AMETEK®
AIRCONTROL TECHNOLOGIES

Moving on from TEDA Carbons

The Effects of Enclosure Sealing and CO_2 Level Control in minimising the power of Regenerable COLPRO CBRN Systems

E.J. Bennett

June 2005

The debate regarding Regenerative Chemical Filtration for CBRN systems has moved on from ‘IF’ (it is needed) to ‘HOW’ (it can be practically applied).

System Power

A perceived disadvantage of Regenerable Systems is their relatively high power demand when compared with current carbon technology.

This Presentation describes how, by skilled systems and vehicle designs, and a review of how such systems are specified, can reduce the power required for an installation by up to 80%.

AMETEK®
AIRCONTROL TECHNOLOGIES

The power requirement of a filtration system can be reduced in two ways:

- The development of efficient systems to minimise the power required to filter a given volume of air.

- Minimising the quantity of air required to provide:

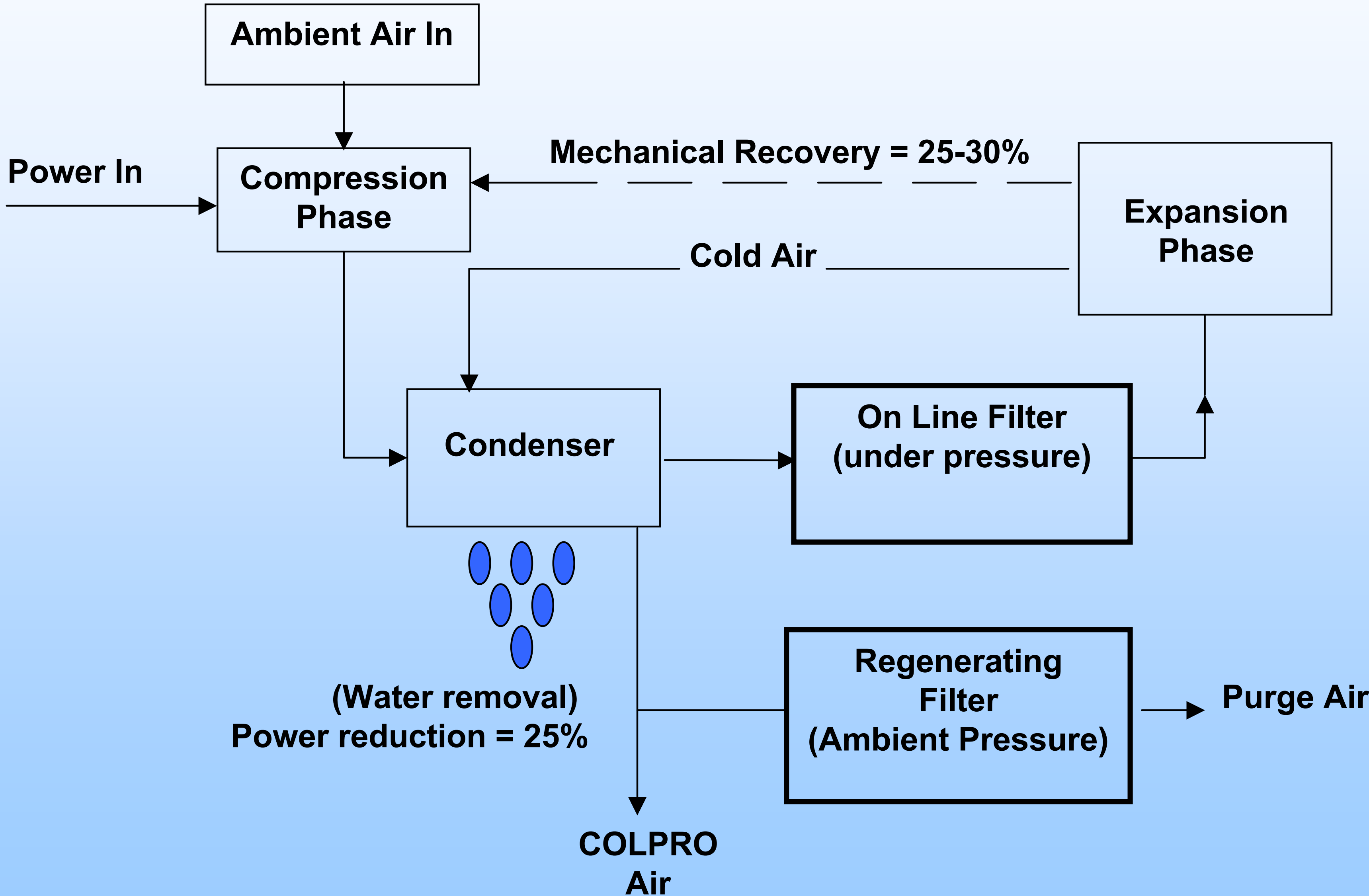
  - protection (overpressure)
    by good vehicle design

