ISO 5149, IEC60335-2-40 Proposed Changes to Incorporate 2L Refrigerants

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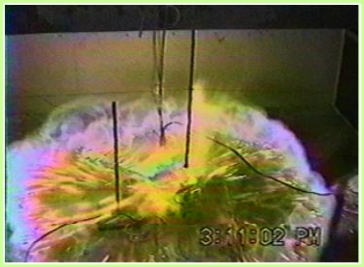
Standards of the World relating 2L

Field	US (affects ME&A)	Europe	International
Refrigerant Classification	ASHRAE 34 UL 2182	-NA- (based on ISO)	ISO817
Usage Restriction for Safety	ASHRAE 15	EN378	ISO5149
	UL 207 UL 250 UL 471 UL 474 UL 484 UL 984 UL 1995 UL 60335-2-40	EN60335-2-40	IEC60335-2-40

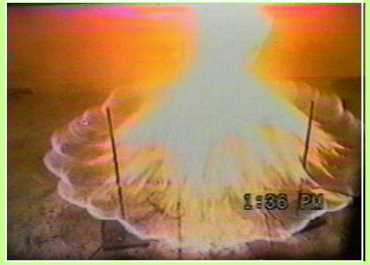
Classification History of 2L (1)

- 2001 Flammability indices were discussed in ASHRAE. Ammonia is criteria substance and not flammable gas in US DOT.
- Old ASHRAE indices show lower flammability of R152a than ammonia, but it is more flammable.



Propane

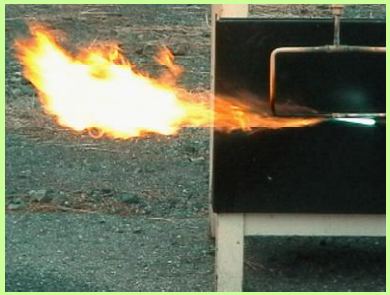
Ammonia



R152a

R32

R32



R32+Ether oil

R22+Mineral Oil

Classification History of 2L (2)

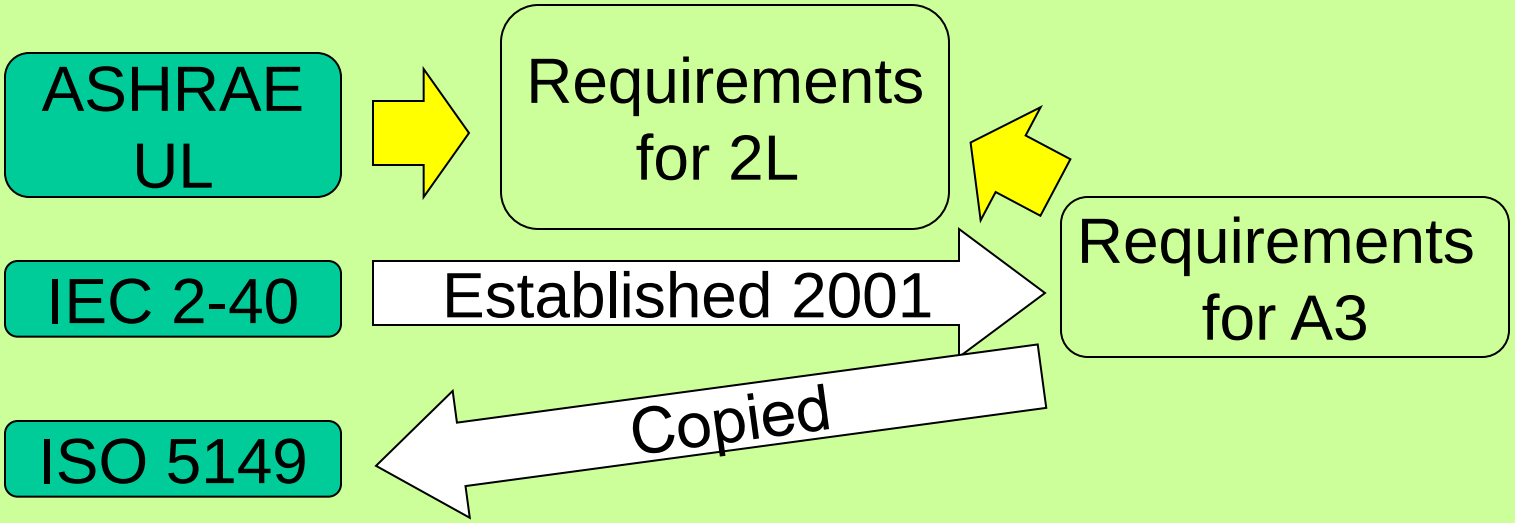
- 2003 ISO TC86 SC8 WG5 (ISO 817 revision) agreed to add BV (Burning Velocity) for class 2 criteria
- 2005 ISO TC86 SC8 WG5 decided to use 2L instead of 2 to maintain 152a in class 2
- 2010 ASHRAE 34 revised to include class 2L
- 2012 ISO 817 will be published?

