Homeland Security Chemical Filter Technology

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Outline

- Homeland Security Chemical Vapor Filtration
- Military Filter Requirements and Design
- “Single Attack” Homeland Security Filter Design Approach
  - Flat sheet testing
  - Establish a reasonable threat scenario
  - Pleated filters
- Homeland Security Filter Application

Homeland Security Chemical Vapor Filtration

Goal : Protect personnel in buildings and safe rooms from Chemical Warfare Agents (CWA's) and identified Toxic Industrial Chemicals (TIC's).

Issues : "Level" of protection desired, Threat chemicals, Filter cost, Filter size, Filter configuration (fit), Make-up air requirements for overpressure (flow rate)

Homeland Security Filter Design Objectives

- Design and fabricate a filter that provides protection for personnel in a building against a reasonable chemical threat level.
- Minimize Cost
  - capital cost
  - integration cost (into new and existing HVAC systems)
  - operating cost (low pressure drop)

Military Chemical Threat Classification

- Threat chemicals can be generally divided into two categories
  - High boiling vapors removed almost exclusively by physical adsorption, e.g., Sarin (GB) and Mustard (HD)
  - Low boiling vapors requiring chemical reaction to prevent elution, e.g., cyanogen chloride (CK) and hydrogen cyanide (AC)

Military Filters
Ct requirements

- Protection defined as Ct where Ct is Concentration x Time (mg * min / m^3)
- For military applications, the required protection levels are set based on multiple attacks
  - High boiling vapors – 300,000 Ct
  - Low boiling vapors - 120,000 Ct
- “Deep beds” are tested using a 5,000 mg/m^3 challenge of DMMP to reduce test time

Military Filters
Required Protection Ratios

- Protection Ratio (PR) Definition
  - Challenge Concentration / Maximum Allowed Effluent Concentration (breakthrough conc.)
- PR for GB = 4,000/0.04 = 100,000
- PR for CK = 4,000/5 = 800
- A large PR, e.g., 100,000, requires special manufacturing procedures and large safety margins

Military Filters
Filtration Material

- All fielded filters contain only an impregnated activated carbon, ASZM-TEDA
  - Base carbon filters high boiling agents
  - Impregnates required to prevent the low boiling threat vapors from eluting through the filter
  - Removal mechanisms for low boiling chemicals can be complicated, e.g., CK and AC

Military Filters
ASZM-TEDA Impregnates

A = Copper, removes acid gases including acid gas chemical reaction products (e.g., HCl from phosgene)

S = Silver, removes Arsine at high RH's

Z = Zinc, same as copper, but special AC behavior

M = Molybdenum, used to remove cyanogen produced from AC reaction with copper

TEDA = Triethylenediamine, improves CK performance

ASZM-TEDA

ASZM-TEDA - Effective in removing the following toxic vapors:

Blister/Vesicants
Distilled Mustard (HD)
Lewisite (L)
Mustard Gas (H)
Nitrogen Mustard (HN-2)
Phosgene Oxime (CX)
Ethyldichloroarsine (ED)
Lewisite 1 (L-1)
Lewisite 1 (L-2)
Lewisite 1 (L-3)
Methyldichloroarsine (MD)
Mustard/Lewisite (HL)
Mustard/T
Nitrogen Mustard (HN-1)
Nitrogen Mustard (HN-3)
Phenodichloroarsine (PD)
Sesqui Mustard

Blood
Arsine (SA)
Cyanogen Chloride (CK)
Methyl Isocyonate
Hydrogen Cyanide (AC)

Choking/Lung/Pulmonary Damaging
Chlorine (CL)
Diphosgene (DP)
Phosgene (CG)
Sulfur Trioxide-Chlorosulfonic Acid (FS)
Titanium Tetrachloride (FM)

Incapacitating
Agent 15
BZ
Canniboids
Fentanyls
LSD
Phenothiazines

Vomiting
Adamsite (DM)
Diphenylchloroarsine (DA)
Diphenylcyanoarsine (DC)

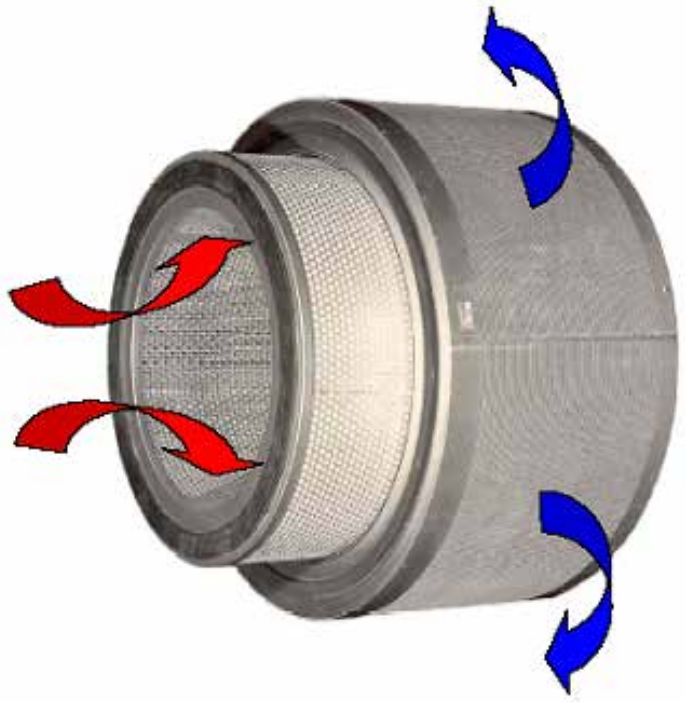
Nerve
Cyclohexyl Sarin (GF)
GE
Sarin (GB)
Soman (GD)
Tabun (GA)
VE
VG
VM
VX

