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Benchmark Study

Canister Survey of Existing "First Responder" Type Products

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Canister Description

- “First Responder” / Multi-gas Canisters
- All use 40 mm “NATO” threads
- All use P-100 or equivalent particulate filter

CBRN APR Test Challenge

Guidelines for determining test challenge concentrations:

1. (REL) X (Full Face APF) X (Safety Factor)
2. Set APF= 50
3. Set Safety Factor, S.F. = 2.0
4. Minimum Test Challenge = 3 X (IDLH)
5. Breakthru = (REL) / 2

Calculated Test Challenge										
	REL	APF	S.F.	1. (REL) X (F.F. APF) X (SF)		IDLH	3(IDLH)		Test Conc. Initial	Brkthru Conc. Initial
Ammonia	25	50	2	**2500**		300	**900**		**2500**	**12.5**
Carbon Monoxide	35	50	2	**3500**		1200	**3600**		**3600**	**17.5**
Carbon Tetrachloride	2	50	2	**200**		200	**600**		**600**	**1**
Cyanogen Chloride	0.03	50	2	**3**		------	**----**		**3**	**0.02**
Cyclohexane	300	50	2	**30000**		1300	**3900**		**30000**	**150**
Formaldehyde	1.5	50	2	**150**		20	**60**		**150**	**0.016**
Hydrogen Cyanide	4.7	50	2	**470**		50	**150**		**470**	**2.35**
Hydrogen Sulfide	10	50	2	**1000**		100	**300**		**1000**	**5**
Nitrogen Dioxide	1	50	2	**100**		20	**60**		**100**	**0.5**
Phosgene	0.2	50	2	**20**		2	**6**		**20**	**0.1**
Phosphine	0.3	50	2	**30**		50	**150**		**150**	**0.15**
Sulfur Dioxide	2	50	2	**200**		100	**300**		**300**	**1**

CBRN APR Test Challenge

Guidelines for determining test challenge concentrations:

1. (REL) X (Full Face APF) X (Safety Factor)
2. Set APF= 50
3. Set Safety Factor, S.F. = 2.0
4. Minimum Test Challenge = 3 X (IDLH)
5. Breakthru = (REL) / 2

Calculated Test Challenge				
	Test Conc. Initial	Test Conc. Draft	Brkthru Conc. Initial	Bkthru Conc Draft
Ammonia	2500	2500	12.5	12.5
Carbon Monoxide	3600	3600	17.5	17.5
Carbon Tetrachloride	600	3000	1	5
Cyanogen Chloride	3	300	0.02	2
Cyclohexane	30000	3900	150	10
Formaldehyde	150	1000	0.016	1
Hydrogen Cyanide	470	940	2.35	4.7
Hydrogen Sulfide	1000	1000	5	5
Nitrogen Dioxide	100	200	0.5	1
Phosgene	20	250	0.1	1.25
Phosphine	150	1500	0.15	5
Sulfur Dioxide	300	1500	1	5

CBRN APR Test Challenge

Guidelines for determining test challenge concentrations:

1. (REL) X (Full Face APF) X (Safety Factor)
2. Set APF= 50
3. Set Safety Factor, S.F. = 2.0
4. Minimum Test Challenge = 3 X (IDLH)
5. Breakthru = (REL) / 2

Calculated Test Challenge			Survey Tests	
	Test Conc. Draft	Bkthru Conc Draft	Test Conc.	Brkthru Conc
Ammonia	2500	12.5	2000	50
Carbon Monoxide	3600	17.5	Not Tested	Not Tested
Carbon Tetrachloride	3000	5	5000	5
Cyanogen Chloride	300	2	1590	1.98
Cyclohexane	3900	10	5000	10
Formaldehyde	1000	1	1000	1
Hydrogen Cyanide	940	4.7	5000	4.7
Hydrogen Sulfide	1000	5	5000	10
Nitrogen Dioxide	200	1	2500	1
Phosgene	250	1.25	4500	1.24
Phosphine	1500	5	1500	5
Sulfur Dioxide	1500	5	2000	5

Canister Details

Canister Description	Carbon Type (Fill Volume)	Fill (ml)	Bed Depth (cm)	Bed Diameter (cm)	Linear Flow @ 64 l/m (cm/m)
Commerical First Responder	ASZM-T (178 ml)	178	2.1	10.5	0.67
Special Canister (Cr^{+6})	ASC-1%T (248 ml)	248	2.6	11.0	0.67
Commerical First Responder	IMP/(250 ml)	250	2.6	10.0	0.67
Commerical First Responder	IMP/2 (260 ml)	260	3.3	11.0	0.82
EN Multi-Gas Canister ABEK2P3	IMP (Cr^{+6}) + Others (355 ml)	355	4	10.6	0.73

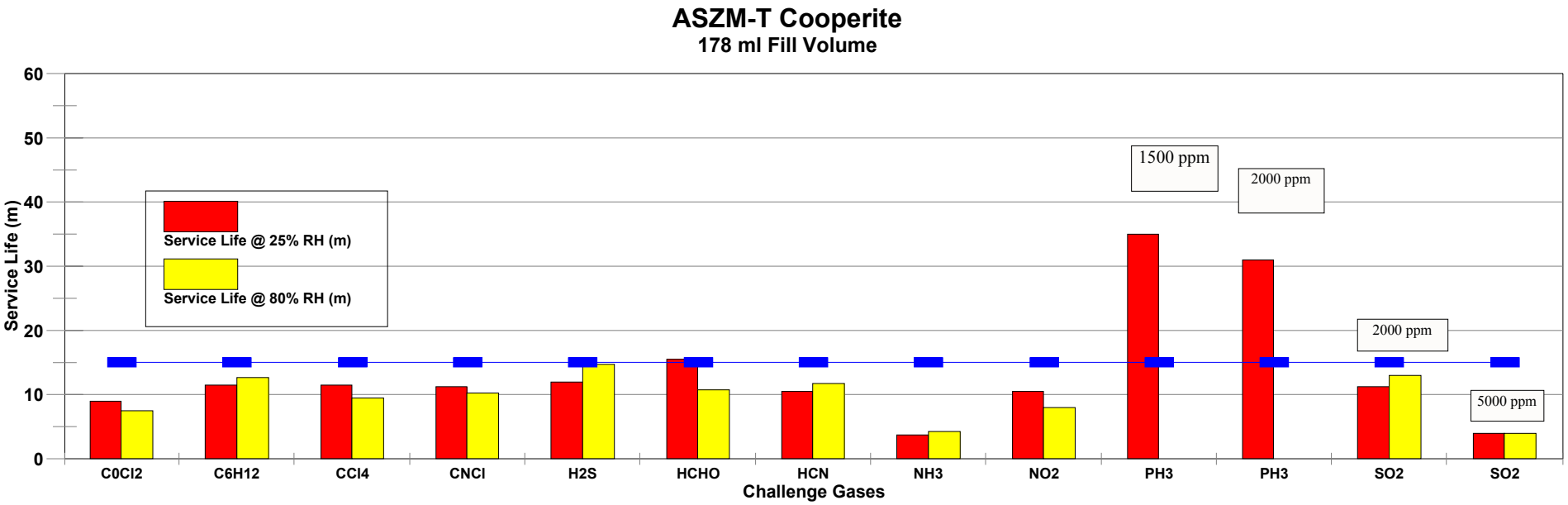
Testing Conditions

- Air Flow Rate = 64 l/m
- Temperature = 25 $\pm$ 3 ^{0}C
- Humidity Conditions
  - Dry = 25% Relative Humidity
  - Wet = 80% Relative Humidity

Challenge Gases/Vapors

- **Ammonia (NH_3)**
- **Carbon Tetrachloride (CCl_4)**
- **Cyanogen Chloride (CNCl)**
- **Cyclohexane (C_6H_{12})**
- **Formaldehyde (HCHO)**
- **Hydrogen Cyanide (HCN)**
- **Hydrogen Sulfide (H_2S)**
- **Nitrogen Dioxide (NO_2)**
- **Phosgene ($C0Cl_2$)**
- **Phosphine (PH_3)**
- **Sulfur Dioxide (SO_2)**