R32, 143a, 1234yf are A2L Ammonia is B2L

		Lower toxicity	Higher toxicity
Higher flammability		A3	B3
Lower flammability	Burning velocity >10cm/s	A2	B2
	Burning velocity ≤ 10cm/s	A2L	B2L
No flame propagation		A1	B1

Use Restriction History of 2L

- 2001 IEC ISO JWG finalized proposal for flammable refrigerants (for A3) in IEC 60335-2-40.
- Formula was copied to ISO5149 draft.
- 2010 ISO TC86 SC1 WG1 agreed to employ 1.5 times larger boundary for 2L than IEC
- 2012 ISO 5149 will be published?
- 2011 IEC 61D WG9 started to provide (relaxed) requirements for A2L



Behavior of released Refrigerant

- Large rate with low velocity gives the worst concentration (stagnation).
- Gravity generates flow and dilution even in such cases
- Based on this property current allowable charge formula of IEC & ISO is established assuming 4 minutes entire release.

$$m_{max} = 2{,}5 \times LFL^{\frac{5}{4}} \times h_0 \times \sqrt{A}$$

- Room floor area (m^2)
- Installation height(m)
- Lower flammability limit(kg/m^3)
- Coefficient

Points to Revise and Progress

1. Ignition Source (Switches, Contactors & Hot surfaces)
2. Charge Limit Boundary
3. Charge Limit Additional Formula
4. Mechanical Structure
5. Symbols and Marking
6. Training

Point (1) Ignition Source

- Current IEC60335-2-40 requires conformity to 60079-15. This is sufficient, but more relaxed requirements should be prepared for A2L.
- Many standards such as ASHRAE 15 do not require anti explosion system for ammonia.

Class	Gas
IIA	Methane Ethane CO Ammonia
IIB	Ethylene Ethyl ether
IIC	Hydrogen Acetylene

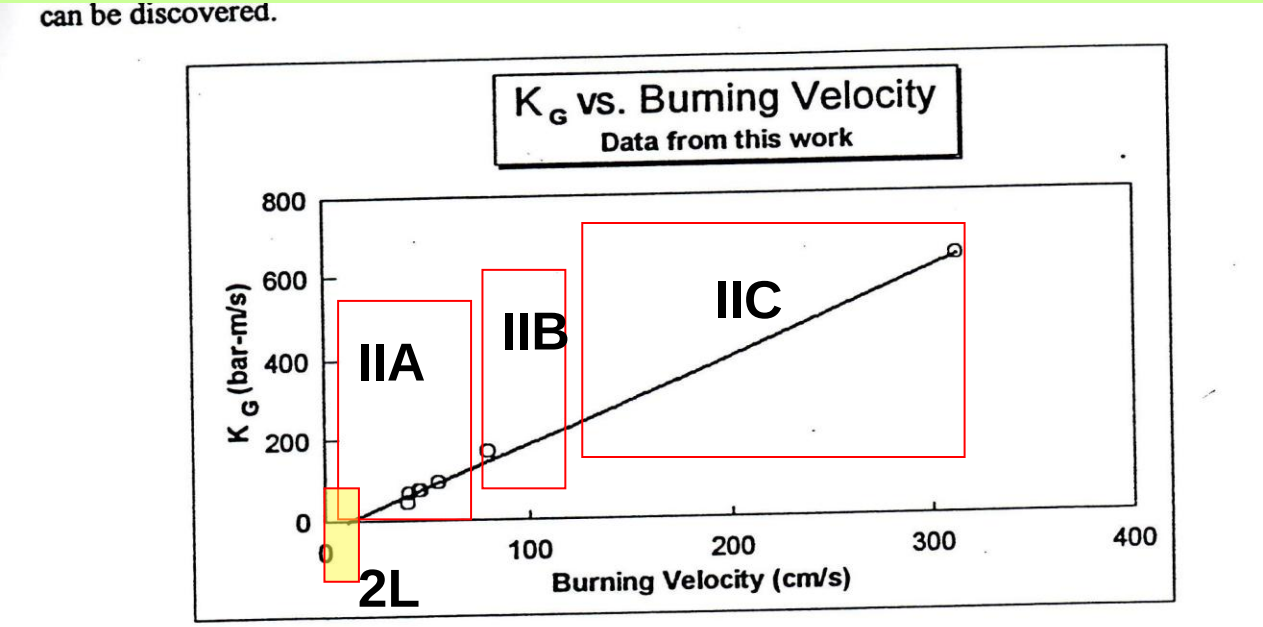


Figure 4. Correlation of K_G with published burning velocity values.

Ignition tests in UL (DOE/CE/23810-92)

