperature/Outlet Dewpoint of 150 mbar TSA Prototype NBC System 30 mins 1/2 cycle.
B2 inlet (Approx 30°C 53% RH). Outlet flow variation (70 & 58m³/hr)



Inlet RH %/Temperature/Outlet Dewpoint of 150 mbar TSA Prototype NBC System 25 min & 27.5 min 1/2 cycle.
B3 inlet (Approx 31°C 100% RH). Heater cycle Top 4 mins, Bottom 8 mins & 9 mins



Testing of a PTSA regenerative filtration system with high volatility chemicals

Test set-up

A Pressure Temperature Swing Adsorption system was assembled for testing at pressures above 4barg to determine the efficiency of removal of a Freon 23 challenge. Compressed air at 7 barg was taken at a flow rate of 51 Nm^3/hr as the delivered air volume flow rate. The air was humidified and heated to provide A1 and B2 conditions at the inlet port to the NBC filter.

The test set up, shown in the following photograph, was allowed to run in excess of 500 hours at rated flow on a cyclic basis to establish stable conditions and 'aged' beds for the Freon challenge.

As with the TSA test run, the inlet challenge concentration was set at 30000 mg.min/m^3, injected at 15000 mg/min over a 2 minute period at the start of a full cycle.

Both inlet and outlet concentrations were sampled using Tedlar sample bags over the full half cycle to determine any penetration of the beds or displacement effects. The analysis was performed under independent scrutiny by the Public Analyst with all instrumentation having satisfactory and documented calibration status.

All other test parameters such as dewpoints, temperatures, pressures, flow rates etc were data logged over the continual test period.

Results

Freon 23 Adsorption Performance

Inlet Concentration	15033 mg/m^3
Inlet CT	**30066 mg.min/m^3**
Outlet CT (0-10mins)	99 mg.min/m^3
Outlet CT (10-20mins)	175 mg.min/m^3
Outlet CT (20-30mins)	187 mg.min/m^3
Outlet CT (30-40mins)	181 mg.min/m^3
Total CT	**642 mg.min/m^3**
Average CT	160.5 mg.min/m^3
Reduction Factor	46.8317
Average Freon level.	16.055 mg/m^3
Average Efficiency (Conc. based)	**99.8932%**
Average Efficiency (CT based)	**99.4661%**

Conclusions

Chemical challenge tests have been performed on both regenerative TSA and PTSA filtration systems.

Both systems have shown > 99.9% removal of the low boiling point (-82°C) simulant, Freon 23.

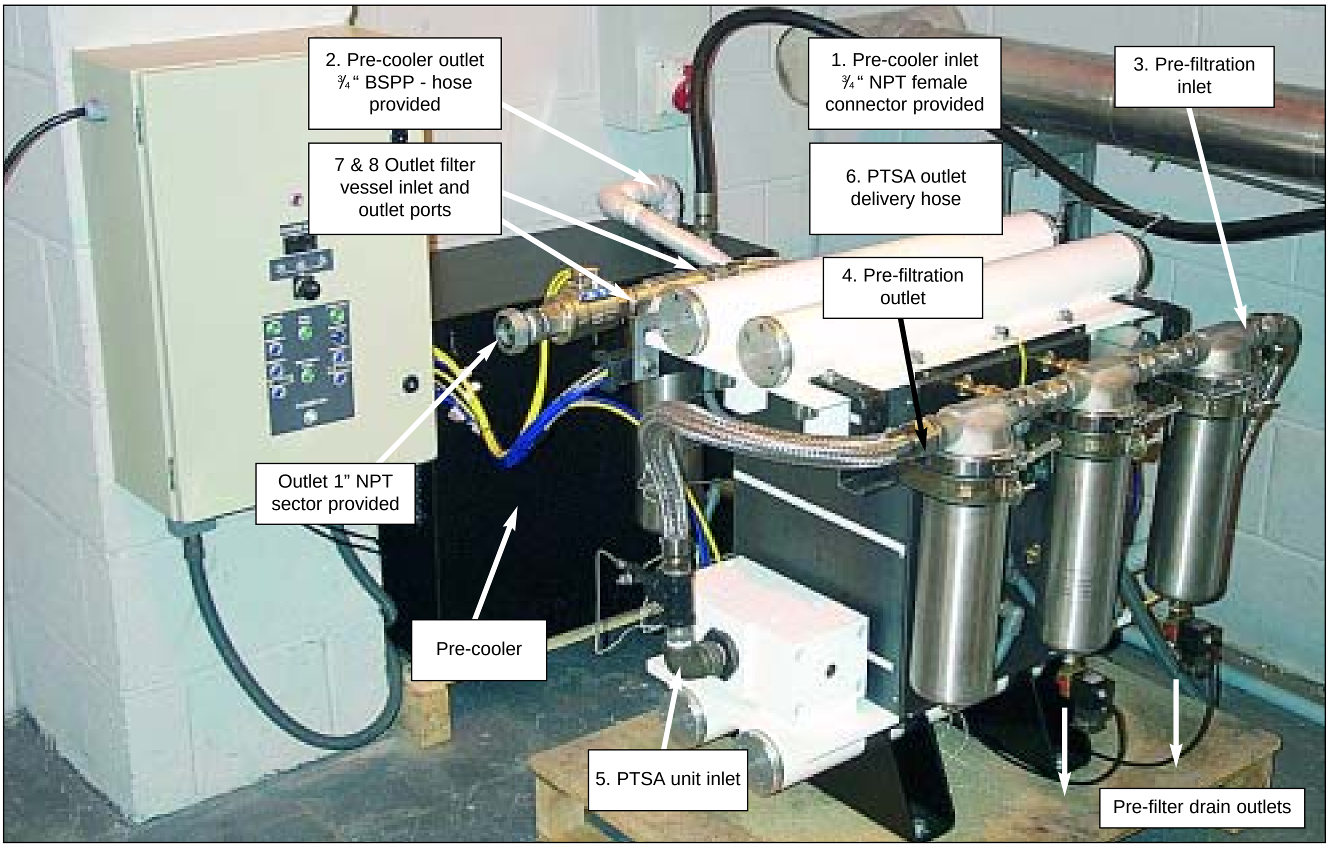
Inlet challenge levels were determined by Dstl Porton Down, and the tests were witnessed by the Public Analyst for the City of Newcastle upon Tyne, England.