Canister Type vs. Challenge Gas/Vapors



Challenge Gas	Challenge Conc. (ppm)	End Pt. Conc. (ppm)	Draft CBRN Standard Challenge Conc. (ppm)	Draft CBRN Standard End Pt.Conc. (ppm)
Phosgene	**4500**	**1.24**	**250**	**1.25**
Cyclohexane (C_6H_{12})	**5000**	**10**	**3900**	**10**
Carbon Tetrachloride (CCl_4)	**5000**	**5**	**3000**	**5**
Cyanogen Chloride (CNCl)	**1590**	**1.98**	**300**	**2**
Hydrogen Sulfide (H2S)	**5000**	**10**	**1000**	**5**
Formaldehyde (HCHO)	**1000**	**1**	**1000**	**1**
Hydrogen Cyanide (HCN)	**5000**	**4.70**	**940**	**4.70**
Ammonia (NH_3)	**2000**	**50**	**2500**	**12.5**
Nitrogen Dioxide (NO_2)	**2500**	**1**	**200**	**1**
Phosphine (PH_3)	1500	5	1500	5
Phosphine (PH_3)	2000	5	1500	5
Sulfur Dioxide (SO_2)	**2000**	**5**	**1500**	**5**
Sulfur Dioxide (SO_2)	**5000**	**5**	**1500**	**5**

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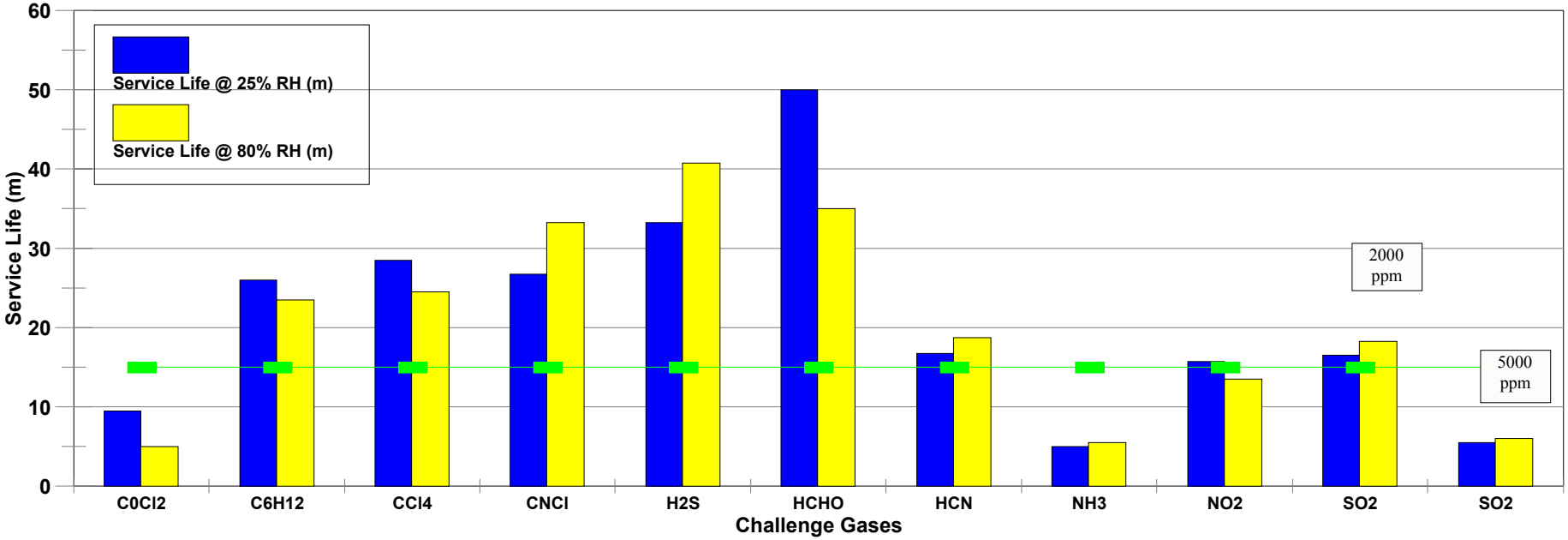
ASC WHETLERITE (Cr+6) - 1% TEDA

248 ml Fill Volume



Challenge Gas	Challenge Conc. (ppm)	End Pt. Conc. (ppm)	Draft CBRN Standard Challenge Conc. (ppm)	Draft CBRN Standard End Pt.Conc.
Phosgene ($C0Cl_2$)	4500	1.24	250	1.25
Cyclohexane (C_6H_{12})	5000	10	3900	10
Carbon Tetrachloride (CCl_4)	5000	5	3000	5
Cyanogen Chloride (CNCl)	1590	1.98	300	2
Hydrogen Sulfide (H_2S)	5000	10	1000	5
Formaldehyde (HCHO)	1000	1	1000	1
Hydrogen Cyanide (HCN)	5000	4.70	940	4.70
Ammonia (NH_3)	2000	50	2500	12.5
Nitrogen Dioxide (NO_2)	2500	1	200	1
Sulfur Dioxide (SO_2)	2000	5	1500	5
Sulfur Dioxide (SO_2)	5000	5	1500	5

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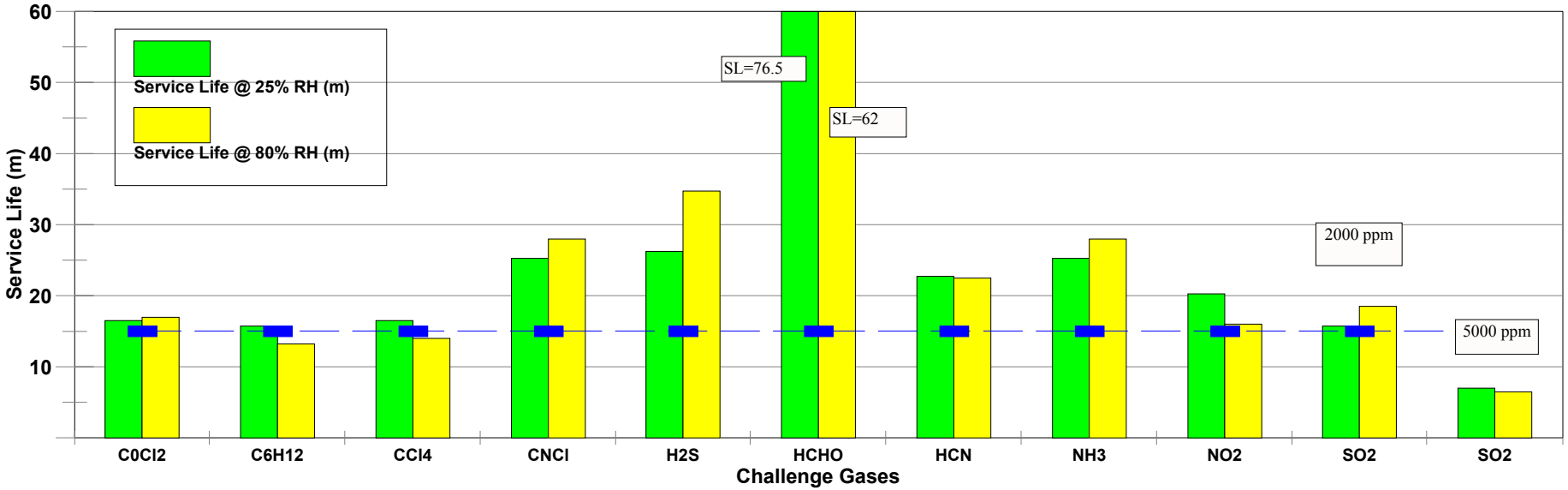
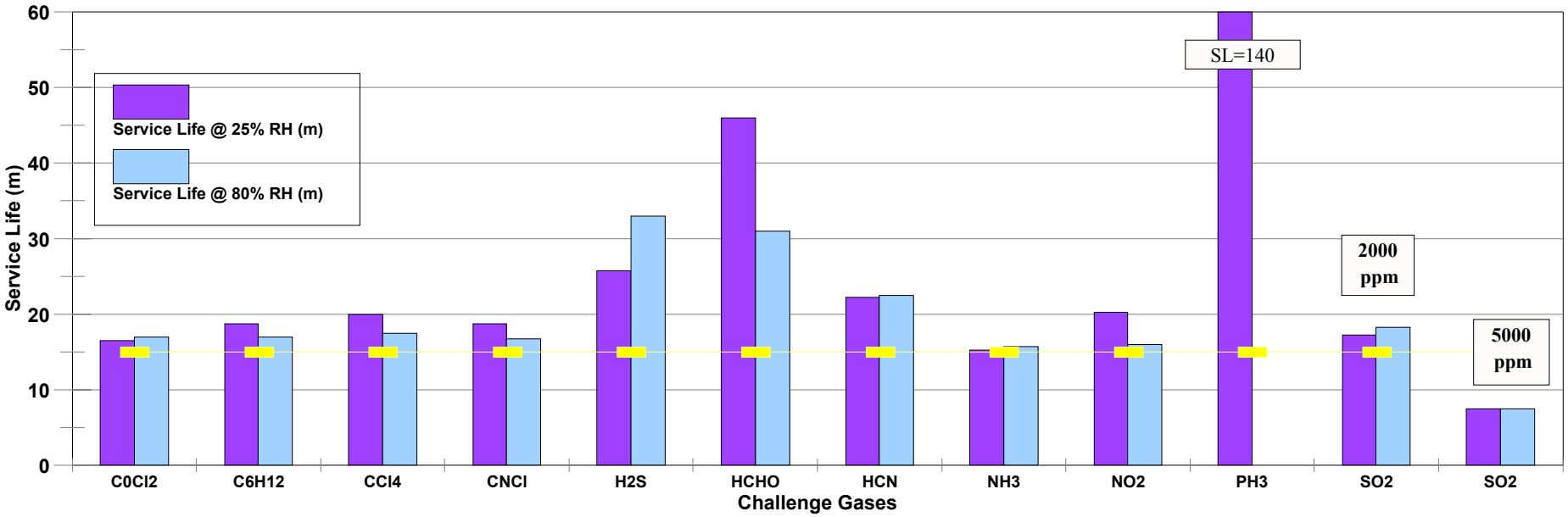
Impregnated Carbon
250 ml Fill Volume