Table 4-1: Small Scale Ignition Source Test Results

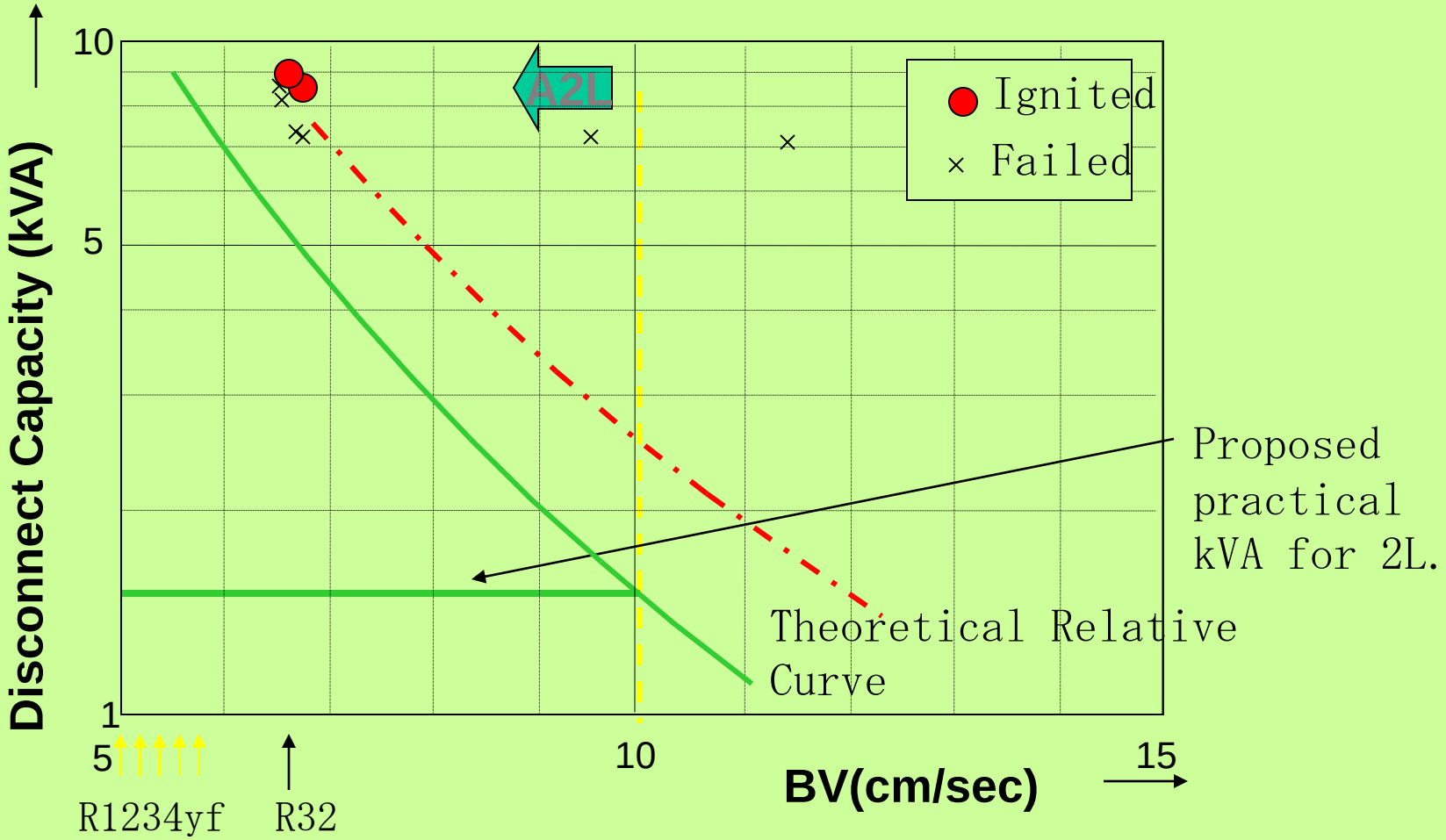
Ignition Source	Characteristics	Represents	R-32 Ignition	R-32/134a (60/40 Ignition)
High Voltage	15,000 V secondary	For certain ignition	Y	Y
Low voltage Arc	17,000 V secondary peak 24 V input	Oil-fired residential furnace ignitor	Y	Y
		Gas fired residential furnace ignitor	N	N
Electric Spark Across Wires	240 V, 96 A, 42 PF	Loose wires at LRA*	Y	N
	120 V, 72 A, 50 PF	Loose wires at LRA*	Y	N
	120 V, 16 A, 75 PF	Loose wires at typical wall current	N	-
Supplemental Heating Element	Normal operating temperature	Normal operation	N	N
	Red hot	No air flow	N	N
	White hot	Current limiter failure	Y	Y
Hot Wire Ignitor	120V rated	120V rated	N	N
Light Bulb	Envelope broken	Broken bulb	Y	Y
	Halogen (intact)	Normal operation	N	-
Match	Ohio Blue Tip Wooden Match	--	Y	Y
Switches	120V, 96A, 50% PF	120V, 96A, 50% PF	N	--
	120V, 72A, 50% PF	120V, 72A, 50% PF	N	--
	120V, 15.2A	120V, 15.2A	N	--
Open Flame	Propane	Pilot light - water heater, furnace	Y	Y
	Natural Gas	Pilot light - water heater, furnace	Y	Y
Motor	Open, 240V, 5.4A 3/4 hp Totally enclosed, 240V, 1.4A, 1/4hp	Condenser Fan	N	N
		Evaporator Blower Motor	N	N
	Electric Drill, 120V, 2.2A	Electric Drill	N	N
Contactor	240V, 96A, 42 PF, Open	Compressor at LRA*	Y[1]	Y[2]
	240V, 35A, 77 PF, Open	Compressor at FLA	Y[3]	N
	240V, 96A, 42 PF, Top Removed	Compressor at LRA*	N	--
	240V, 20.5A, 47 PF, Open	Evaporator Motor at LRA*	N	--