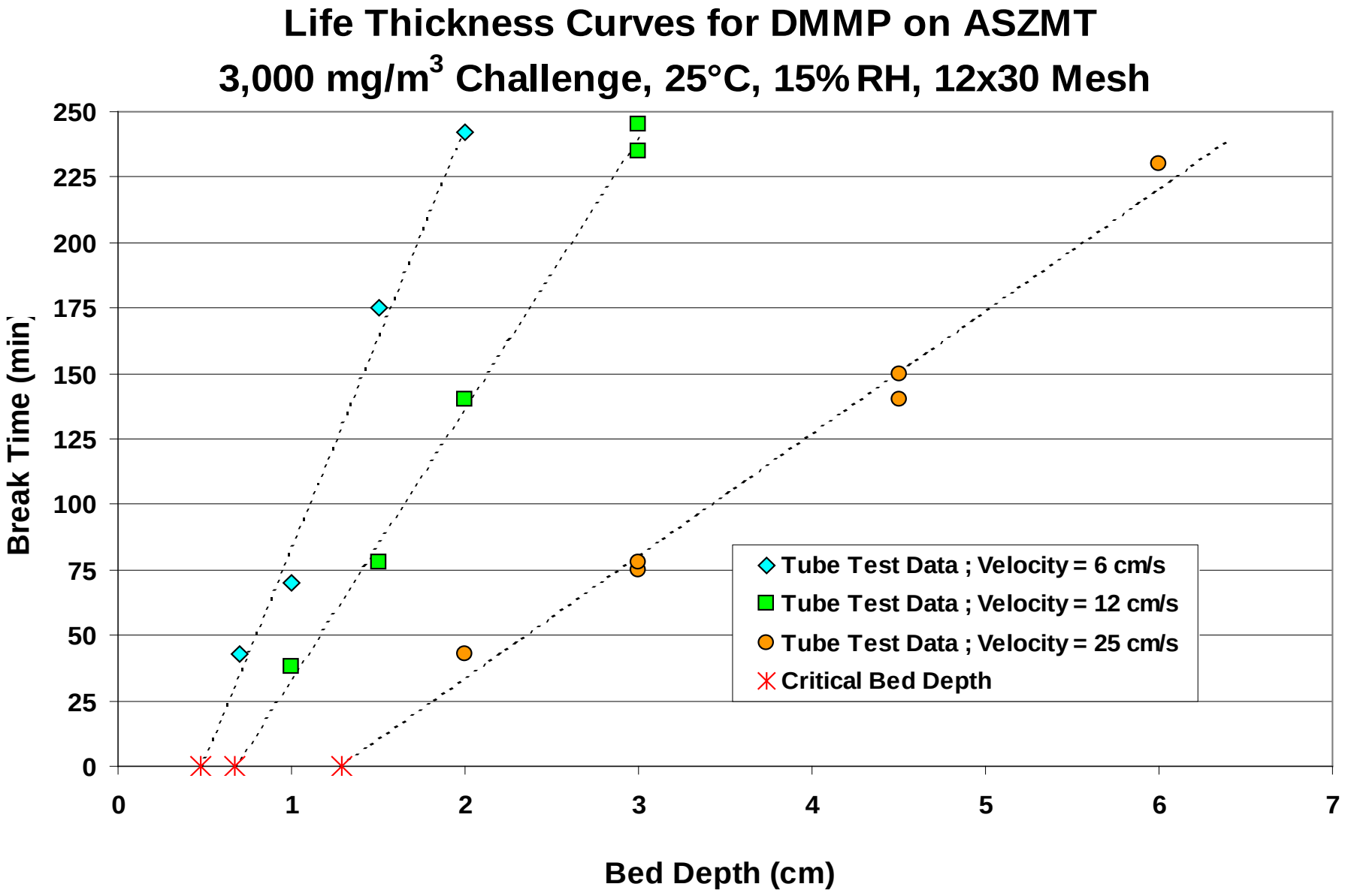
Riot Control/Tear
Bromobenzylcyanide (CA)
Chloroacetophenone (CN)
Chloropicrin (PS)
CNB - (CN in Benzene and Carbon Tetrachloride)
CNC - (CN in Chloroform)
CNS - (CN and Chloropicrin in Chloroform)
CR
CS

Shading denotes chemicals removed by only ASZM-TEDA – not Activated Carbon

MIL-SPEC Filters

- Carbon Element
  - 2-inch packed beds of 12x30 mesh ASZMT carbon
  - No binder – maximum adsorption capacity
  - High pressure drop (3.5 iwg)
- 200 cfm for an M98
- High cost per cfm
- Large Ct requirement drives design