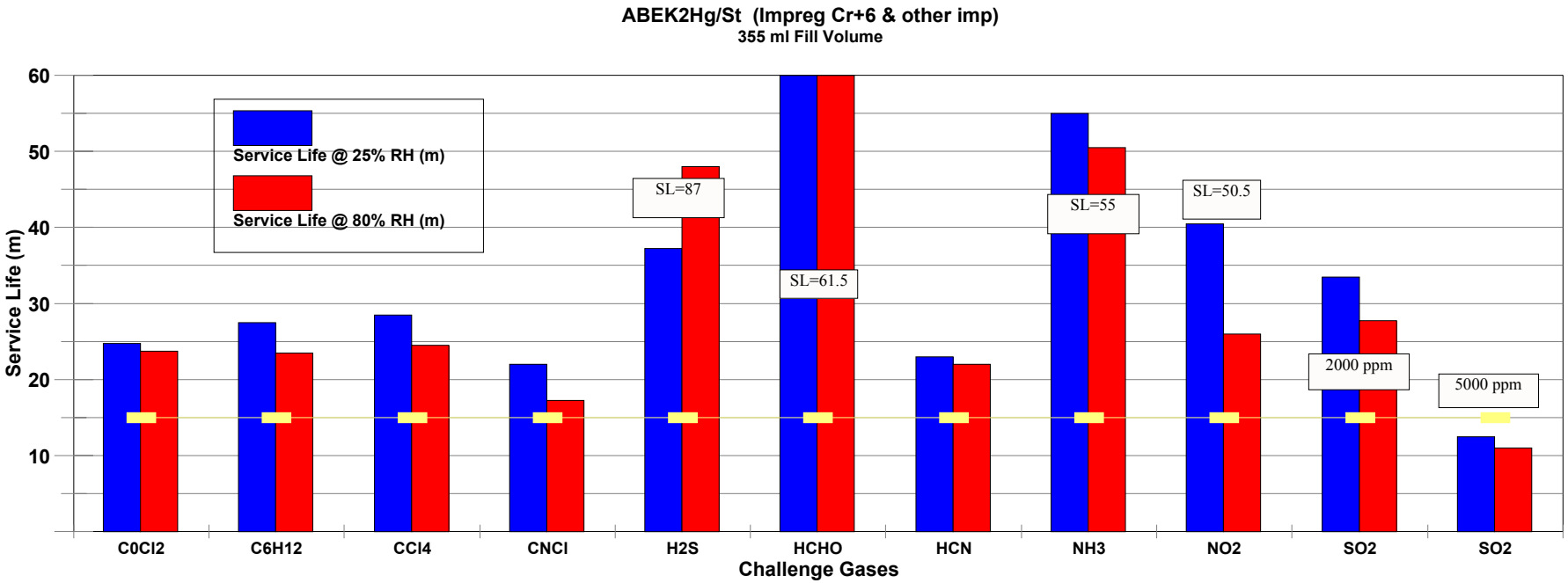
Challenge Gas	Challenge Conc. (ppm)	End Pt. Conc. (ppm)	Draft CBRN Standard Challenge Conc. (ppm)	Draft CBRN Standard End Pt.Conc.
Phosgene ($C0Cl_2$)	4500	1.24	250	1.25
Cyclohexane (C_6H_{12})	5000	10	3900	10
Carbon Tetrachloride (CCl_4)	5000	5	3000	5
Cyanogen Chloride (CNCl)	1590	1.98	300	2
Hydrogen Sulfide (H_2S)	5000	10	1000	5
Formaldehyde (HCHO)	1000	1	1000	1
Hydrogen Cyanide (HCN)	5000	4.70	940	4.70
Ammonia (NH_3)	2000	50	2500	12.5
Nitrogen Dioxide (NO_2)	2500	1	200	1
Sulfur Dioxide (SO_2)	2000	5	1500	5
Sulfur Dioxide (SO_2)	5000	5	1500	5

IMPREGNATES-2

260 ml Fill Volume



Challenge Gas	Challenge Conc. (ppm)	End Pt. Conc. (ppm)	Draft CBRN Standard Challenge Conc. (ppm)	Draft CBRN Standard End Pt.Conc. (ppm)
Phosgene (C0Cl2)	4500	1.24	250	1.25
Cyclohexane (C6H12)	5000	10	3900	10
Carbon Tetrachloride (CCl4)	5000	5	3000	5
Cyanogen Chloride (CNCl)	1590	1.98	300	2
Hydrogen Sulfide (H2S)	5000	10	1000	5
Formaldehyde (HCHO)	1000	1	1000	1
Hydrogen Cyanide (HCN)	5000	4.70	940	4.70
Ammonia (NH3)	2000	50	2500	12.5
Nitrogen Dioxide (NO2)	2500	1	200	1
Phosphine (PH3)	1500	5	1500	5
Sulfur Dioxide (SO2)	2000	5	1500	5
Sulfur Dioxide (SO2)	5000	5	1500	5



Challenge Gas	Challenge Conc. (ppm)	End Pt. Conc. (ppm)	Draft CBRN Standard Challenge Conc. (ppm)	Draft CBRN Standard End Pt.Conc. (ppm)
Phosgene ($C0Cl_2$)	4500	1.24	250	1.25
Cyclohexane (C_6H_{12})	5000	10	3900	10
Carbon Tetrachloride (CCl_4)	5000	5	3000	5
Cyanogen Chloride (CNCl)	1590	1.98	300	2
Hydrogen Sulfide (H_2S)	5000	10	1000	5
Formaldehyde (HCHO)	1000	1	1000	1
Hydrogen Cyanide (HCN)	5000	4.70	940	4.70
Ammonia (NH_3)	2000	50	2500	12.5
Nitrogen Dioxide (NO_2)	2500	1	200	1
Sulfur Dioxide (SO_2)	2000	5	1500	5
Sulfur Dioxide (SO_2)	5000	5	1500	5