* locked rotor amperage
[1] Ignition on 1st, 7th, 16th, and 20th cycles
[2] Ignition on 4th and 5th cycle
[3] Ignition only after many cycles

abnormal
abnormal
abnormal
abnormal
abnormal

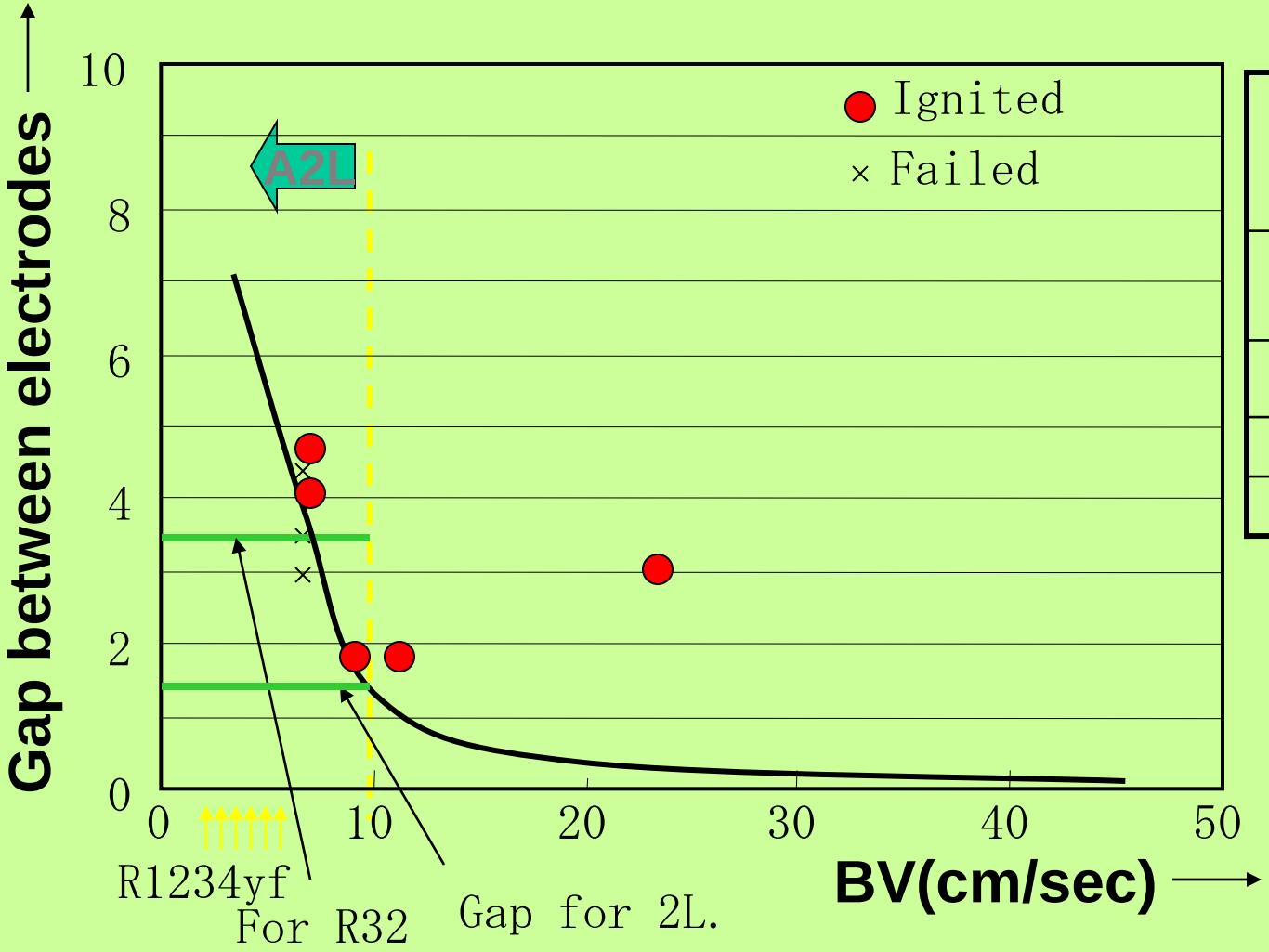
Ignition and kVA

- Up to 7.2kVA contactor did not ignite R32, but 8.5kVA in UL tests did. Further tests indicate difficulty of ignition.
- Results are not so stable and repeatable.



Quenching distance and relay cover

- Up to 4 mm gap is sufficient to prevent flame propagation of R32 from enclosure, but 1.5 mm for all A2L.



R32 Ignition test

Gap width (mm)	or hole Diameter	
	Gap	Hole
3	0/10 0/150	0/5
3.5	0/10	-
4	1/1	1/5
5	-	5/5

Hot surface

- IEC 60335-2-40 requires

  AIT –100 ° K> hot surface temperature

  AIT: Auto Ignition Temperature
- 700 ° C is proposed for A2.
- AIT test is not for hot surface limit. Much higher temperature hot surface than AIT cannot ignite even hydrocarbon.
- No objection, but confirming other data. Limiting known substance only.