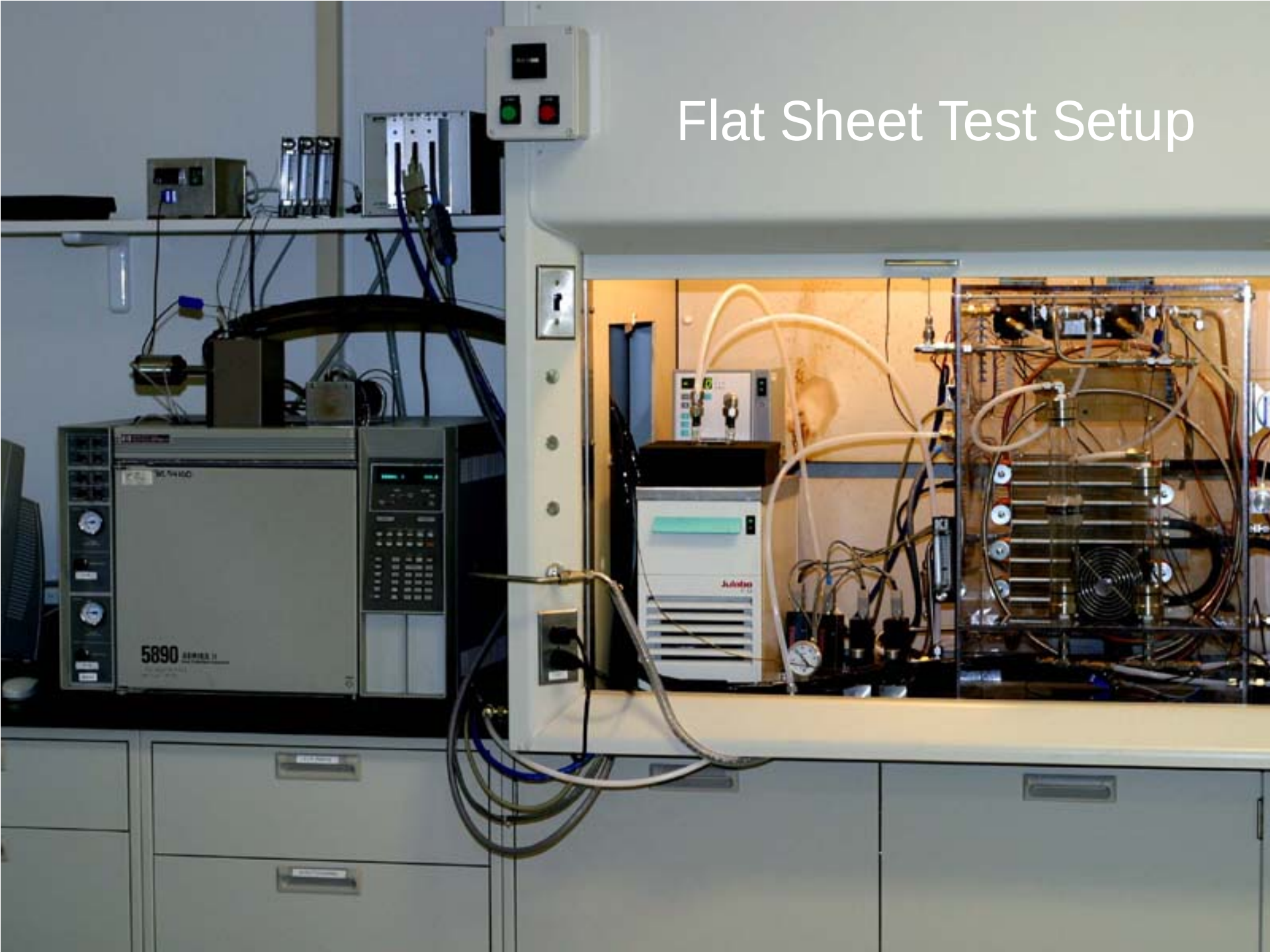



Life Thickness Curves for DMMP on ASZMT
3,000 mg/m3 Challenge, 25°C, 15% RH, 12x30 Mesh
Break Time (min)
250
225
200
175
150
125
100
75
50
25
0
0
1
2
3
4
5
6
7
Bed Depth (cm)
Tube Test Data ; Velocity = 6 cm/s
Tube Test Data ; Velocity = 12 cm/s
Tube Test Data ; Velocity = 25 cm/s
Critical Bed Depth