The Tests were performed on adsorption beds with in excess of 500hrs operation.

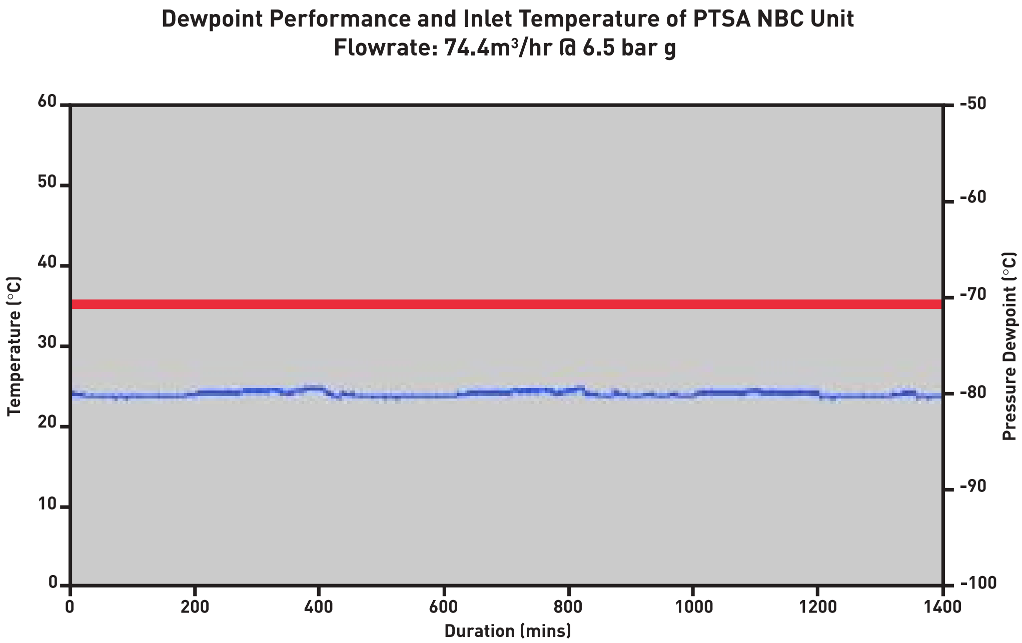
Full regeneration of the beds was shown to be within two subsequent cycles of the system.

Further tests with Freon have been completed with similar results, showing no deterioration in performance over extended periods of time.

Testing with Freon 134A (Bpt. - 28°C), showed complete removal ie > 99.99% with non-detectable levels downstream.



Regenerative PTSA test rig



Computer simulation model of the effect of a Sarin gas attack on a fixed facility

Introduction

Subsequent to the terrorist attacks on the World Trade Centre, the USA have embarked on a significant upgrading of her readiness for further attacks under the umbrella of a Homeland Defence Programme.

Various fixed facilities are being considered for collective protection using both non-regenerative and regenerative filtration.

The following models were developed using FLUENT, a computational modelling software code.

The intention of the work was to determine the effect of using filtration devices of varying efficiencies to protect a fixed facility, and assess the amount of time individuals would have within the facility to retire to a safe area.

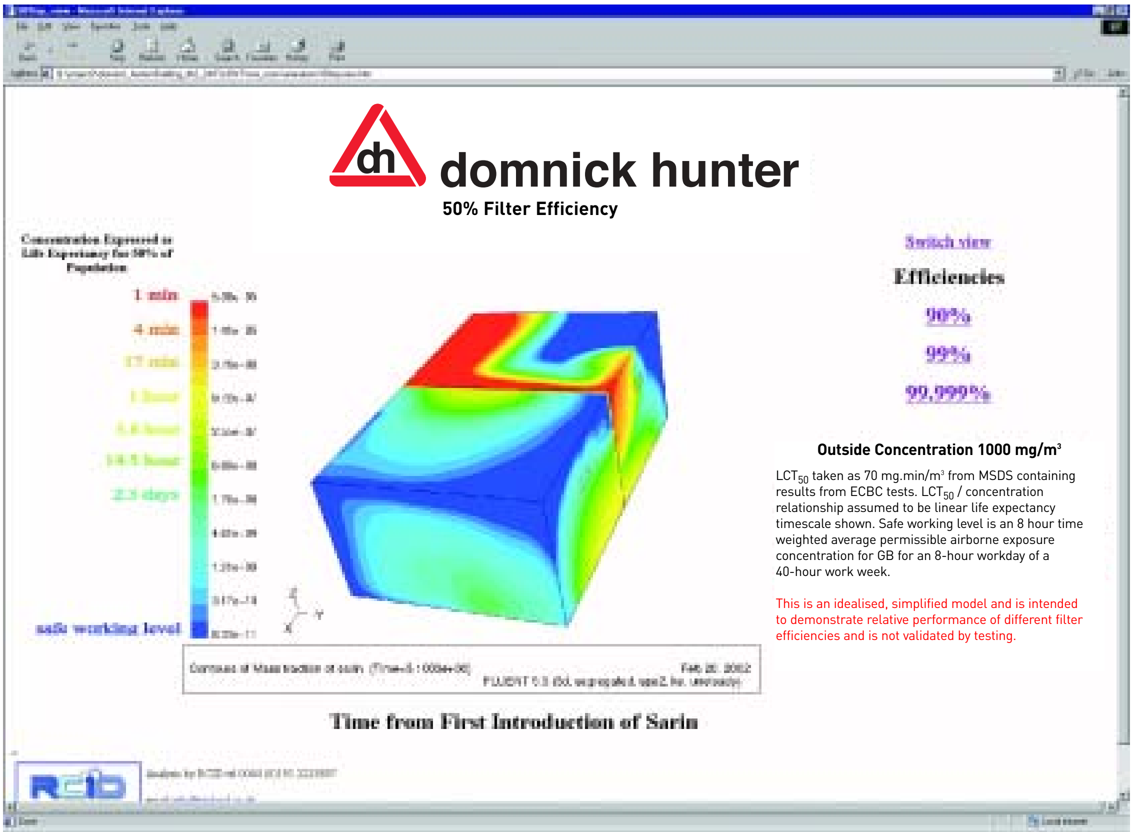
The Sarin introduction was via the intake vent for a typical air conditioning system, and the external concentration was set at 1000mg/m^3, some thirty times less that the CT values used to test both the TSA and PTSA systems.