Point (2) Boundary of Formula

- Only very small flammable cloud is allowed for A3. Theoretical relative calculation gives around 5 times larger amount of 2L could generate the same pressure rise.
- The same level of risk to HC equipment appears too high for real public use.

- Proposal is to increase 2 times for formula use limit and maximum charge with measures, but 1.5 times for no restriction amount.

Difference between IEC, ISO, and proposal

- $M_{max}=2.5 \times (LFL)^{(5/4)} \times ho \times (A)^{1/2}$

A2, A3		4 x LFL		26 x LFL		130 x LFL	
A2L Proposal		6 x LFL		52 x LFL		260 x LFL	
IEC 60335 –2-40	No restriction	According to formula		Mechanical Ventilation (Ventilated enclosure)		Authority Judgment	
A2, A3		4 x LFL (150g)		26 x LFL (1kg)		130 x LFL (5 kg)	
A2L		6 x LFL (1.8 kg)		39 x LFL (12 kg)		195 x LFL (60 kg)	
ISO 5149 Draft	No restriction	According to formula		Mechanical Ventilation Multi Split Specification		Authority Judgment	

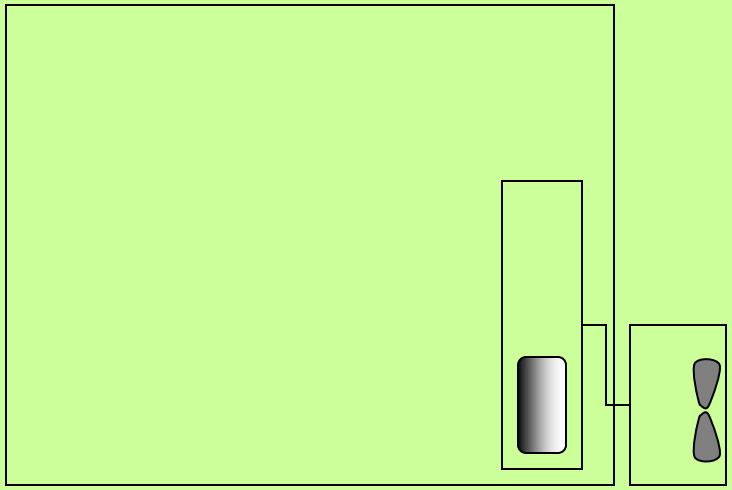
Points (3) Additional Formula

- Current formula is assuming 4 minutes to release all refrigerant.

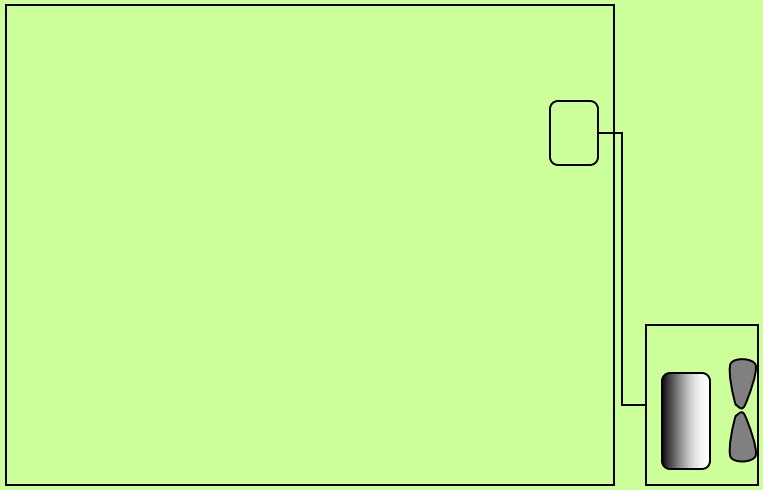
  $M_{max}=2.5 \times (LFL)^{(5/4)} \times ho \times (A)^{1/2}$
- Proposed formula is for location II of ISO5149.

  $M_{max}=0.5 \times LFL \times ho \times A$
- CFD results indicate sufficient safety except floor mount type with new formula.