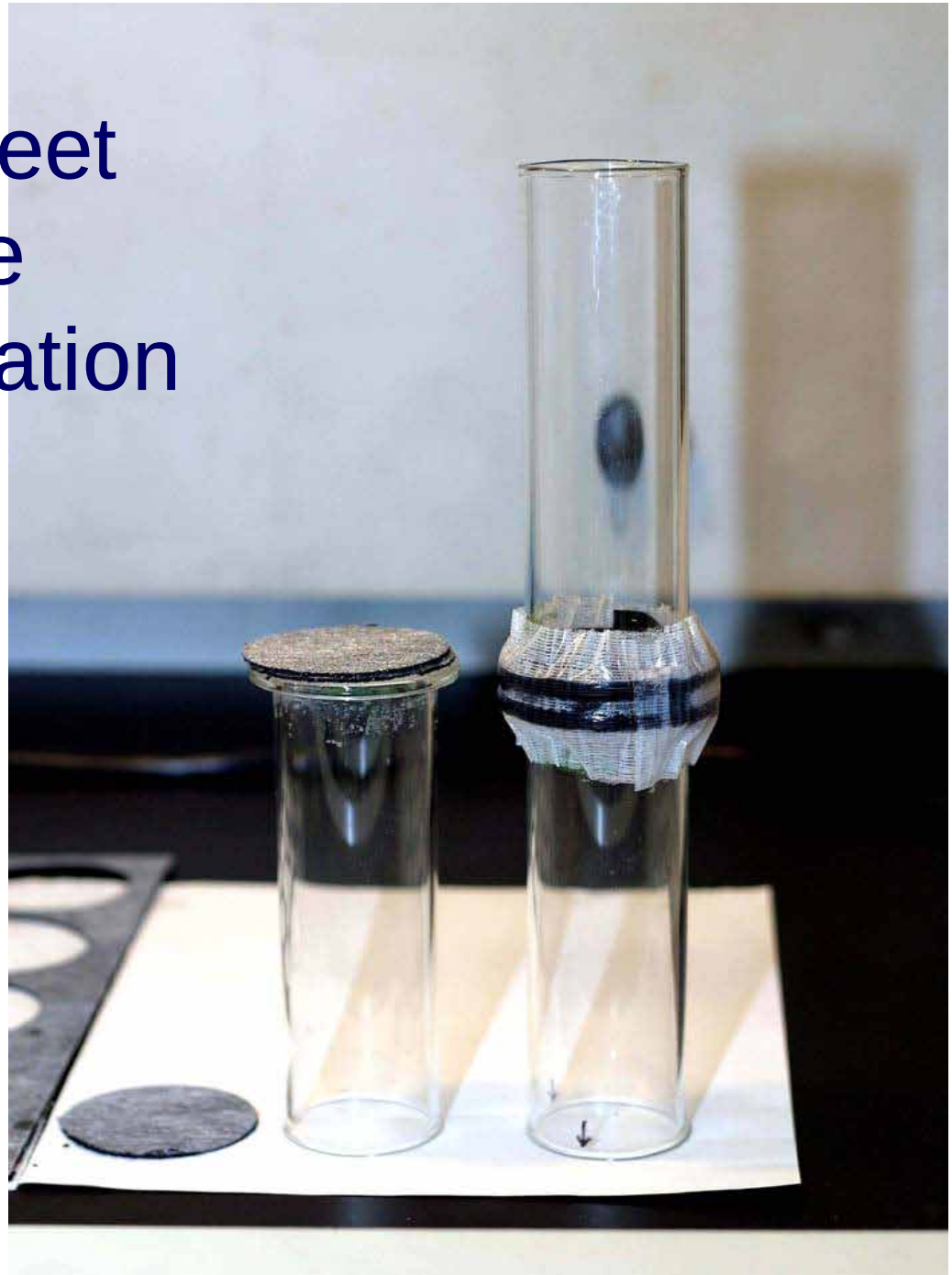
Homeland Security Filter Design

- Measure unpleated media filtration performance data on a laboratory scale at anticipated filter conditions (flat sheet testing).
  - Establishes best possible performance
  - Identifies the magnitude of manufacturing losses
- Determine the sensitivity of protection time to changes in velocity and the number of media layers
  - Sets manufacturing targets
  - Data used to establish reasonable safety margins