Description of work

The multiple images have been used to create a demonstrator animation with the option to examine the comparative behaviour of different filter efficiencies. As expected, the high efficiency indicates that the model will saturate at a low level, allowing longer periods before death. The low efficiency indicates very short periods before the dose is deadly. With all the different filter efficiencies, it takes approximately the same amount of time before the room is saturated at the filter output concentration. This is the maximum concentration that the room should reach. With the lower filter efficiencies, although they will reach their maximum concentration in the same time as the high efficiencies, the time it takes the room average concentration to exceed a given value is smaller.

The data on which the model is based is referenced in the model screen shots.

The domnick hunter 2-room Sarin (GB) model is not a fully refined model. The model has not been developed to the mesh size where it could be considered truly grid independent. This is due to the processing penalty involved with the finer meshes, large volumes and the dynamic nature of the model required over long time periods. The general flow and mixing will provide an indication of how flow into this particular room will develop and an idea of time-scale involved. However it is not intended to provide very accurate timing in specific locations. The model is also greatly idealised in that there are no obstructions or heat sources in the room or temperature gradients that would create buoyancy effects.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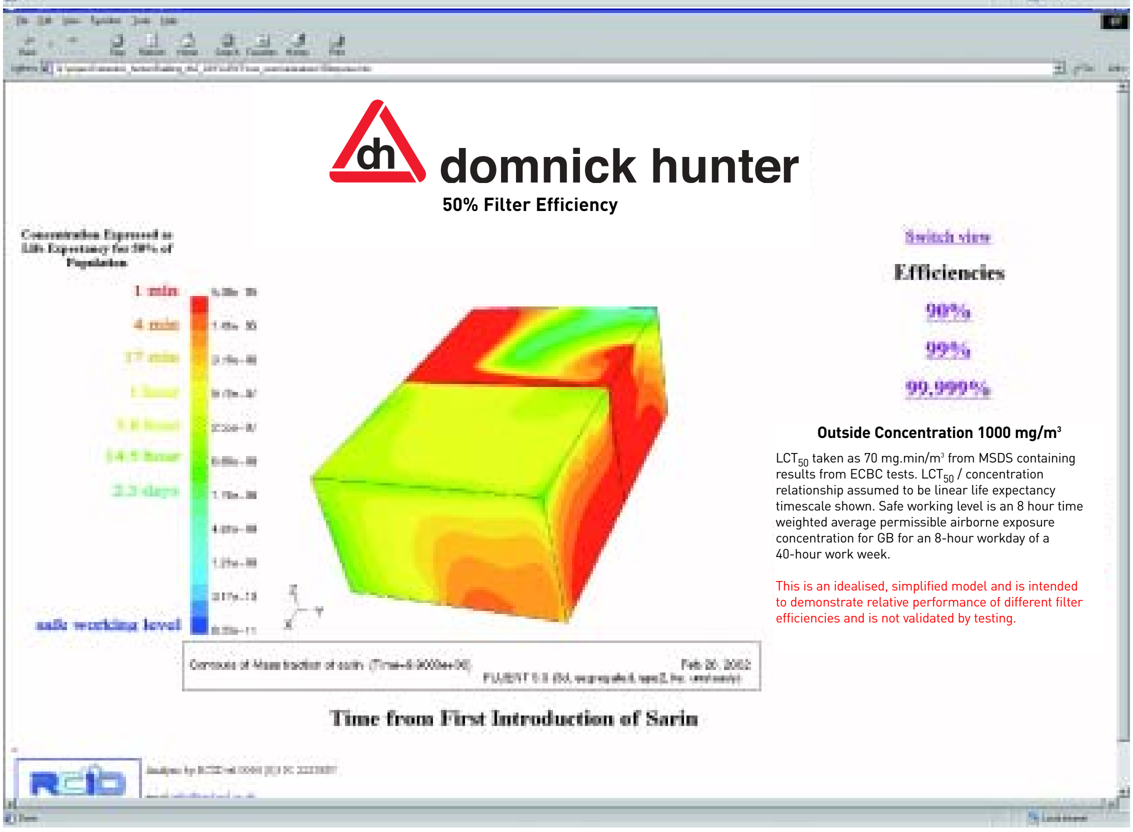
50% Filter Efficiency
Concentration Expressed as Life Expectancy for 50% of Population
1 min
4 min
17 min
1 hour
safe working level
Switch view
Efficiencies
90%
99%
99.999%
Outside Concentration 1000 mg/m^3
LCT$_{50}$ taken as 70 mg.min/m^3 from MSDS containing results from ECBC tests. LCT$_{50}$ / concentration relationship assumed to be linear life expectancy timescale shown. Safe working level is an 8 hour time weighted average permissible airborne exposure concentration for GB for an 8-hour workday of a 40-hour work week.