Location I



Location II



1 Dimensional Dilution Calculation

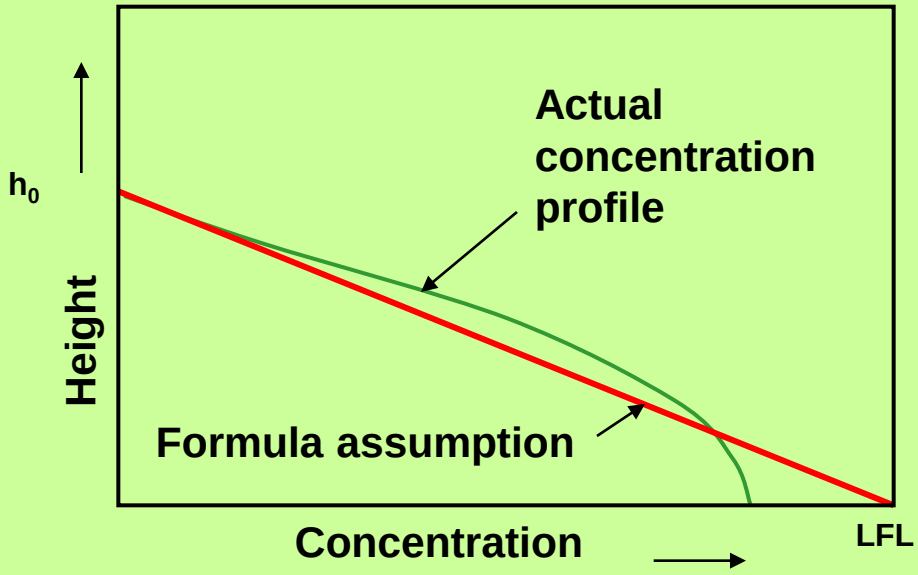
Leak Rate	250g/min		125g/min		250g/min	
Fall	R32		Propane		R1234yf	
Height	Vol%	Vel(m/s)	Vol%	Vel(m/s)	Vol%	Vel(m/s)
0.01	26.09	0.18	21.19	0.13	10.00	0.22
0.02	20.71	0.23	16.82	0.17	7.94	0.28
0.03	18.09	0.27	14.69	0.19	6.93	0.32
0.04	16.44	0.29	13.35	0.21	6.30	0.35
0.05	15.26	0.32	12.39	0.23	5.85	0.38
0.06	14.36	0.34	11.66	0.24	5.50	0.40
0.07	13.64	0.35	11.08	0.26	5.23	0.42
0.08	13.05	0.37	10.59	0.27	5.00	0.44
0.09	12.54	0.38	10.19	0.28	4.81	0.46
0.10	12.11	0.40	9.83	0.29	4.64	0.47
0.20	9.61	0.50	7.81	0.36	3.68	0.60
0.30	8.40	0.57	6.82	0.42	3.22	0.68
0.40	7.63	0.63	6.19	0.46	2.92	0.75
0.50	7.08	0.68	5.75	0.49	2.71	0.81
0.60	6.66	0.72	5.41	0.53	2.55	0.86
0.70	6.33	0.76	5.14	0.55	2.43	0.91
0.80	6.06	0.80	4.92	0.58	2.32	0.95
0.90	5.82	0.83	4.73	0.60	2.23	0.98
1.00	5.62	0.86	4.56	0.62	2.15	1.02
1.10	5.45	0.88	4.42	0.64	2.09	1.05
1.20	5.29	0.91	4.30	0.66	2.03	1.08
1.30	5.15	0.94	4.18	0.68	1.97	1.11
1.40	5.02	0.96	4.08	0.70	1.93	1.14
1.50	4.91	0.98	3.99	0.71	1.88	1.17
1.60	4.81	1.00	3.90	0.73	1.84	1.19
1.70	4.71	1.02	3.82	0.74	1.81	1.22
1.80	4.62	1.04	3.75	0.76	1.77	1.24
1.90	4.54	1.06	3.69	0.77	1.74	1.26
2.00	4.46	1.08	3.62	0.79	1.71	1.28

- Balance calculation of acceleration by gravity and density difference is performed.
- This calculation reveals that A2L dilutes quickly by gravity while hydrocarbons make considerable flammable cloud.
- Flow down velocity also prevents ignition of A2L.

Theoretical background

- For location II following formula is to avoid concentration more than LFL assuming 10kg/hr leak

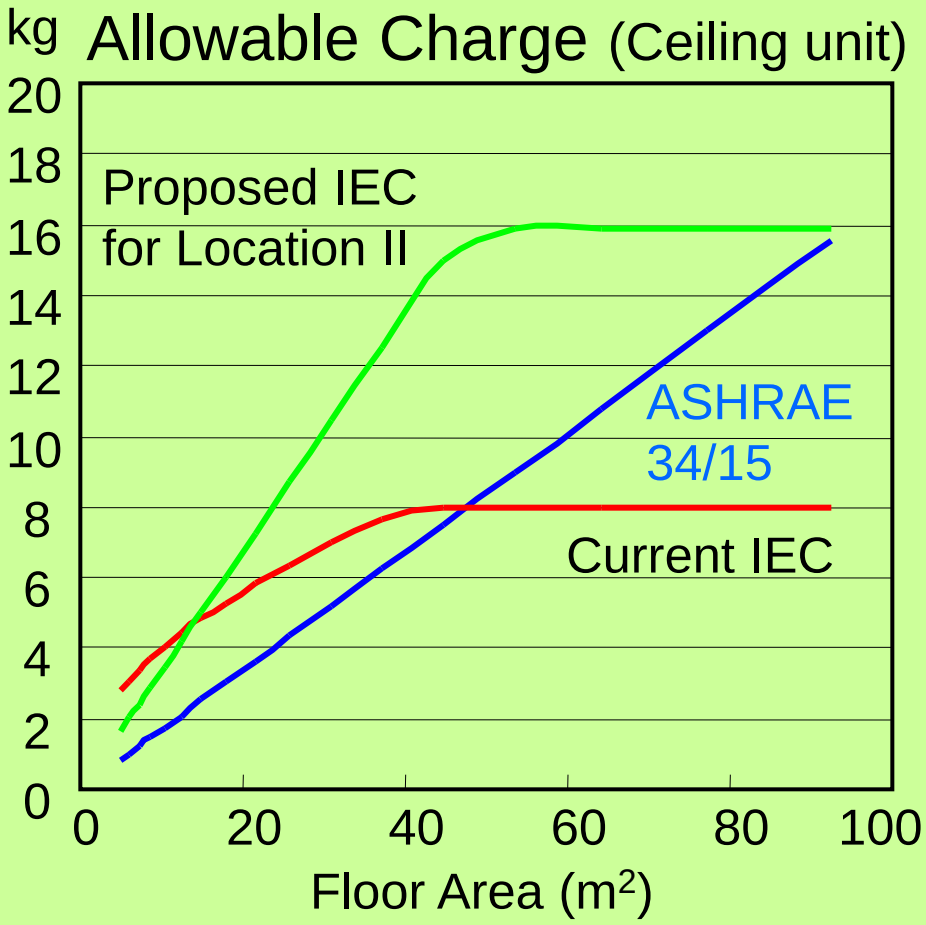
  m_{max}=1/2 x LFL x h_0 (Install Height) x A(Floor Area)
- Concentration is parabolic curve against height.
- Linear assumption gives worse profile except floor mount type.