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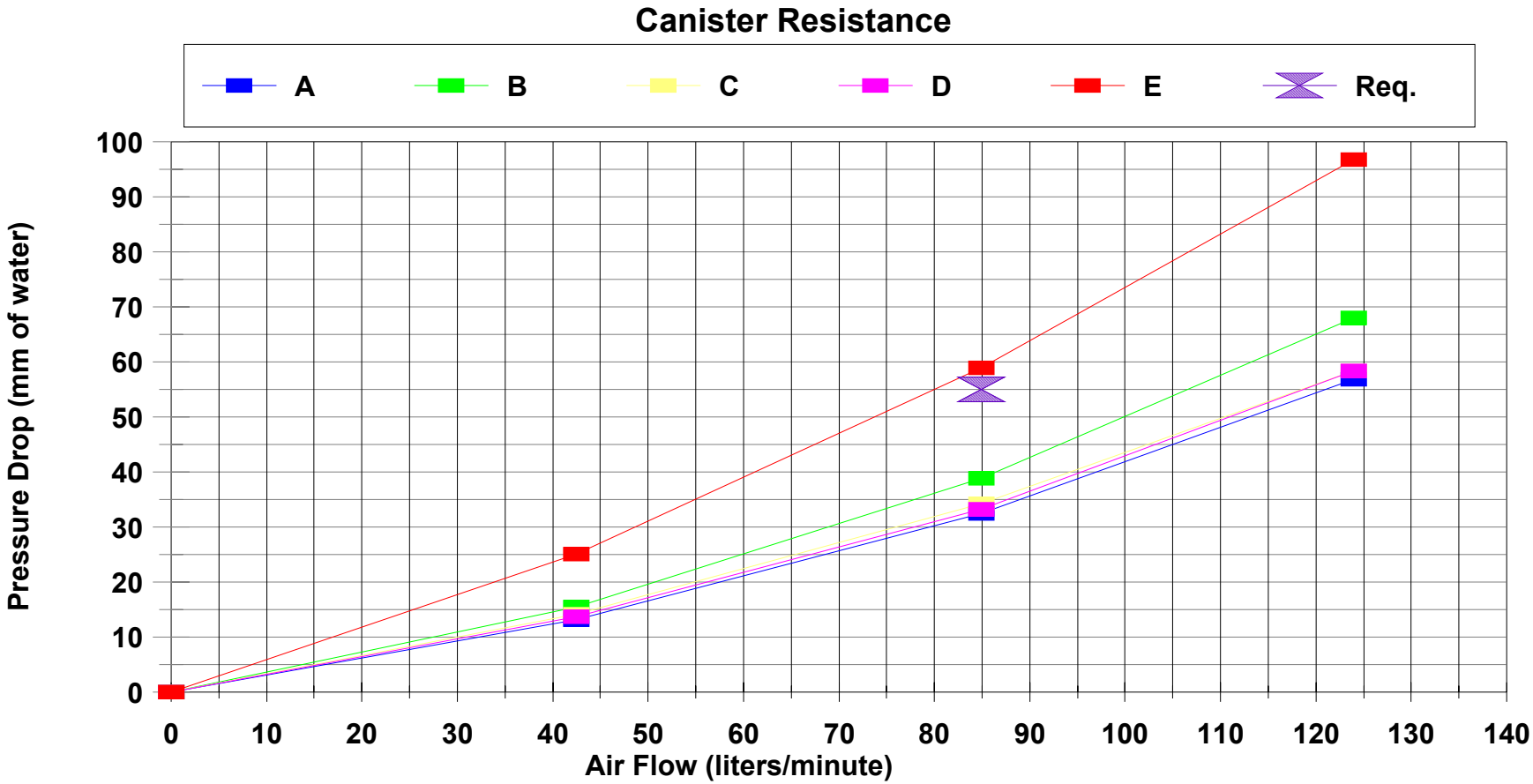


Canister Resistance

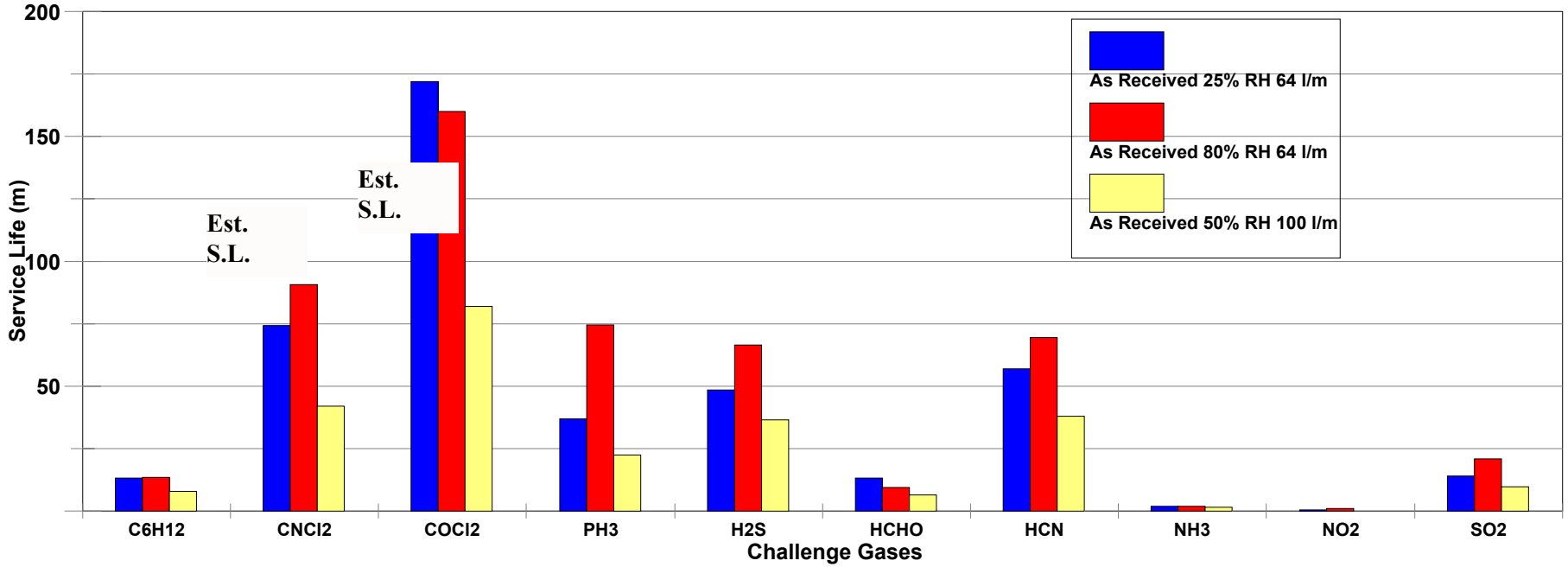
		Air Flow (liters/minute)			
Legend I.D.	Carbon Type (Fill Volume)	0	42.5	85	124
A	ASZM-T (170 ml Fill Vol)	0	13.2	32.5	56.9
B	Whetlerite(Cr+6)-1% TEDA (248 ml Fill Vol.)	0	15.5	38.9	68.1
C	Impreg. Carbon (250 ml Fill Vol.)	0	14.2	34.3	58.4
D	Impreg. Carbon - 2 (260 ml Fill Vol.)	0	13.7	33.3	58.4
E	ABEK2Hg/St (355 ml Fill Vol.)	0	25.1	58.9	96.8
Req.	CBRN Gas Mask Stardard Requirement			55	

Baseline Study

Canisters Tests using proposed chemicals and associated concentrations & end points

Service Life - Baseline Study

ASZM-TEDA Canister (178 ml fill)



Challenge	Challenge	Cartridge Type	Challenge Conc. (ppm)	Break Conc. (ppm)	As Received 25% RH 64 l/m	As Received 80% RH 64 l/m	As Received 50% RH 100 l/m	Special Notes
Cyclohexane	C6H12	ASZM-TEDA	3900	10	13.25	13.5	8	
Cyanogen Chloride**	CNCl2	ASZM-TEDA	300	2	74.25	90.75	42.08	
Phosgene**	COCl2	ASZM-TEDA	250	1.25	172	160	82	
Phosphine	PH3	ASZM-TEDA	1500	5	37	74.5	22.5	
Hydrogen Sulfide	H2S	ASZM-TEDA	1000	5	48.5	66.5	36.5	
Formaldehyde	HCHO	ASZM-TEDA	1000	1	13.25	9.5	6.5	
Hydrogen Cyanide	HCN	ASZM-TEDA	940	4.7	57	69.5	38	2
Ammonia	NH3	ASZM-TEDA	2500	12.50	2	2	1.5	
Nitrogen Dioxide	NO2	ASZM-TEDA	200	1	0.5	1		1
Sulfur Dioxide	SO2	ASZM-TEDA	1500	5	14	21	9.75	