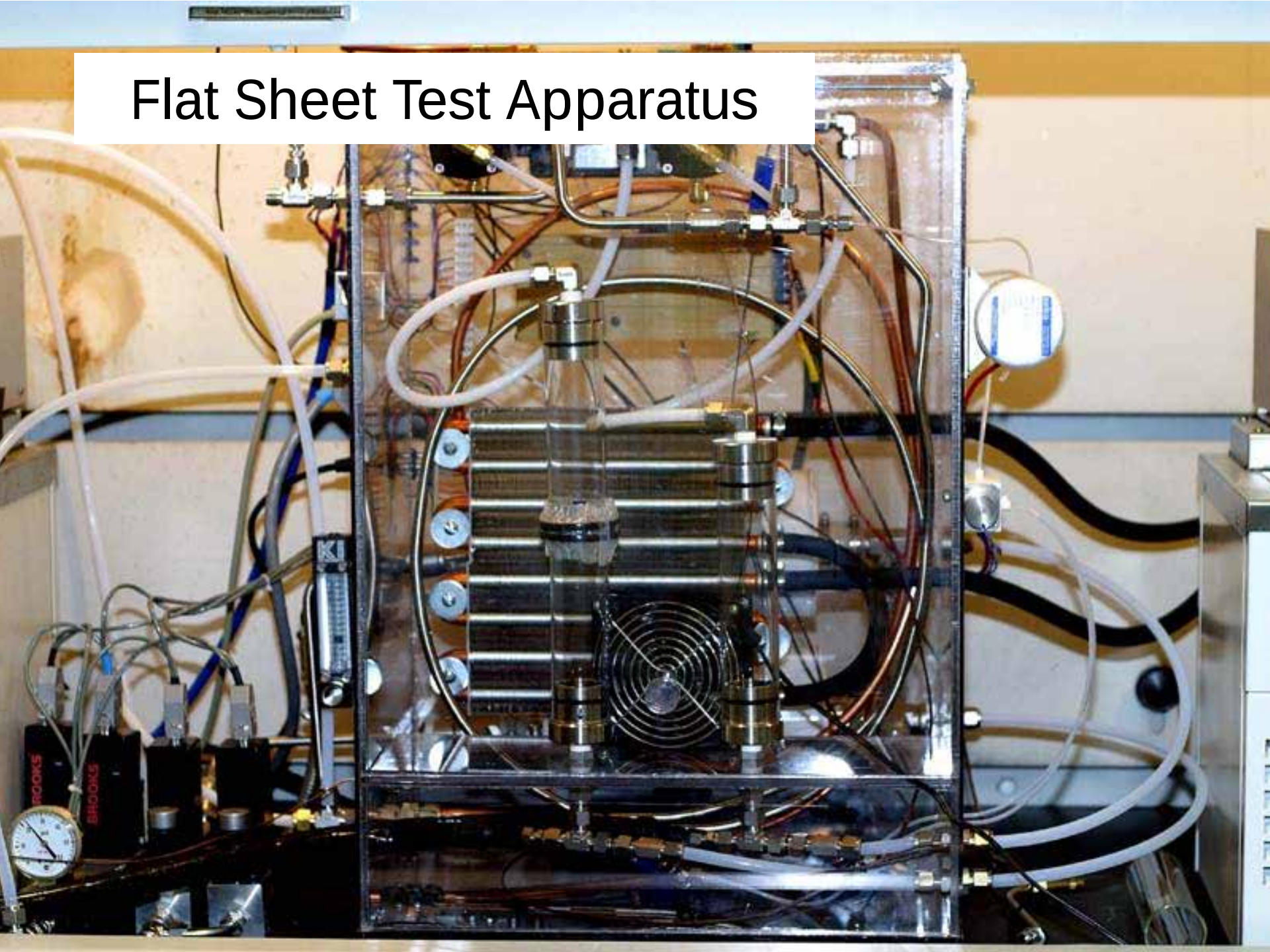
Flat Sheet Test Setup

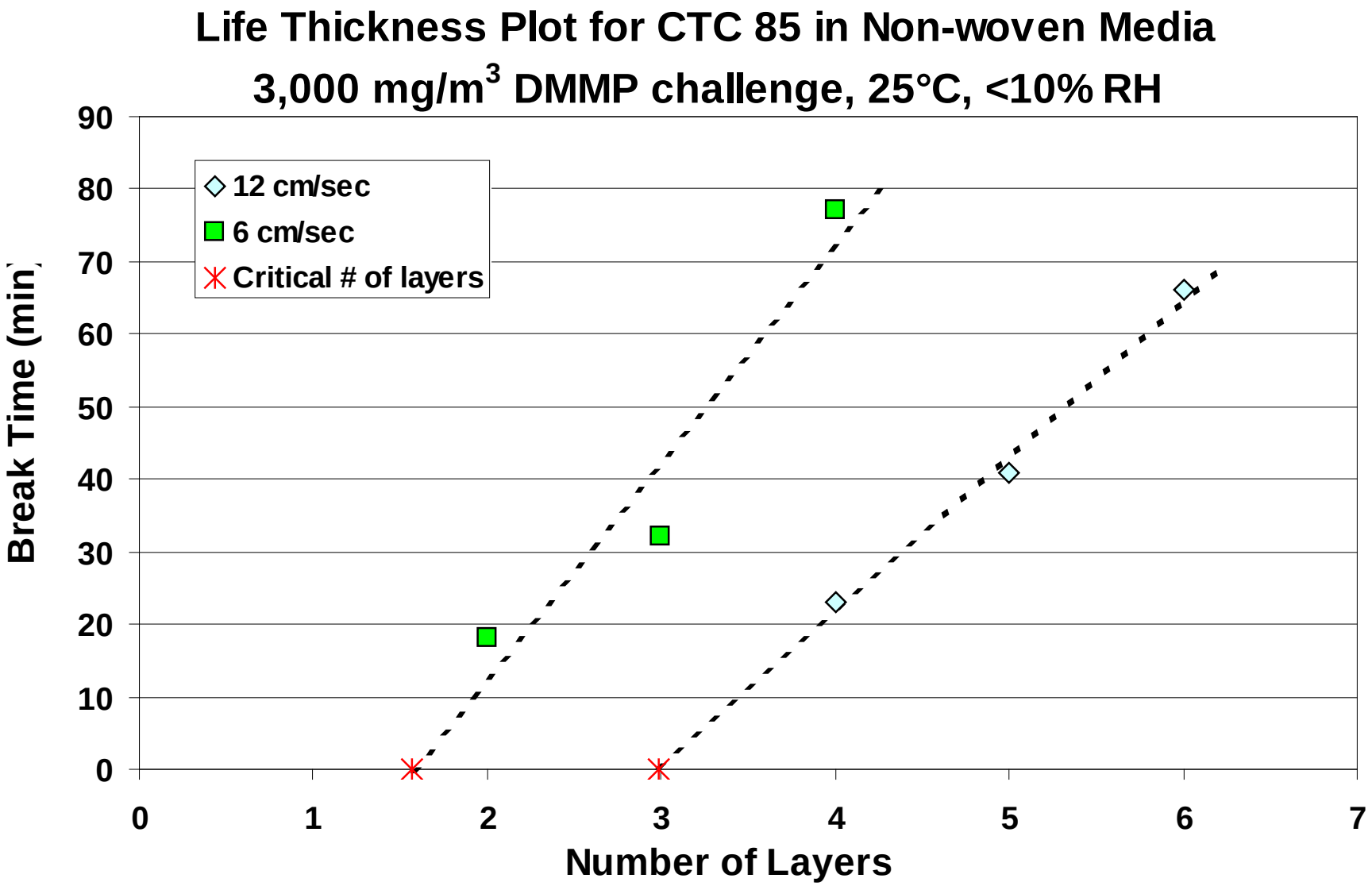


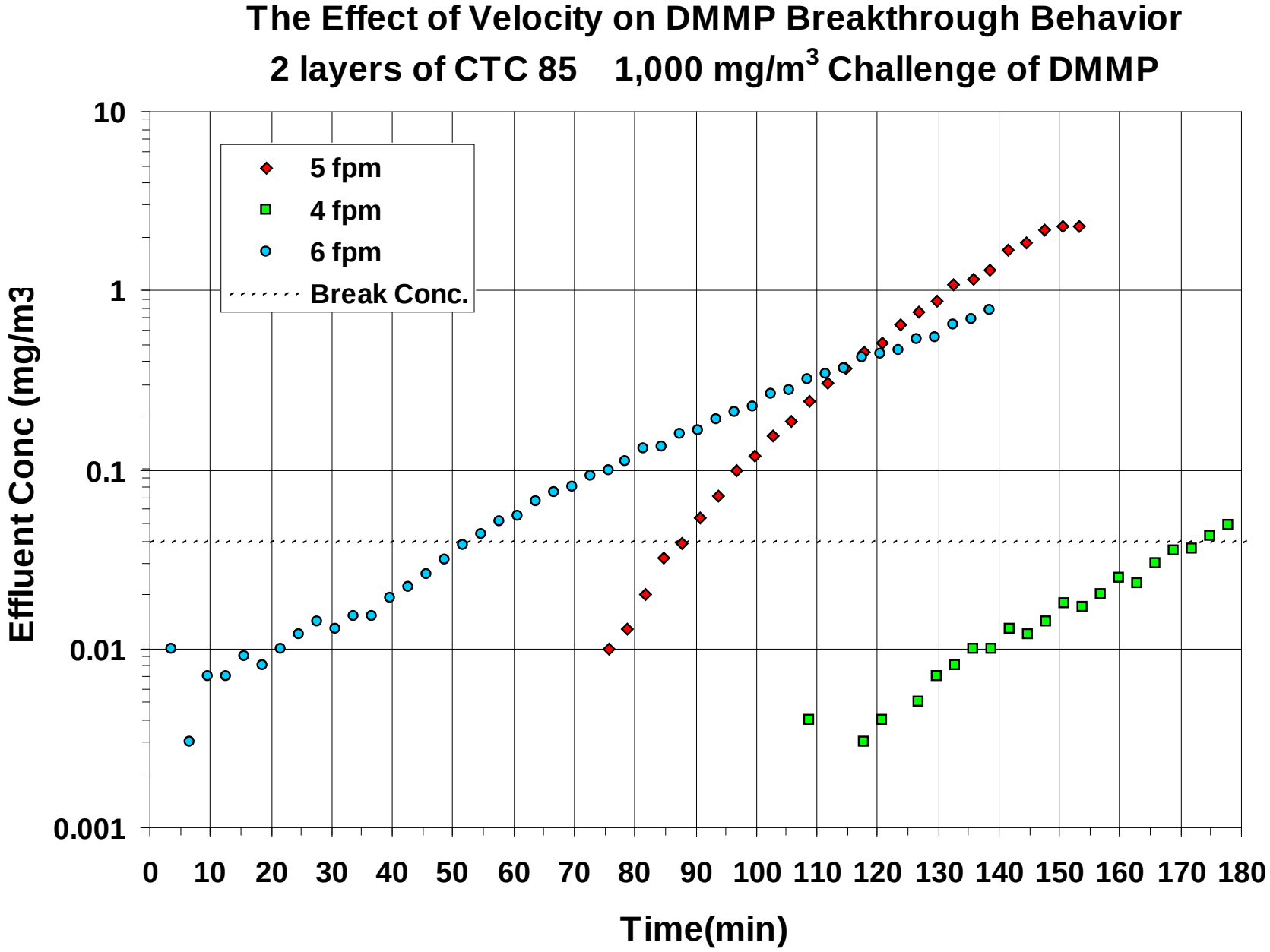
Flat Sheet Sample Preparation

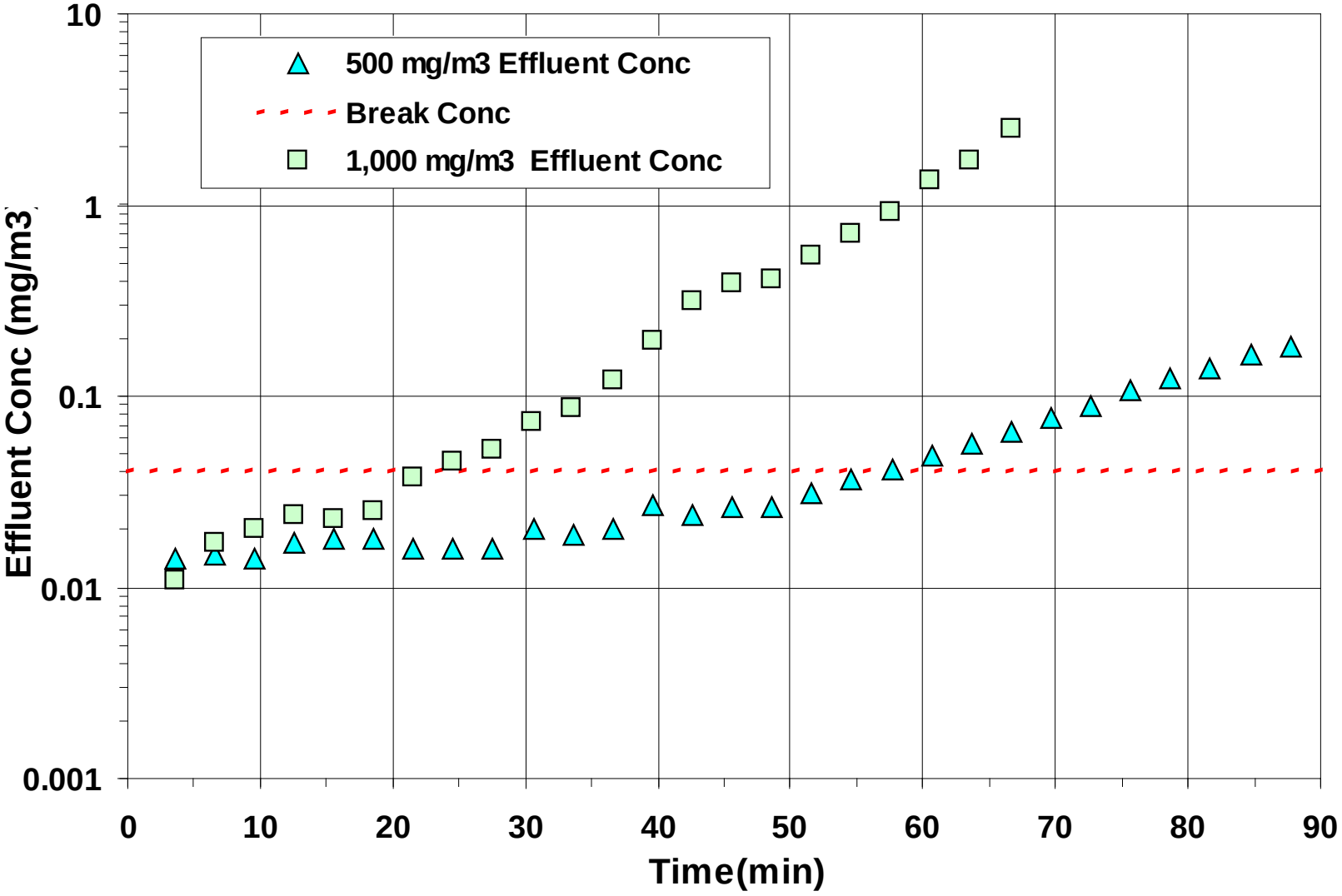


Flat Sheet Test Apparatus




Life Thickness Plot for CTC 85 in Non-woven Media
3,000 mg/m3 DMMP challenge, 25°C, <10% RH
Break Time (min)
Number of Layers
12 cm/sec
6 cm/sec
Critical # of layers
0
10
20
30
40
50
60
70
80
90
0
1
2
3
4
5
6
7


The Effect of Velocity on DMMP Breakthrough Behavior
2 layers of CTC 85 1,000 mg/m3 Challenge of DMMP
Effluent Conc (mg/m3
10
1
0.1
0.01
0.001
5 fpm
4 fpm
6 fpm
Break Conc.
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
Time(min)


Effect of Challenge Concentration
4 layers of CTC 85, 600 g/m2, 31 fpm (15.8 cm/sec)
500 mg/m3 Effluent Conc
Break Conc
1,000 mg/m3 Effluent Conc
Effluent Conc (mg/m3
10
1
0.1
0.01
0.001
0
10
20
30
40
50
60
70
80
90
Time(min)

Flat Sheet Testing Conclusions

- The protection performance of “shallow bed” filters is very sensitive to challenge velocity and challenge concentration
- The most important design parameters for filtration performance in shallow beds are flow velocity and bed depth (number of layers).