  - breathable air (ventilation)
    by reviewing specified requirements

AMETEK®
AIRCONTROL TECHNOLOGIES

EFFICIENT DESIGNS

Aircontrol Technologies Pressure Swing Adsorption (PSA) System with 50% Energy Recovery



AMETEK AIRCONTROL TECHNOLOGIES

Fresh air required to provide overpressure protection is the higher of the following:

- to purge agents: Dependent on hazard
- to dilute gun smoke: Dependent on the amount allowed to enter the crew compartment
- for overpressure: Dependent on vehicle sealing level
- for ventilation: Dependent on specification used

AMETEK®
AIRCONTROL TECHNOLOGIES

Airflow required to purge agents from the Crew Compartment

- If vapour enters the crew compartment during entry or exit, overpressure COLPRO systems will purge it from the vehicle – the time taken being flow-dependent.
- The crew will be wearing Individual Protective Equipment – (IPE)
- The time to resume COLPRO conditions is usually specified as ‘reasonable’.
- The time taken has been considered as non-critical in this study.

AMETEK AIRCONTROL TECHNOLOGIES

Airflow required to dilute self-generated noxious fumes (gun smoke)

- **Failure to address weapon integration in the past, to limit gases entering the crew compartment, has resulted in filter air requirements for dilution being up to 5 x that required to protect the crew from enemy chemical attack.**
- **This study assumes that in future, it will be a requirement that weapons integration ensures that gun smoke entering the crew compartment must be diluted to safe limits by the airflow from the CBRN system, defined by the vehicle sealing level or ventilation rate, whichever is the greater.**

AMETEK®
AIRCONTROL TECHNOLOGIES

Vehicle Sealing – The Airflow required for Overpressure COLPRO

- The level to which any enclosure is sealed is critical as it defines the minimum airflow (power) for protection.
- This should be recognised at initial vehicle design and good practice adopted.
- For most vehicles, a Production Acceptance Test showing design overpressure can be achieved with 15 l/s (32 cfm) is achievable.
- To allow for seal deterioration in service, the system airflow should allow for a 25% margin (seal life) between servicing or 20 l/s (42 cfm)

AMETEK
AIRCONTROL TECHNOLOGIES

Airflow for ventilation

- Various specifications exist which attempt to define the fresh air requirements for vehicle occupants on an “Airflow per Person” basis.
- The most common being MIL-STD-1472, requiring 20 cfm (9.4 l/s) per person.
- To specify on a “Rule of Thumb” basis without recognising the levels of activity of individuals is an inefficient approach to defining a habitable environment.
- To ensure acceptable conditions, the required environment itself should be specified, in terms of CO_2 levels for instance.

AMETEK®
AIRCONTROL TECHNOLOGIES

Effects of reduced ventilation rates

Oxygen %

Lower Working Limit:	**19**
Slight Increase of Breathing Rate:	**18**
Impaired Judgement / Co-ordination:	**14**
Unconsciousness / Death:	**10**

Carbon Dioxide (ppmv):

Normal Threshold Limit Value (TLV):	**5,000**
Increase of Breathing Rate:	**10,000**
15 min. Short Term Exposure Limit	**30,000**
Panting / Intoxication:	**50,000**

Assumptions:

1 person sealed in $1m^3$ volume box:

Initial Oxygen level = 21%

Initial CO_2 level = 300 ppmv

The lower working level for **O_2** will be reached in approx **50 mins**.

The Normal TLV for **CO_2** will be reached in **13mins**.

Conclusion: The control of CO_2 levels is definitive for habitability

AMETEK AIRCONTROL TECHNOLOGIES

Some maximum CO_2 levels specified in various sources

Expressed in Parts per Million by Volume (PPMV)

EH40/2002	NIOSH	MAK	Submarines	Space Shuttle	Space Station
5,000 (8 hour reference period)	5,000 (8 hour reference period)	5,000 (8 hour reference period)	5,000 average (30-90 day mission) short term up to 30,000	6,600 max average for flight duration	4,000 max average over period of occupation

AMETEK AIRCONTROL TECHNOLOGIES

Selected Crew Compartment Environment

- The levels accepted for submarines is considered to be most closely related to a CBRN life support system <u>= CO_2 TWA of 5,000 ppmv</u>

- The maximum period that a vehicle is closed down is likely to be less than 24 hours or 1 battlefield day, significantly less than for a submarine.

AMETEK®
AIRCONTROL TECHNOLOGIES

Crew Breathing Air Volumes (BAV)

- To establish the airflow required to maintain a given CO_2 level, the rate of CO_2 production by individuals must be known.
- Testing is to be carried out in the UK on vehicle crews undertaking their various tasks to establish a database.
- Available data for other subjects has been used in this study.