Notes:

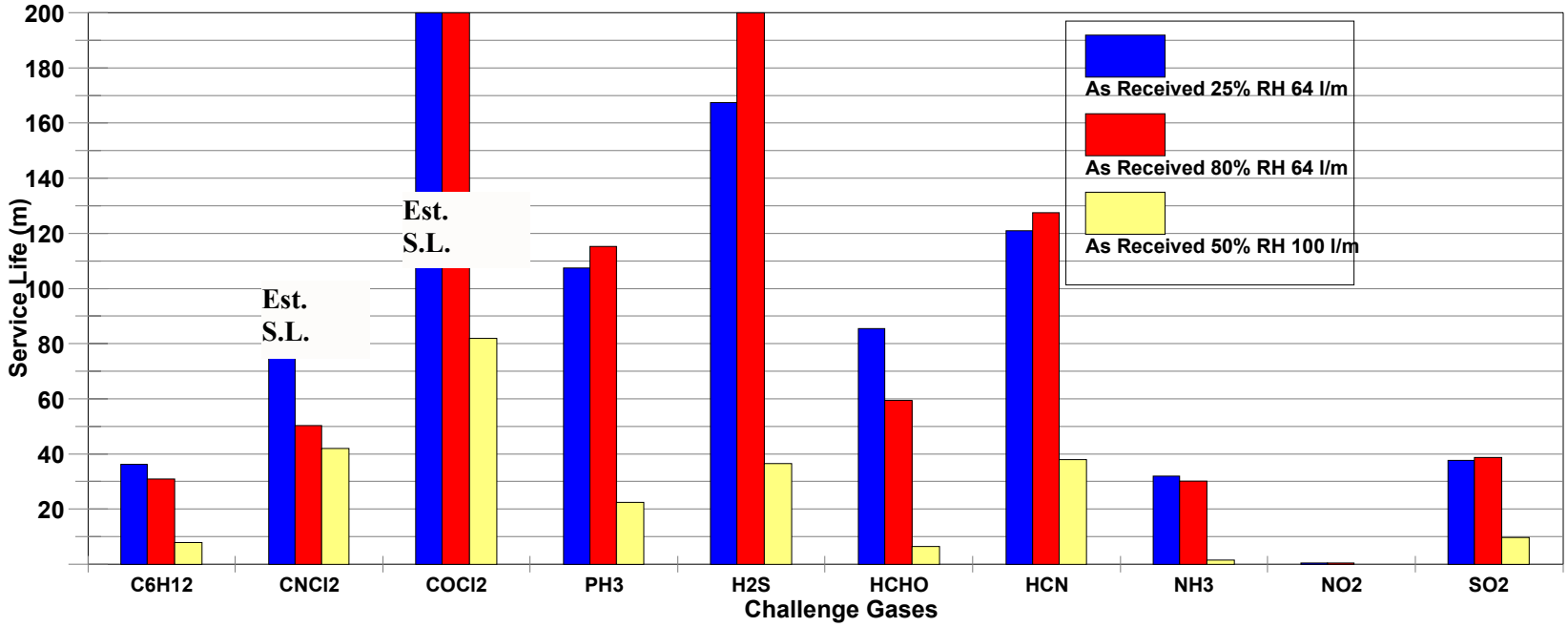
1 Detectors used detected NO2 & NO, but NO always came thru first.

2 Detector only detected HCN, not cyanogen

** Estimated Service Life based on actual 1000 ppm Challenge results[(CNCl2*3.3) or (COCl2*4)]

Service Life - Baseline Study

ABEKP3 Canister (355 ml fill)



Challenge	Challenge	Cartridge Type	Challenge Conc. (ppm)	Break Conc. (ppm)	As Received 25% RH 64 l/m	As Received 80% RH 64 l/m	As Received 50% RH 100 l/m	Special Notes
Cyclohexane	C6H12	ASZM-TEDA	3900	10	36.25	31	21.75	
Cyanogen Chloride**	CNCl2	ASZM-TEDA	300	2	79.2	50.325	13.20	
Phosgene**	COCl2	ASZM-TEDA	250	1.25	426	434	242	
Phosphine	PH3	ASZM-TEDA	1500	5	107.5	115.3	42	
Hydrogen Sulfide	H2S	ASZM-TEDA	1000	5	167.5	231	134	
Formaldehyde	HCHO	ASZM-TEDA	1000	1	85.5	59.5	36	
Hydrogen Cyanide	HCN	ASZM-TEDA	940	4.7	121	127.5	71	1
Ammonia	NH3	ASZM-TEDA	2500	12.50	32	30.25	15	
Nitrogen Dioxide	NO2	ASZM-TEDA	200	1	0.5	0.5		2
Sulfur Dioxide	SO2	ASZM-TEDA	1500	5	37.75	38.75	20.75	

Notes:

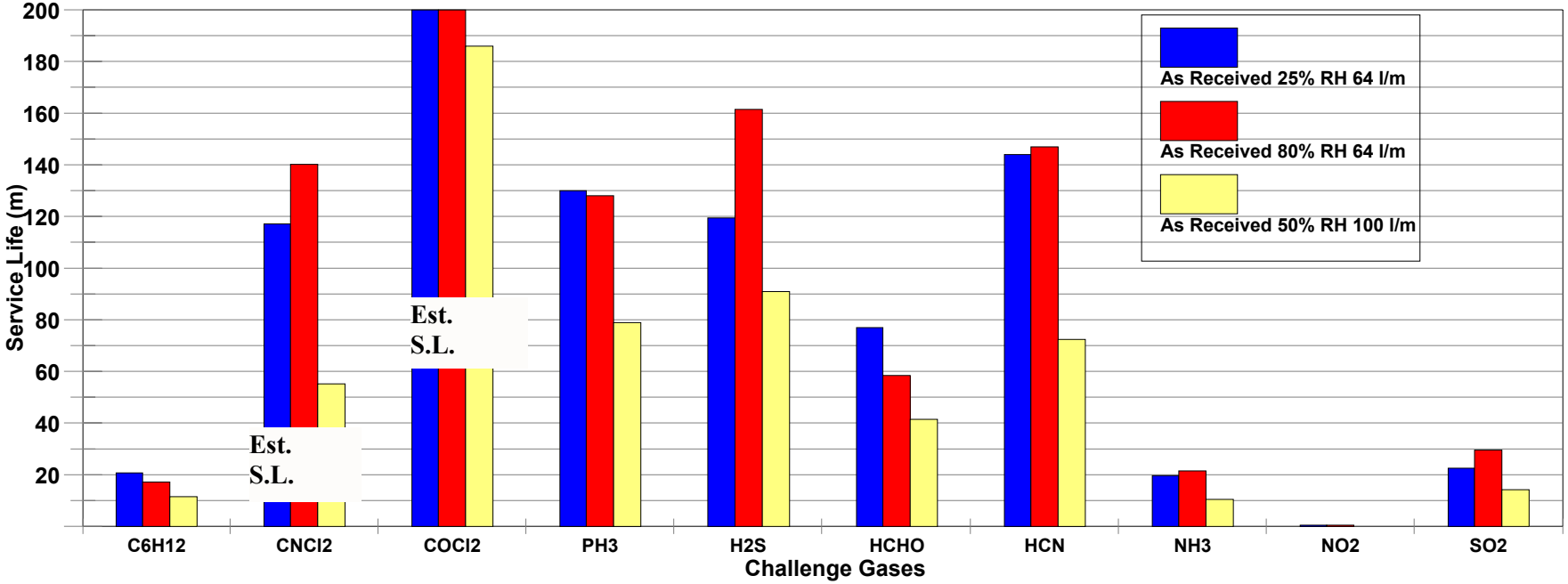
1 Detectors used detected NO2 & NO, but NO always came thru first.