Establish a Threat Level Current Lack of Standards

- There are no current building protection standards
- Current military standards are probably not reasonable for buildings, e.g., ACoE has developed some military type standards not suitable for typical civil applications.
- ASHRAE is also exploring protection standards definitions

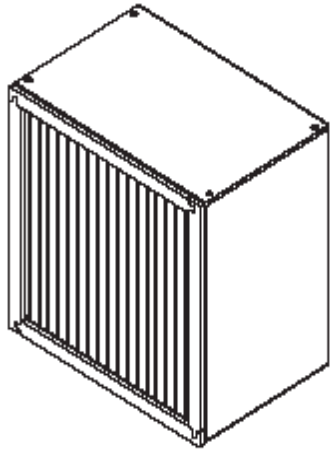
Establish a Threat Level

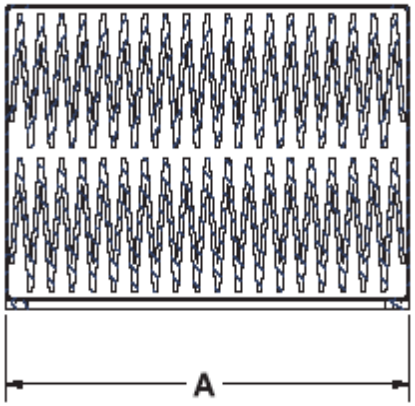
- Focus initially on the high boiling threats (by far the most toxic and most persistent)
- Hunter HLS Filter Requirements
  - Use a reasonable (but still very high) challenge concentration of 500 mg/m^3 (ACoE: 250 mg/m^3)
  - Establish a minimum target Ct of 10,000 mg*min/m^3– corresponds to a 20-minute filter life at 500 mg/m^3

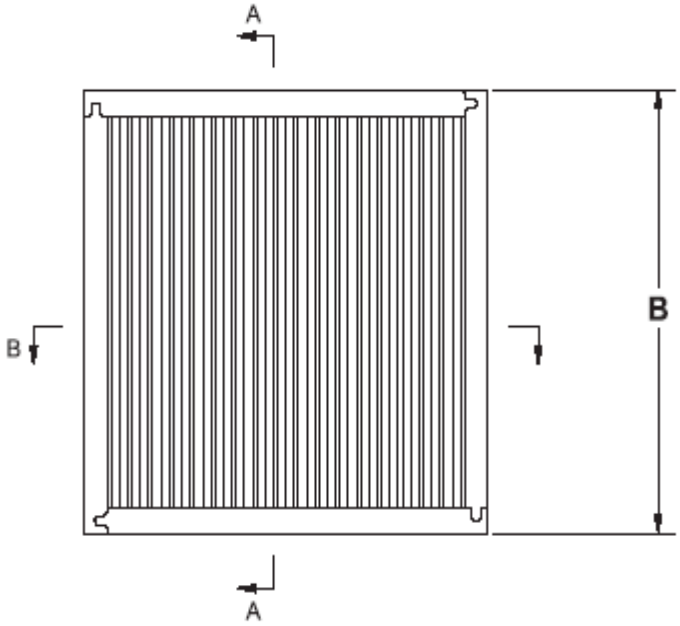
Pleated “Single Attack” Filter

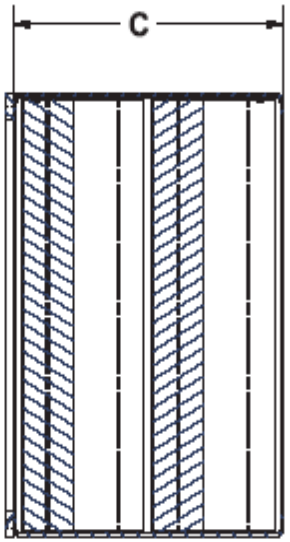
- Designed to offer adequate protection against a intentional or accidental chemical release while minimizing installations costs and HVAC system disruptions.
  - Significantly lower pressure drop than MIL-SPEC filters (1-1.25 iwg)
  - Standard panel filter size (24”x24”x12”, 24”x24”x16” & 24”x24”x24”)
  - Long filter life (avg. 1 year)
  - Large flows (2,000 cfm)

Chemical Adsorber









Single Attack Chemical Filter

Integration in AHUs

- HEPA media used upstream of Carbon Adsorbers to remove aerosols and particulates
- Three Standard Sizes:
  - 24”x24”x12”
  - 24”x24”x16”
  - 24”x24”x24”

Anniston, AL – Custom Air Handling Unit with Single Attack Chemical Adsorbers

Conclusions

- Building protection filters have a unique set of design relationships
- Velocity is the key design parameter for “shallow bed” filters
- Pleated filtration media provides large flow areas to reduce velocity.
- The number of layers required depends on the required Ct AND challenge concentration
- Single Attack Chemical Filters: High protection factor, low pressure drop and low integration costs

Questions

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