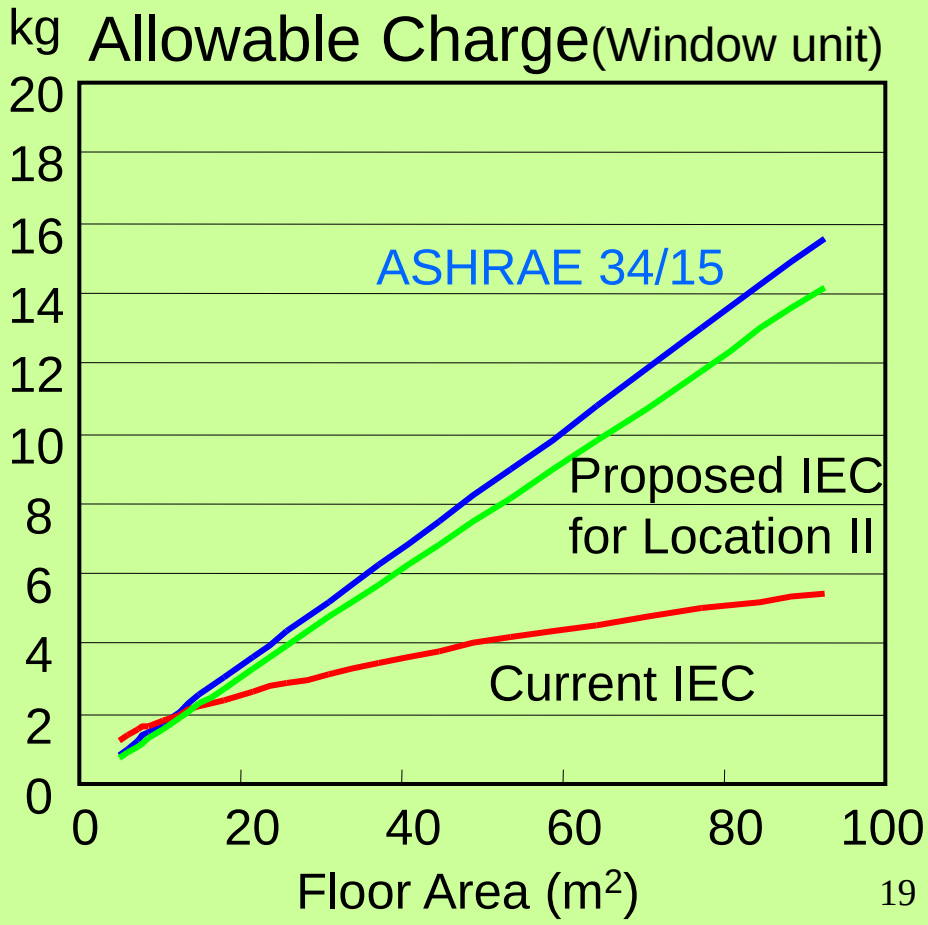


Safety Factors;
-Linear vs. Parabolic
-Wake height
-Not all refrigerant leaks out
-Opening of room
-Diffusion at molecular level
-Local air flow due to equipment and human heat and movement

Allowable Charge Examples R32, 1234yf

- At elevated installation, new formula is more permissive than ASHRAE. At lower installation, current ASHRAE is most permissive.





Point (4) Mechanical Structure

- Detachable joints at indoor are not allowed in current IEC for flammable refrigerants
- ISO5149 draft does not require permanent joints for A2L
- IEC 61D WG7 agreed to remove this requirement, but the proposal was accidentally eliminated
- IEC 61D WG9 agreed to follow ISO5149 draft.