2 Detector only detected HCN, not cyanogen

** Estimated Service Life based on actual 1000 ppm Challenge results[(CNCl2*3.3) or (COCl2*4)]

Service Life - Baseline Study

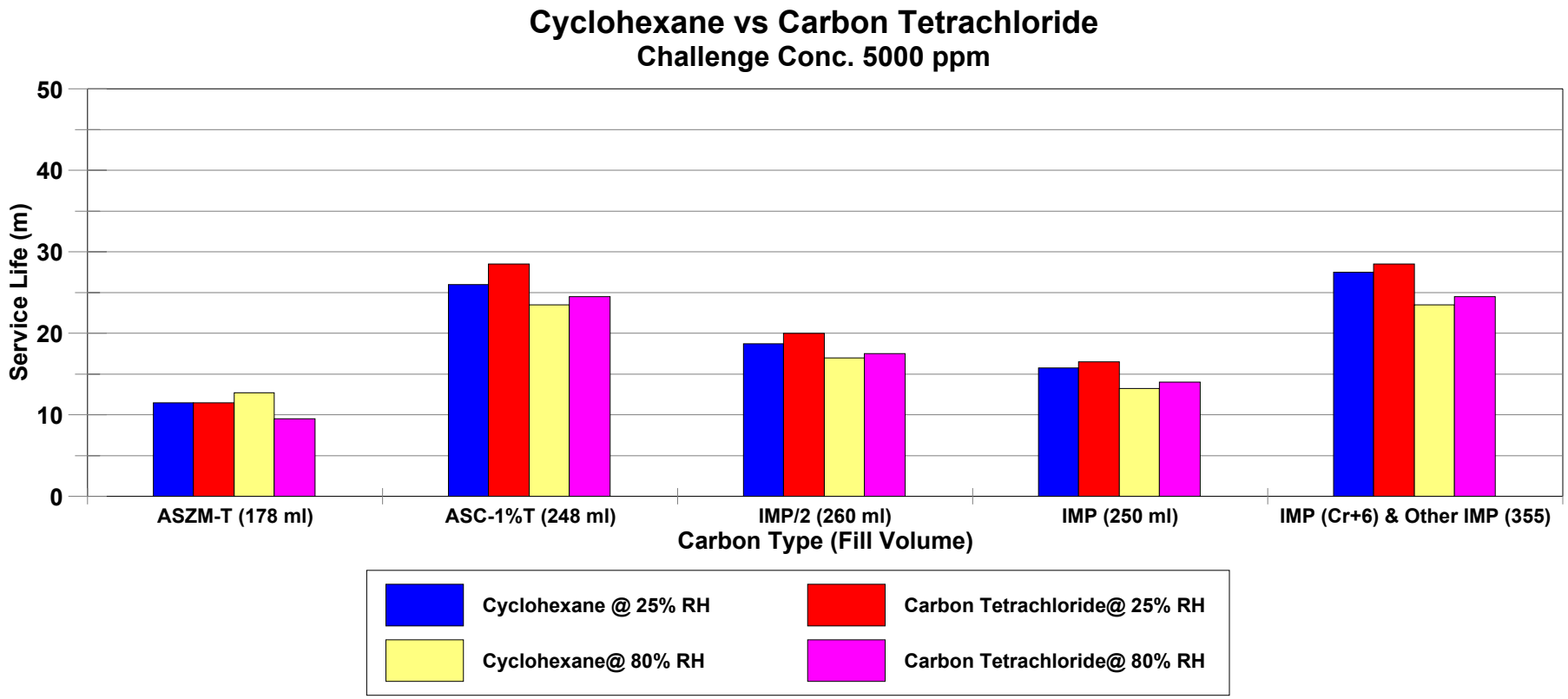
IMP/1 Canister (250 ml fill)



Challenge	Challenge	Cartridge Type	Challenge Conc. (ppm)	Break Conc. (ppm)	As Received 25% RH 64 l/m	As Received 80% RH 64 l/m	As Received 50% RH 100 l/m	Special Notes
Cyclohexane	C6H12	ASZM-TEDA	3900	10	20.75	17.25	11.5	
Cyanogen Chloride**	CNCl2	ASZM-TEDA	300	2	117.15	140.25	55.28	
Phosgene**	COCl2	ASZM-TEDA	250	1.25	354	348	186	
Phosphine	PH3	ASZM-TEDA	1500	5	130	128	79	
Hydrogen Sulfide	H2S	ASZM-TEDA	1000	5	119.5	161.5	91	
Formaldehyde	HCHO	ASZM-TEDA	1000	1	77	58.5	41.5	
Hydrogen Cyanide	HCN	ASZM-TEDA	940	4.7	144	147	72.5	1
Ammonia	NH3	ASZM-TEDA	2500	12.50	19.75	21.5	10.5	
Nitrogen Dioxide	NO2	ASZM-TEDA	200	1	0.5	0.5		2
Sulfur Dioxide	SO2	ASZM-TEDA	1500	5	22.5	29.5	14.25	

Notes:

1 Detectors used detected NO2 & NO, but NO always came thru first.
2 Detector only detected HCN, not cyanogen
** Estimated Service Life based on actual 1000 ppm Challenge results[(CNCl2*3.3) or (COCl2*4)]



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Cyclohexane vs Sarin (GB)

Challenge	Challenge	Cartridge Type	Challenge Conc. (ppm)	Break Conc. (ppm)	Service Life - As Received - 25% RH - 64 l/m (minutes)
Cyclohexane	C6H12	ASZM-TEDA	3900	10	13.25
Sarin	GB	ASZM-TEDA	698*	0.007*	190
Cyclohexane	C6H12	ABEK2P3	3900	10	36.25
Sarin	GB	ABEK2P3	698*	0.007*	>488**
*	U.S. Military Standard Test Conditions				
**	After 488 minutes challenge pumps was shut off, airflow through the canister was continued.				
	Breakthrough of GB occurred after 11 hours after pump shutdown.				

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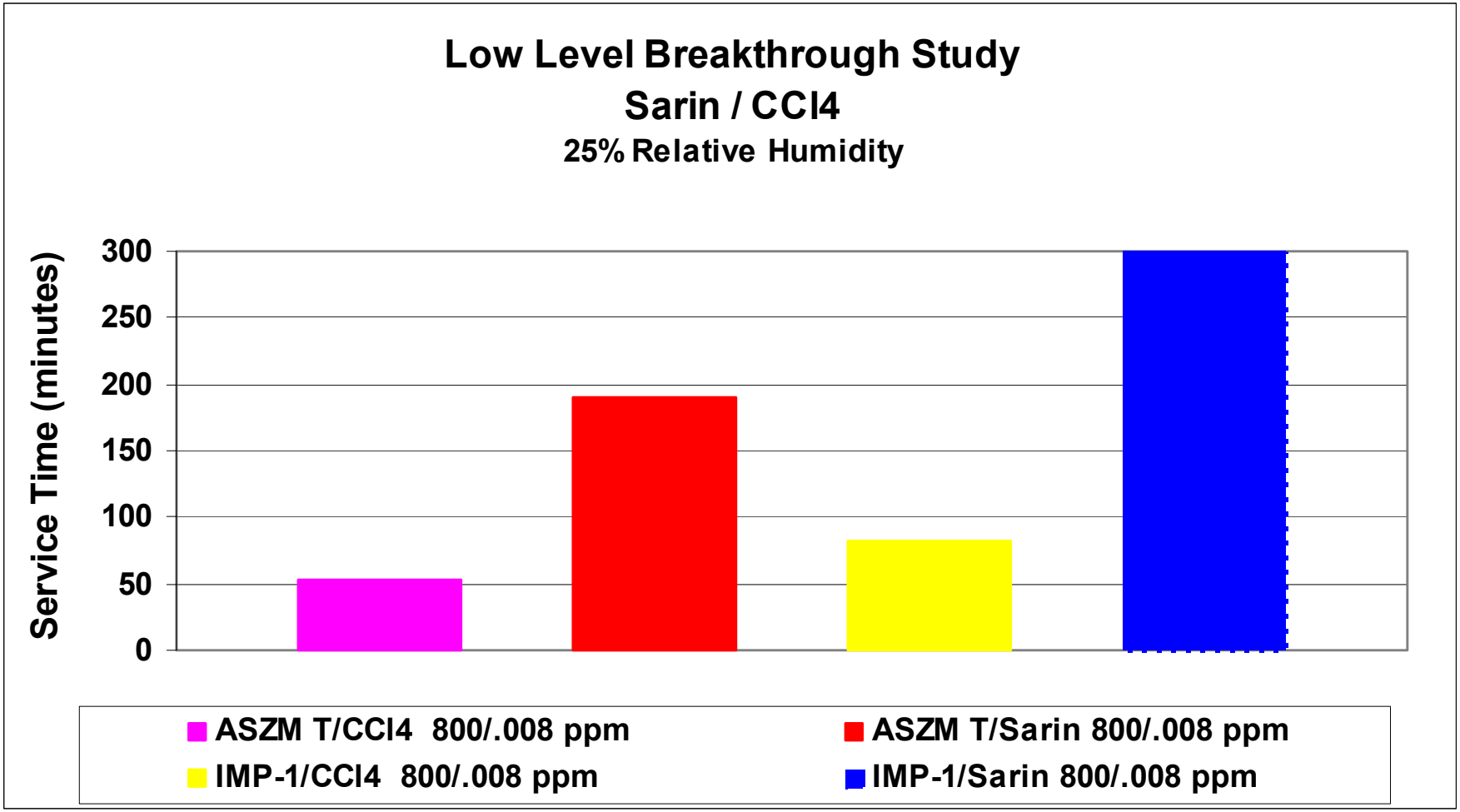