This is an idealised, simplified model and is intended to demonstrate relative performance of different filter efficiencies and is not validated by testing.
Time from First Introduction of Sarin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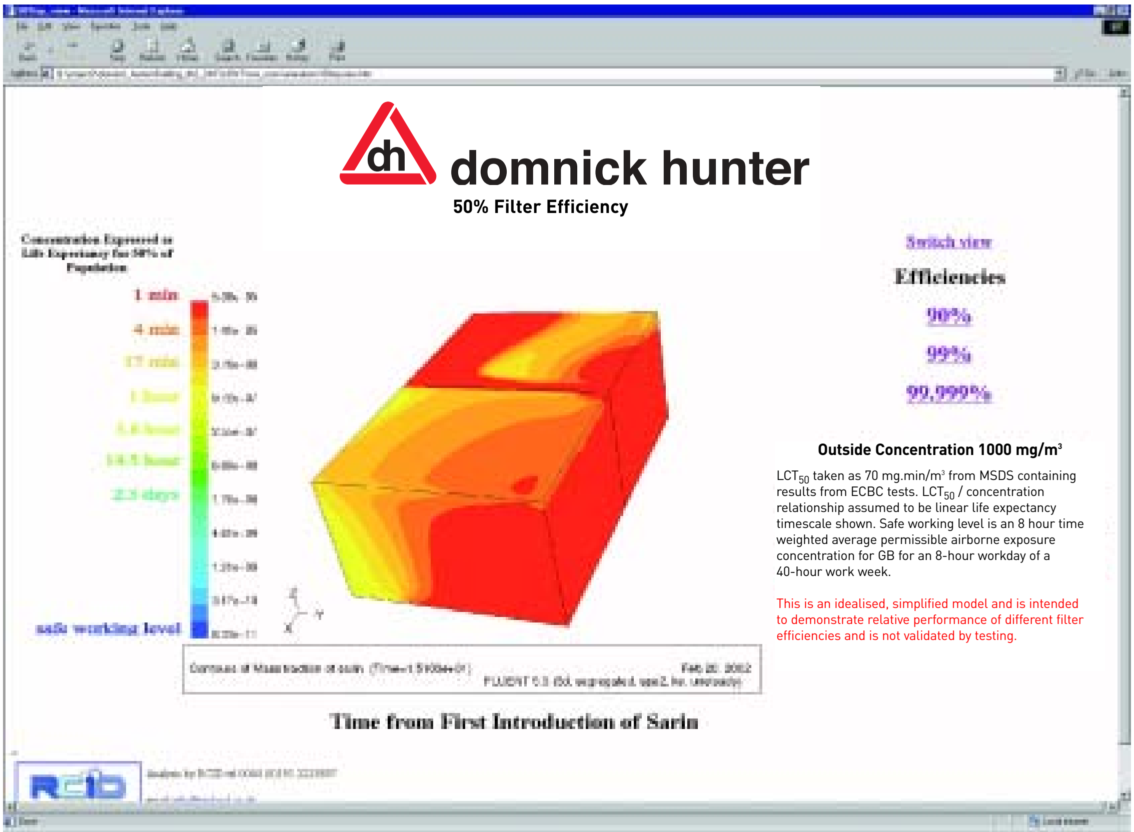
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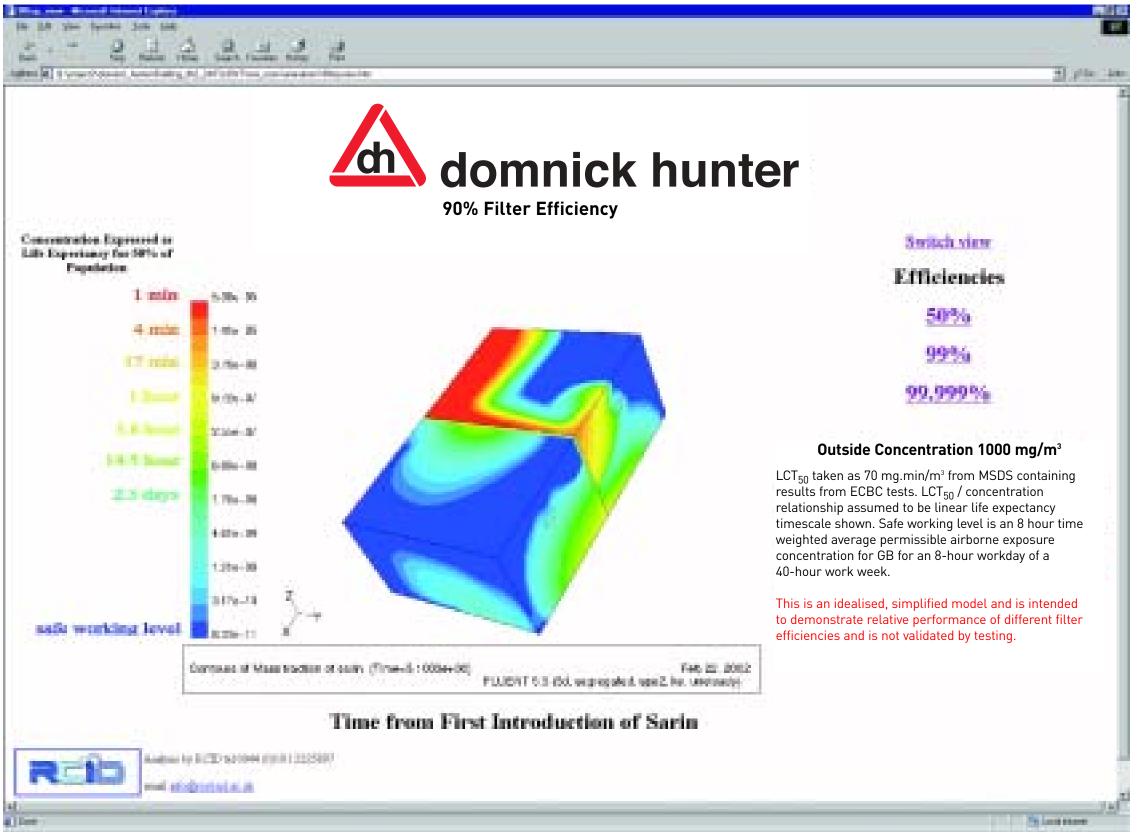
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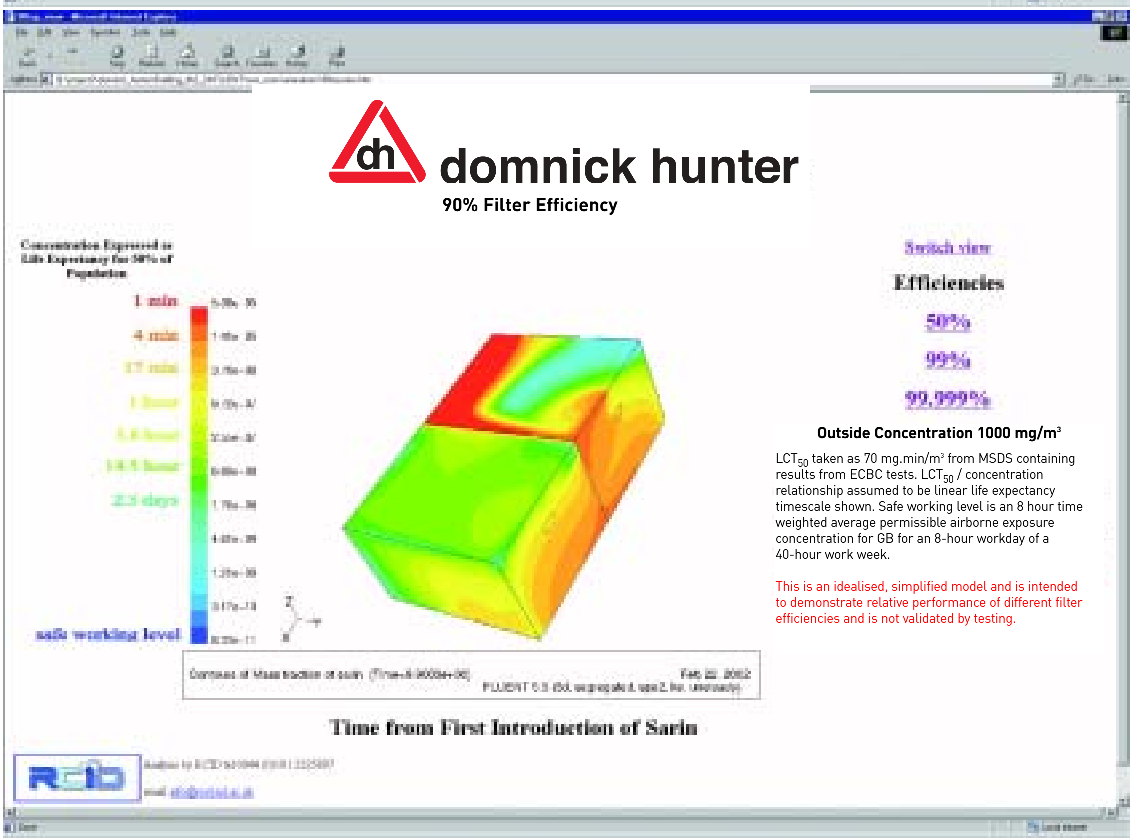
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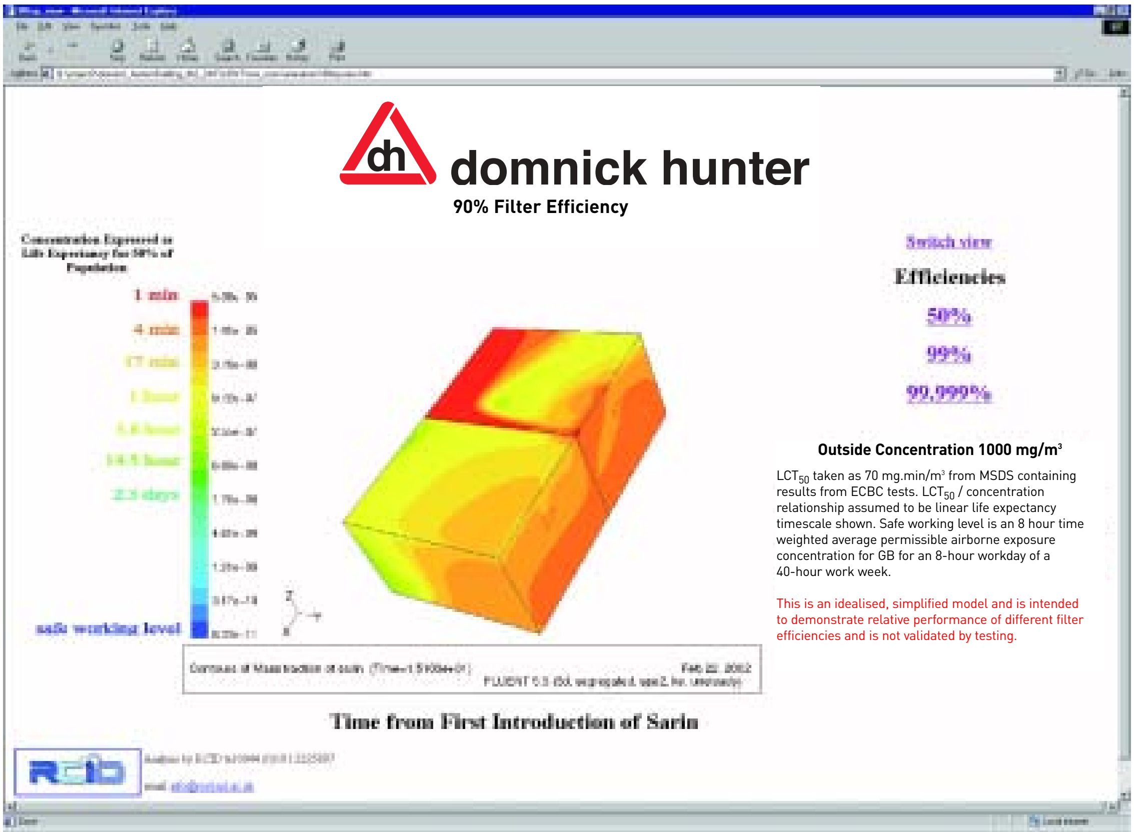
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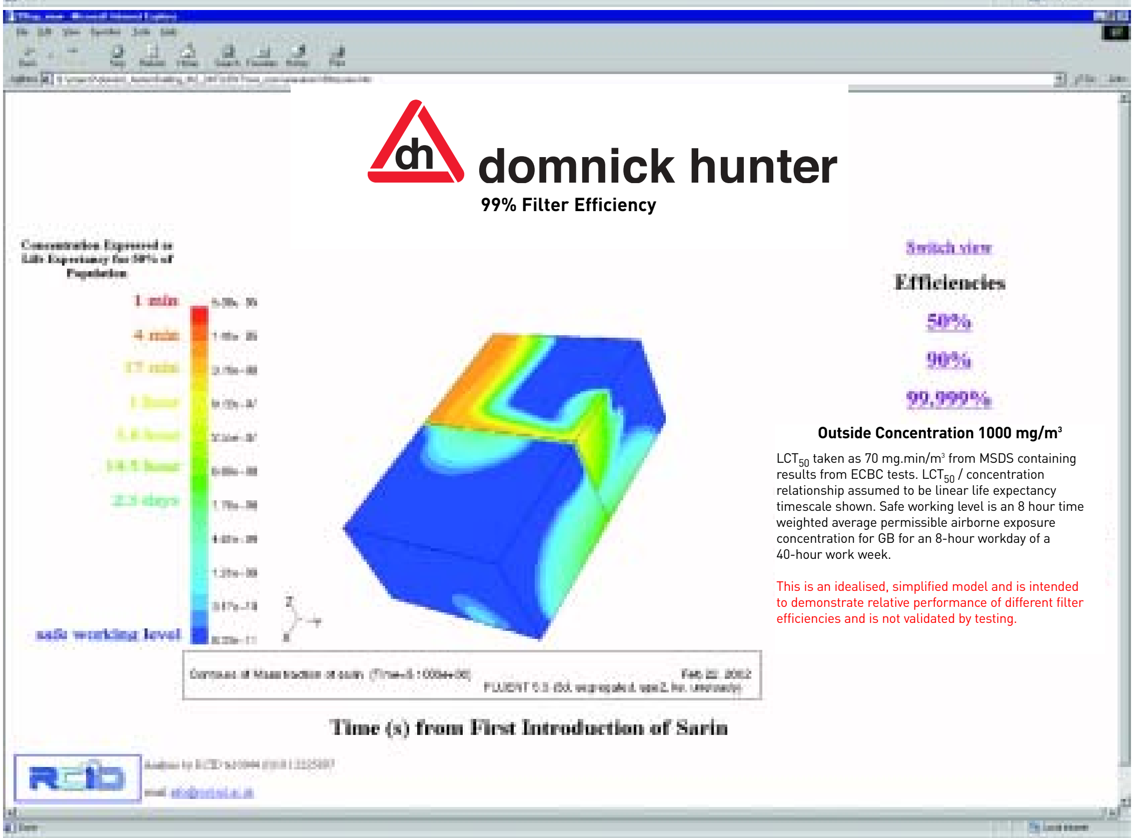
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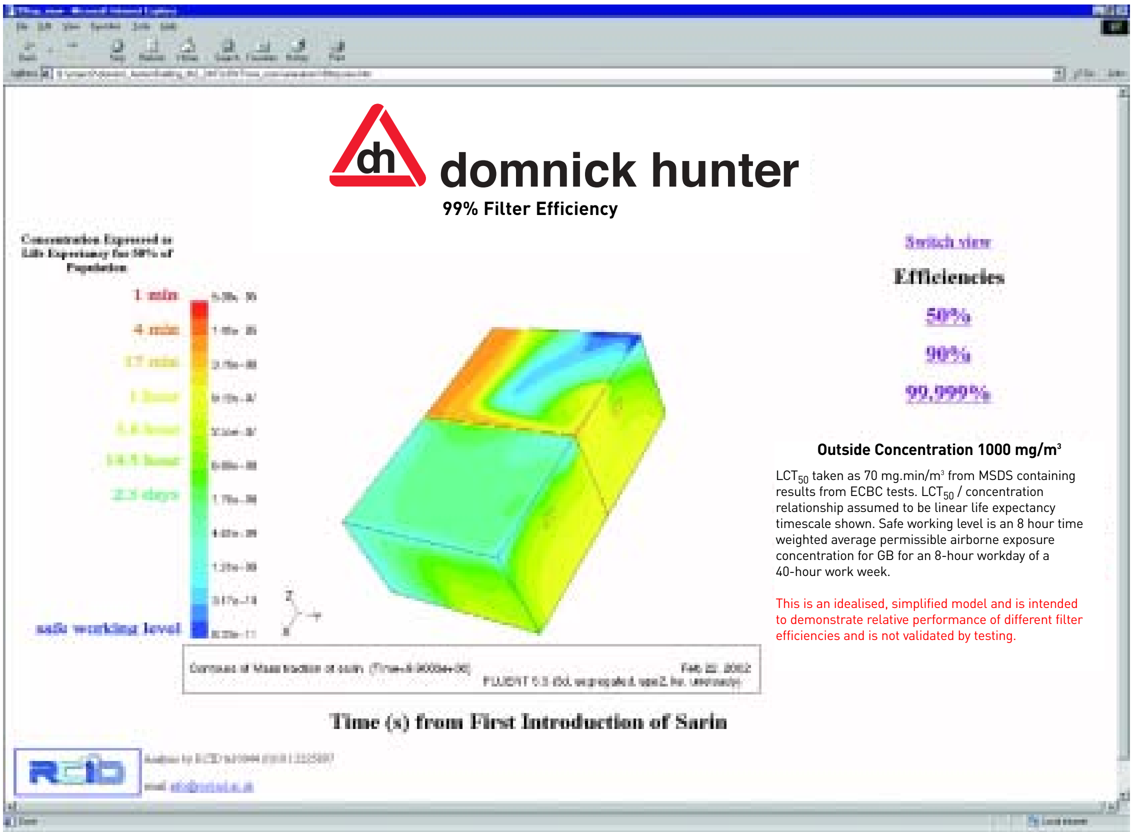