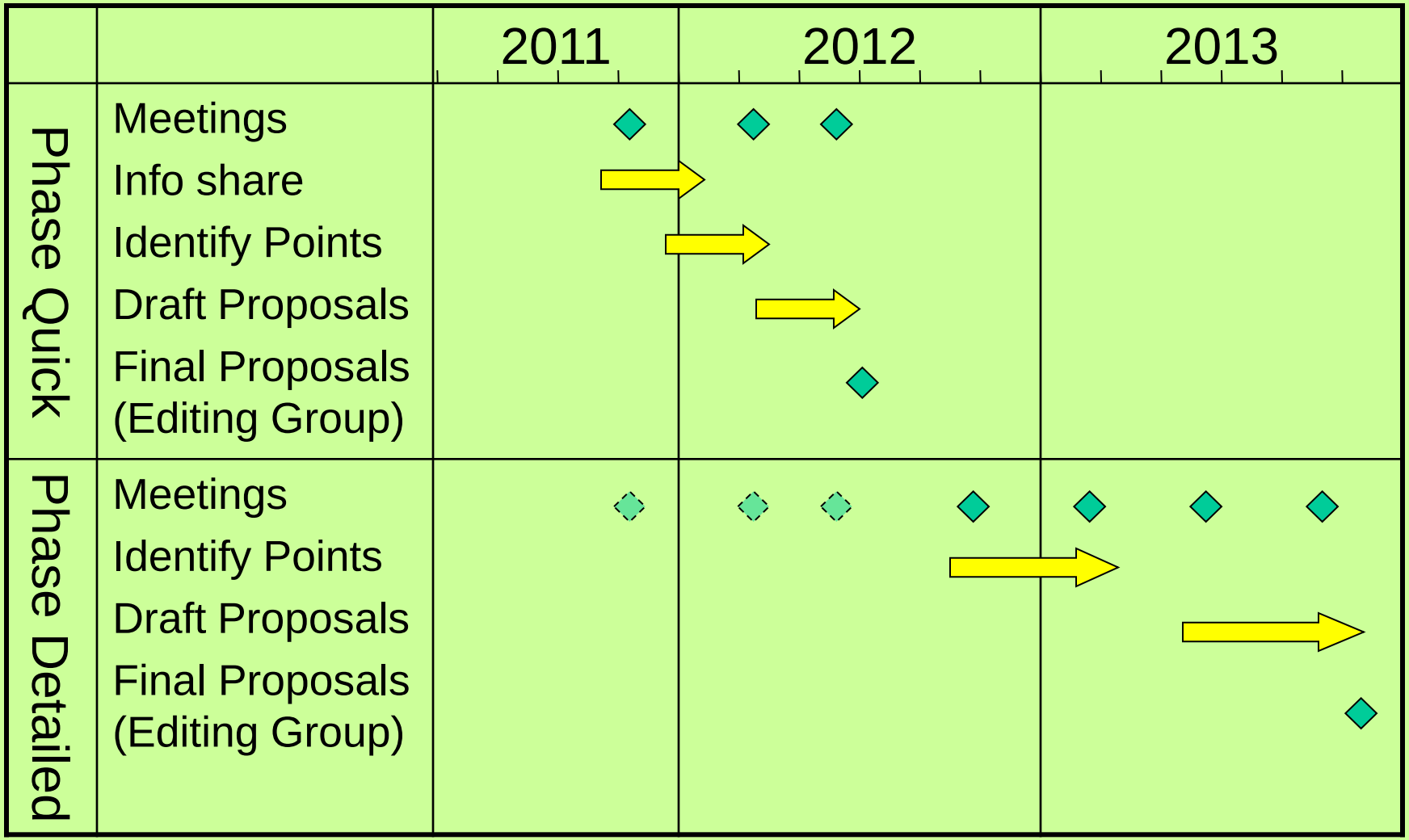
Point (5) Symbols & Marking

- Marking should be different from A3, but marking standard is not clear.
- Transportation marking from GHS that requires “extremely flammable gas: danger” marking and flame symbol may be another problem. Ammonia requires just “warning; flammable gas” marking.
- The Label to require the minimum area does not apply below 1.8 kg of A2L charge.

Point (6) Training

- Current text of Annex DD is for A3. Understanding of A2L flammability is necessary, but not easy to ignite A2L.
- Flammability risk of lubricant may be higher than A2L refrigerant.
- LFL of A2L is higher than RCL of R22. Number of people is more than ignition source of A2L. That means much higher risk of R22 toxicity than A2L flammability. Training for toxicity of R22 was very limited, but accident was rare.
- Relaxed requirements are proposed.

Proposed Schedule (Calendar year)



Developing countries require quick solution for HPMP, but requirements for large units are not so easy. Thus, 2 phase plan was established.

Conclusions

- IEC SC61D WG 9 is taking leading role to establish requirements for A2L in ISO/IEC (and EN) standards.
- Requirements for A2L are proposed and are being established in IEC SC 61D WG9 for smaller or simpler products quickly.
- Relaxation from A3 requirements appear reasonable, specifically for the following points.

  (1) Ignition Source (Switches, Contactors & Hot surfaces)

  (2) Charge Limit Boundary

  (3) Charge Limit Additional Formula

  (4) Mechanical Structure

  (5) Symbols & Marking

  (6) Training
- The standard IEC60335-2-40 will hopefully be revised according to the proposals of WG9 in one year.
- Further requirements will be developed for larger and more complex products in 2 years.

END

Thank you for your attention!