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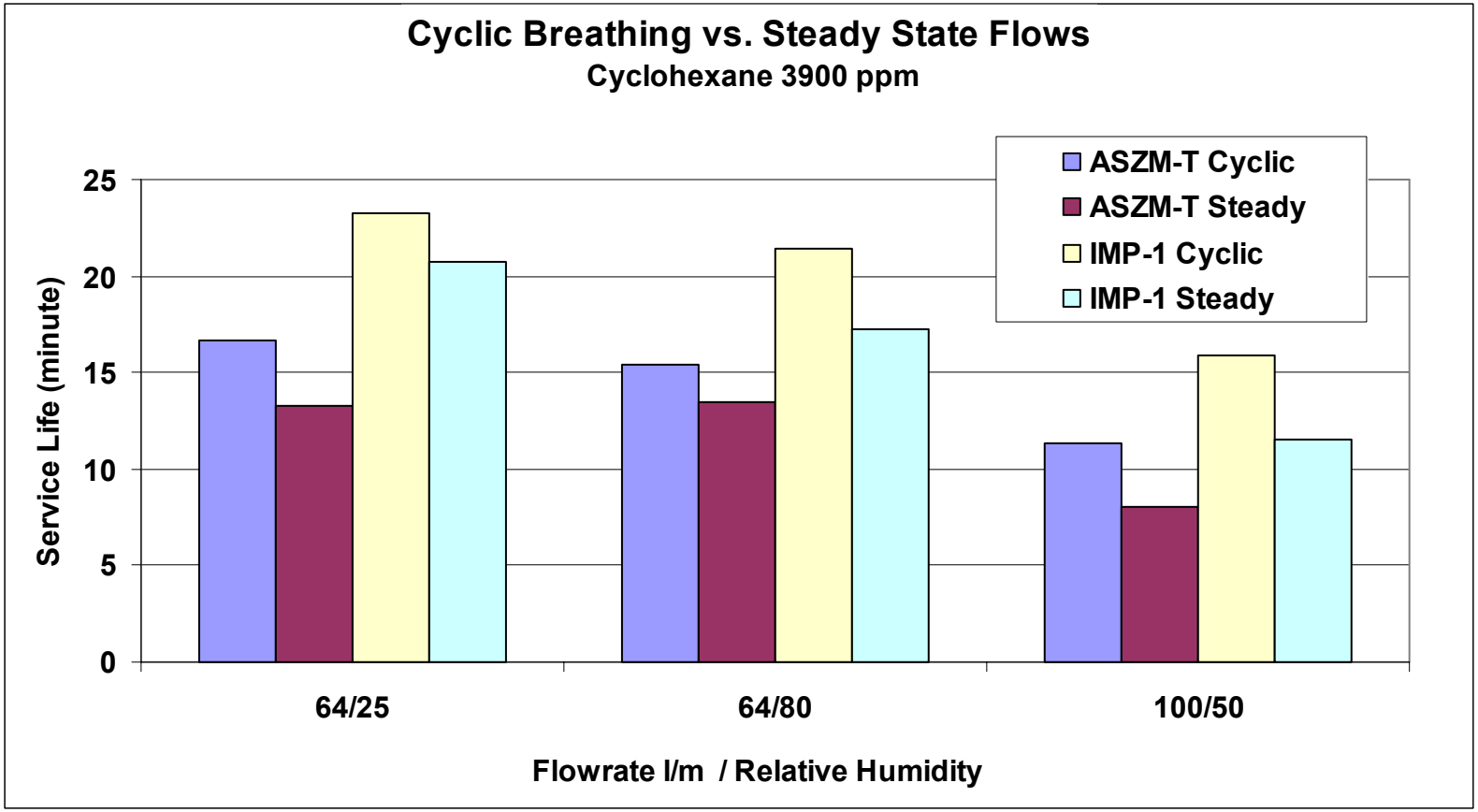

Flowrate / Relative Humidity	ASZM-T Cyclic Service Life (min)	ASZM-T Steady Service Life (min)	IMP-1 Cyclic Service Life (min)	IMP-1 Steady Service Life (min)
64/25	16.7	13.25	23.3	20.75
64/80	15.4	13.5	21.4	17.25
100/50	11.3	8	15.9	11.5
Blue = Est. based on breather results @ 1000 ppm				

Note:	Average Flowrate (l/m)	Cyclic Peak Flowrate (l/m)
	64	201
	100	314

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Pretreated by Environmental / Vibration/Rough Handling vs. Out of Package

Cyclohexane Challenge

Canister	Enviromental Testing	Drop Orientation	RH (%)	Cyclohexane Feed (ppm)	Break Time @ 10 ppm (min)
ASZM-TEDA	No	Control	25	3900	16.2
ASZM-TEDA	Yes	Top Down	25	3900	17.2
ASZM-TEDA	Yes	Side Down	25	3900	17.6
ASZM-TEDA	Yes	Bottom Down	25	3900	17.6
ASZM-TEDA	No	Control	80	3900	15.9
ASZM-TEDA	Yes	Top Down	80	3900	16.5
ASZM-TEDA	Yes	Side Down	80	3900	14.9
ASZM-TEDA	Yes	Bottom Down	80	3900	14.3
IMP/1	No	Control	25	3900	21.1
IMP/1	Yes	Top Down	25	3900	20.4
IMP/1	Yes	Side Down	25	3900	9.5
IMP/1	Yes	Bottom Down	25	3900	8.0
IMP/1	No	Control	80	3900	18.0
IMP/1	Yes	Top Down	80	3900	15.8
IMP/1	Yes	Side Down	80	3900	18.4
IMP/1	Yes	Bottom Down	80	3900	15.4
ABEK2P3	No	Control	25	3900	39.7
ABEK2P3	Yes	Top Down	25	3900	0.5
ABEK2P3	Yes	Side Down	25	3900	35.8
ABEK2P3	Yes	Bottom Down	25	3900	36.7
ABEK2P3	No	Control	80	3900	29.2
ABEK2P3	Yes	Top Down	80	3900	0.3
ABEK2P3	Yes	Side Down	80	3900	30.8
ABEK2P3	Yes	Bottom Down	80	3900	31.5

	Fill Volume (g/cc)	Canister & Package Description
ASZM-TEDA	178	Metal in Metal Can
IMP/1	250	Plastic in Foil Wrap
ABEK2P3	355	Metal in Foil Wrap

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Pretreated by Environmental / Vibration/Rough Handling vs. Out of Package