AMETEK®
AIRCONTROL TECHNOLOGIES

CO_2 Produced by the crew of various vehicles over typical battlefield days of 24 hours

Crew	Activity Levels
1	Crew Resting
2	Crew Working Vehicle Stationery
3	Crew Working Vehicle Moving
4	Engaging Enemy

Vehicle Type	Threat Each Activity (hrs)			
	1	2	3	4
MBT	8	12	3.5	0.5
AVT	12	3.5	7.5	1.0
APC	16	1	7	-

Crew CO_2 Production l/m
Sitting (under stress) = 0.32*
Light Work = 1.50^x
Moderate Work = 2.30^x
Heavy Work = 2.80^x

* = Test Data

^{X} = Biomedical Engineering Handbook, Chapter 26. Exercise Physiology
Table 26.2 – Summary of Exercise Responses for normal young male
Arthur T. Johnson and Cathryn R Dooly – University of Maryland.

AMETEK®
AIRCONTROL TECHNOLOGIES

CO_2 Produced by the crew of various vehicles over typical battlefield day (24 hours)

Vehicle Type MBT (4 Crew)

Activity	Time (mins)	Commander	Driver	Gunner	Loader	l/m x time	24h Average
1	480	0.32	0.32	0.32	0.32	614	3.42 l/m
2	720	1.50	0.32	1.50	0.32	2621	
3	210	1.50	2.30	1.50	1.50	1428	
4	30	1.50	2.30	2.30	2.80	267	
						4930 ltr	

Vehicle Type AFV (3 Crew + 6 Troops)

Activity	Time (mins)	Commander	Driver	Gunner	6 x Troops	L/m x time	24h Average
1	720	0.32	0.32	0.32	1.92	2074	4.80 l/m
2	210	1.50	0.32	1.50	1.92	1100	
3	450	1.50	2.30	1.50	1.92	3249	
4	60	1.50	2.30	2.30	1.92	481	
						6904 ltr	

Vehicle Type APC (2 Crew + 9 Troops)

Activity	Time (mins)	Commander	Driver	9 x Troops		L/m x time	24h Average
1	16	0.18	0.18	1.62		3379	4.47 l/m
2	1	1.50	0.18	1.62		282	
3	7	1.50	2.30	1.62		2772	
4	-	-					
						6433 ltr	

AMETEK®
AIRCONTROL TECHNOLOGIES

The fresh air requirements for considered vehicles TWA = 5,000 ppmv (0.5%) Ref. Period 24 hours

Fresh Air required (l/m) = $\frac{\text{Average Rate of } CO_2 \text{ Produced by Crew}}{\text{TWA limit (0.5\%) - } CO_2 \text{ in Fresh Air (0.03)}}$

MBT (Crew of 4) = $\frac{3.42}{0.47\%}$ l/m = **728 l/m = 12 l/s (26 cfm)**

AFV (3 + 6 Troops) = $\frac{4.8}{0.47\%}$ l/m = **1021 l/m = 17 l/s (36 cfm)**

APC (Crew of 11) = $\frac{4.47}{0.47\%}$ l/m = **951 l/m = 16 l/s (34 cfm)**

System airflow to provide specified ventilation requirements to cover all above vehicle types = 17 l/s.

AMETEK®
AIRCONTROL TECHNOLOGIES

Summary

The filtered fresh air required to maintain the specified crew compartment conditions of 5,000 ppmv TWA over a 24 hour reference period for the vehicles considered
= 17 l/s

The recommended pack airflow to provide the design overpressure with an allowance of 25% increase in leakage during vehicle operation
= 20 l/s

Pack Airflow must be 20 l/s
Defined by vehicle sealing level in this case

AMETEK®
AIRCONTROL TECHNOLOGIES

Comparison with MIL-STD-1422

Power is proportional airflow

Vehicle	MIL-STD-1422	M 48 Filters	Effective Sealing +CO_2 Control	Airflow Reduction
MBT (4 Crew)	80 cfm (37.7 l/s)	1	20 l/s	47%
AFV (3 Crew + 6 Troops)	180 cfm (85 l/s)	2	20 l/s	76.5%
APU (2 Crew + 9 Troops)	220 cfm (104 l/s)	2+	20 l/s	80%

AMETEK®
AIRCONTROL TECHNOLOGIES

Conclusion

By attention to vehicle sealing and specifying the ventilation rates based on acceptable CO_2 levels, the Pressure Swing Adsorption (PSA) Regenerable CBRN systems, as designed by Aircontrol Technologies, are affordable in terms of power and size, even in vehicles with high levels of occupancy.