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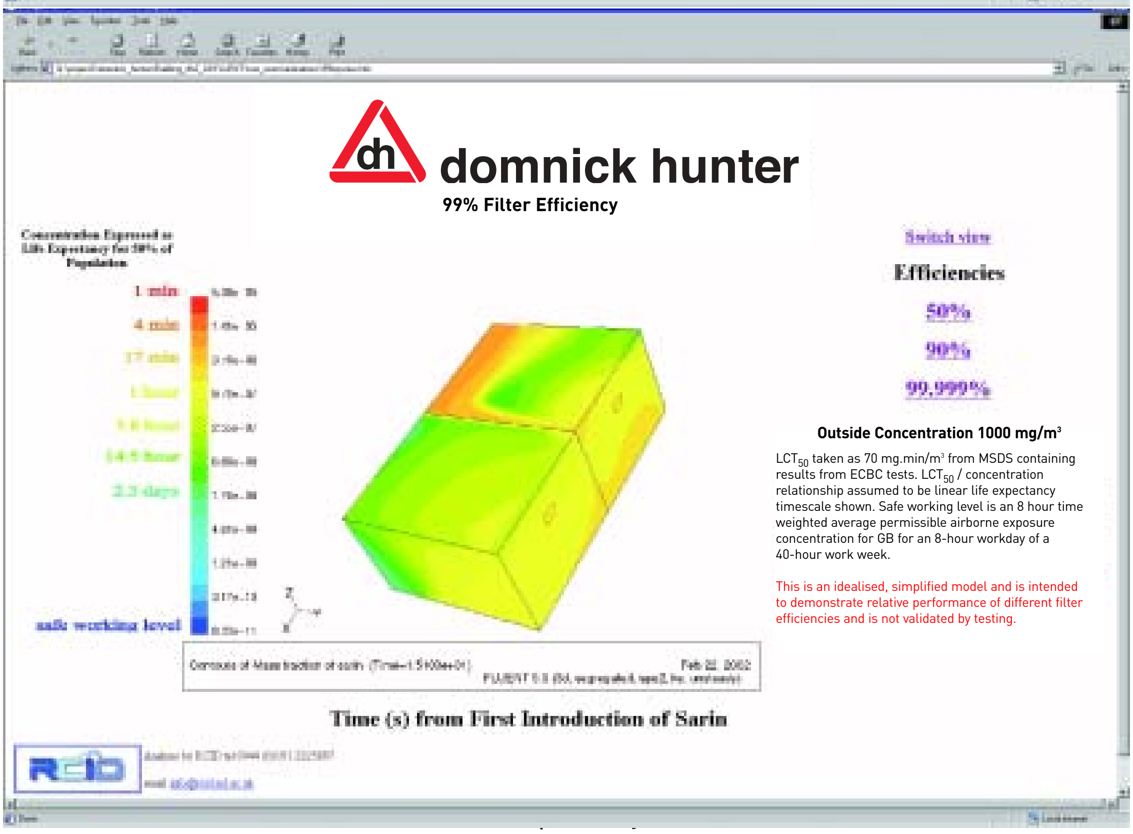
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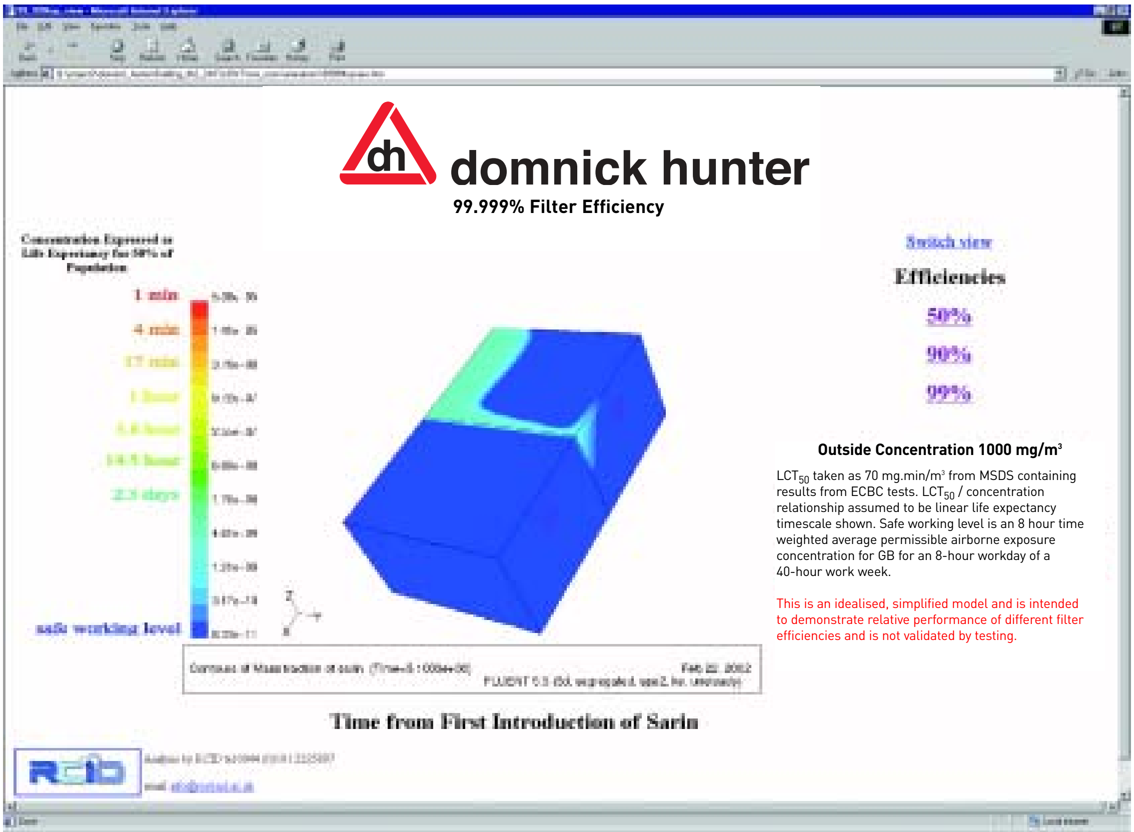
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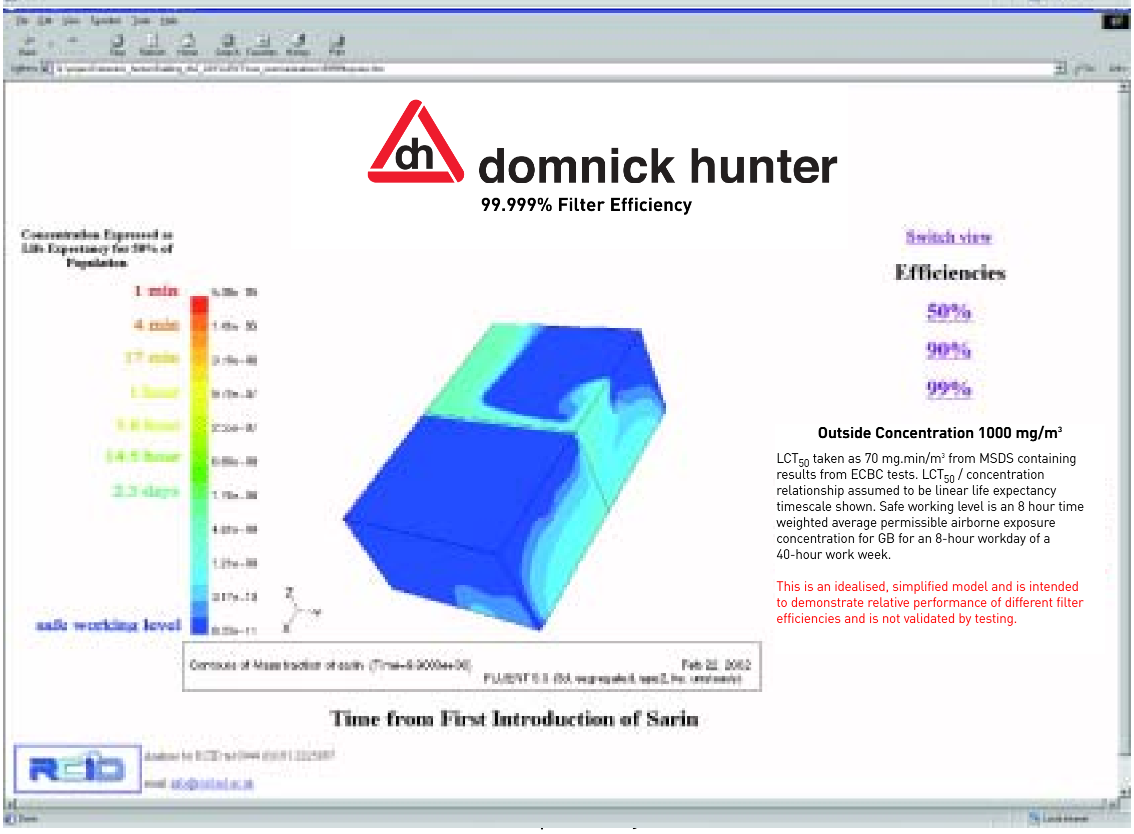
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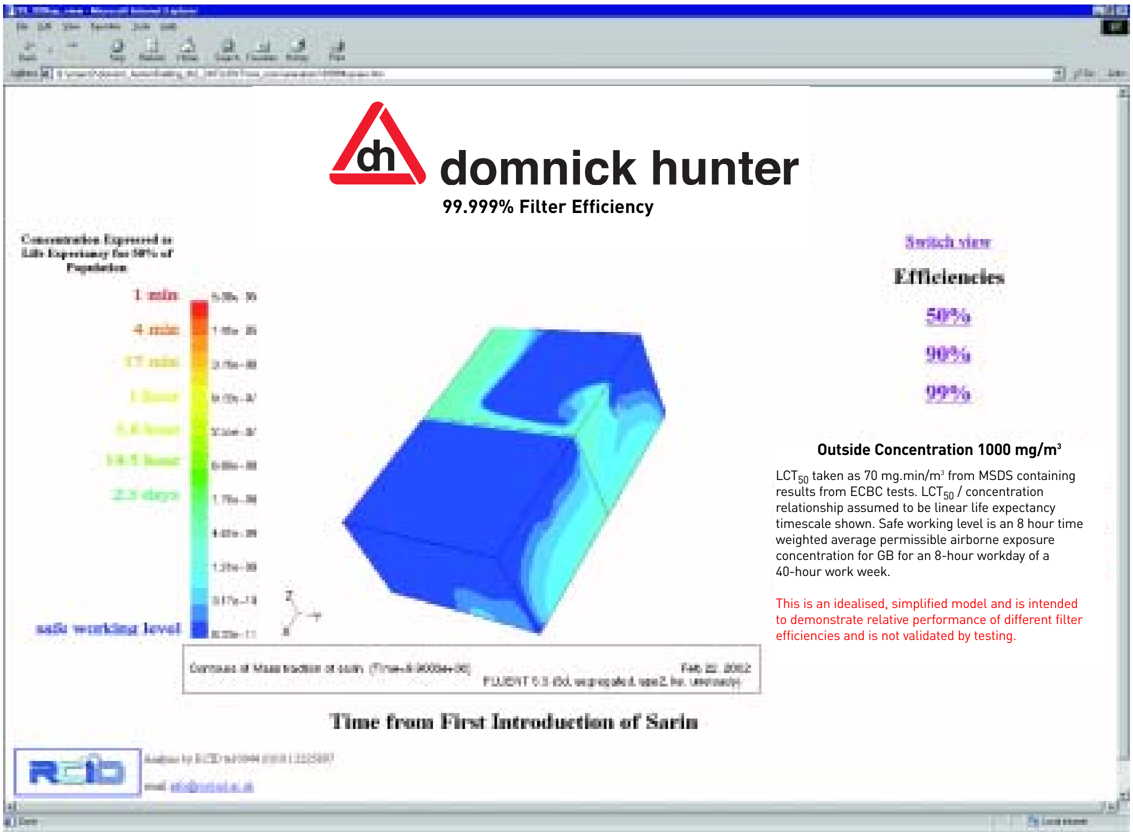

Results

- Using a filter of 50% efficiency, the time for the LCT 50 level to be achieved was only 32 seconds.
- Using a filter of 90% efficiency, the LCT50 level was reached after 15 minutes.
- Using a filter of 99% efficiency, the LCT50 level was reached after 1 hour.
- Using a Filter of > 99.9% efficiency, the LCT50 was not achieved.

Summary

Following on from a comprehensive and significant programme of research, domnick hunter has now developed what is believed to be the world's first fully regenerative filtration systems for protection against all known Chemical and Biological agents.

The systems have been shown to offer significantly improved capability for the complete removal of these CW agents over existing technologies, whilst eradicating the logistical supply problems of replacement filters. Studies on existing UK programmes have shown that the through life cycle cost of ownership of the regenerative filtration is about half of the cost of using activated carbon single pass filters.

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