Ammonia Challenge

Canister	Enviromental Testing	Drop Orientation	RH (%)	Feed (ppm)	Break Time @ 12.5 ppm (min)
ASZM-TEDA	No	Control	25	2500	5.4
ASZM-TEDA	Yes	Top Down	25	2500	3.4
ASZM-TEDA	Yes	Side Down	25	2500	4.4
ASZM-TEDA	Yes	Bottom Dowr	25	2500	4.3
ASZM-TEDA	No	Control	80	2500	5.3
ASZM-TEDA	Yes	Top Down	80	2500	3.8
ASZM-TEDA	Yes	Side Down	80	2500	4.2
ASZM-TEDA	Yes	Bottom Dowr	80	2500	3.3
IMP/1	No	Control	25	2500	27.2
IMP/1	Yes	Top Down	25	2500	23.3
IMP/1	Yes	Side Down	25	2500	23.4
IMP/1	Yes	Bottom Dowr	25	2500	23.2
IMP/1	No	Control	80	2500	28.6
IMP/1	Yes	Top Down	80	2500	22.7
IMP/1	Yes	Side Down	80	2500	23.2
IMP/1	Yes	Bottom Dowr	80	2500	23.5
ABEK2P3	No	Control	25	2500	46.0
ABEK2P3	Yes	Top Down	25	2500	1.4
ABEK2P3	Yes	Side Down	25	2500	46.0
ABEK2P3	Yes	Bottom Dowr	25	2500	44.3
ABEK2P3	No	Control	80	2500	40.9
ABEK2P3	Yes	Top Down	80	2500	0.5
ABEK2P3	Yes	Side Down	80	2500	3.8
ABEK2P3	Yes	Bottom Dowr	80	2500	28.4

	Fill Volume (g/cc)	Canister & Package Description
ASZM-TEDA	178	Metal in Metal Can
IMP/1	250	Plastic in Foil Wrap
ABEK2P3	355	Metal in Foil Wrap

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Pretreated by Environmental / Vibration/Rough Handling vs. Out of Package

Cyanogen Chloride Challenge

Canister	Enviromental Testing	Drop Orientation	RH (%)	Feed (ppm)	Break Time @ 2 ppm (min)
ASZM-TEDA	No	Control	25	300	78.3
ASZM-TEDA	Yes	Top Down	25	300	73.5
ASZM-TEDA	Yes	Side Down	25	300	69.1
ASZM-TEDA	Yes	Bottom Down	25	300	63.2
ASZM-TEDA	No	Control	80	300	105.9
ASZM-TEDA	Yes	Top Down	80	300	117.2
ASZM-TEDA	Yes	Side Down	80	300	120.5
ASZM-TEDA	Yes	Bottom Down	80	300	121.9
IMP/1	No	Control	25	300	78.3
IMP/1	Yes	Top Down	25	300	28.4
IMP/1	Yes	Side Down	25	300	132.9
IMP/1	Yes	Bottom Down	25	300	131.2
IMP/1	No	Control	80	300	105.9
IMP/1	Yes	Top Down	80	300	128.6
IMP/1	Yes	Side Down	80	300	33.8
IMP/1	Yes	Bottom Down	80	300	164.8
ABEK2P3	No	Control	25	300	88.5
ABEK2P3	Yes	Top Down	25	300	0.7
ABEK2P3	Yes	Side Down	25	300	49.8
ABEK2P3	Yes	Bottom Down	25	300	51.6
ABEK2P3	No	Control	80	300	36.3
ABEK2P3	Yes	Top Down	80	300	21.3
ABEK2P3	Yes	Side Down	80	300	21.7
ABEK2P3	Yes	Bottom Down	80	300	20.2
	Fill Volume (g/cc)	Canister & Package Description			
ASZM-TEDA	178	Metal in Metal Can			
IMP/1	250	Plastic in Foil Wrap			
ABEK2P3	355	Metal in Foil Wrap			

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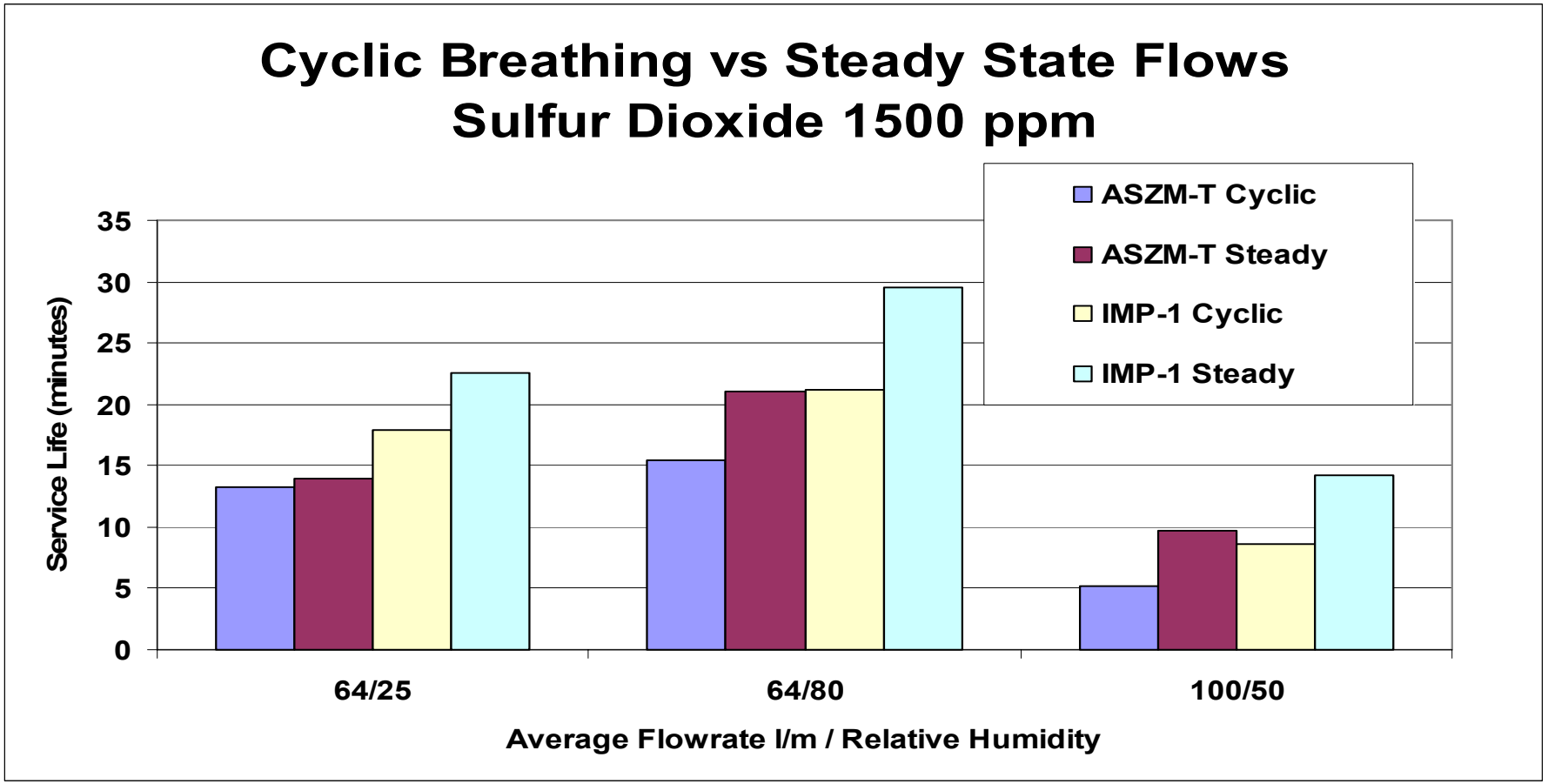

Average Flowrate / Relative Humidity	ASZM-T Cyclic Service Life (min)	ASZM-T Steady Service Life (min)	IMP-1 Cyclic Service Life (min)	IMP-1 Steady Service Life (min)
64/25	13.2	14.0	18.0	22.5
64/80	15.5	21.0	21.3	29.5
100/50	5.3	9.8	8.6	14.3

Note:	Average Flowrate (l/m)	Cyclic Peak Flowrate (l/m)
	64	201
	100	314

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CBRN Standards Development

- Questions?