Cornerstones of proposal February 2025 BAM

This system will also work for the new battery generations, e.g. solid state, without having to introduce new numbers again

UN Numbers for cells and batteries	UN numbers for cells and batteries transported in or with an equipment	
4000	4001	Alkalimetal batteries with organic electrolyte, Division A
4002	4003	Alkalimetal batteries with organic electrolyte, Division B
4004	4005	Alkalimetal batteries with organic electrolyte, Division C
4006	4007	Alkalimetal batteries with organic electrolyte, Division X1
4008	4009	Alkalimetal batteries with organic electrolyte, Division X2
4010	4011	Alkalimetal batteries with organic electrolyte, containing free alkai metal (or containg alkali metal electrode)
	3536	Lithium batteries installed in cargo unit

Either own UN number or added to the name

Delete UN 3090/1, 3480/1, 3551/2 => max 12 UN Numbers altogether

Division	Hazard description: cells or batteries that, when subjected to the test protocol of Manual of Tests and Criteria, subsections 38.3.5 and 38.3.6 present the following hazards:	UN Numbers for cells and batteries	UN numbers for cells and batteries cells and batteries transported in or with an equipment
94X2	Thermal runaway propagation or fire, temperature increase over 20°C/20sec Cell propagation speed > 2mm/sec flammable and toxic gas	4010	4011
9X1	Thermal runaway propagation or fire, temperature increase over 20°C/20sec, Cell propagation speed < 2mm/sec flammable and toxic gas	4008	4009
94C	No thermal runaway propagation, but a flammable gas volume of less than 25l , temperature increase over 20°C/20sec (on reactive cell)=TR (thermal runaway of one cell)	4006	4007
94B *many low SoC batteries would fall in here*	No thermal runaway propagation, temperature increase over 20°C/20sec ~~but a non~~-flammable toxic gas volume of less than 0,25l	4001	4001 or 4011
94A	No thermal runaway reaction	4002	4002 or 4012

Per transport unit? Or per packging?

Is gas evernon-flammable? Test results?

Cornerstones of proposal February 2025

- Untested cells/batteries => 94 X
- Testing to allow for lower divisions in optional
- If tested for lower division, 100%SoC ist mandatory.
  Lower SoC may be tested for lower division additionally

- In chapter 2.9……:
  Consignor is responsible, that the SoC that is tested and marked is not exceeded (during transport);
  SoC must be identified in the transport document
  Test report must include information on SoC => categorisation
- Test report must contain the voltage, which the battery must be below in order to be below the tested SoC. <= for allowing controlls e.g by airport personnel

Cornerstones of proposal February 2025

Manual of tests and criteria:

- 10) last sentence: Batteries **may** be tested for classification
- 16) Re-Testing for classification is not required, if change in battery only applies to software or hardware if this does not have an influence on the test result.
- Change in design => re-testing for classification mandatory

Definition of SoC:

State-of-charge (SOC) means the available capacity in the battery expressed as the percentage of the rated capacity contained in a cell or a battery as measured by subjecting it to a load, temperature and voltage cut-off point specified by the manufacturer.???

Manual of Test and Criteria 38.3

- T1 Altitude Simulation
- T2 Thermal Test Prüfung
- T3 Vibration
- T4 Shock
- T5 External Short
- T6 Impact/Crush Test
- T7 Overcharge
- T8 Forced discharge

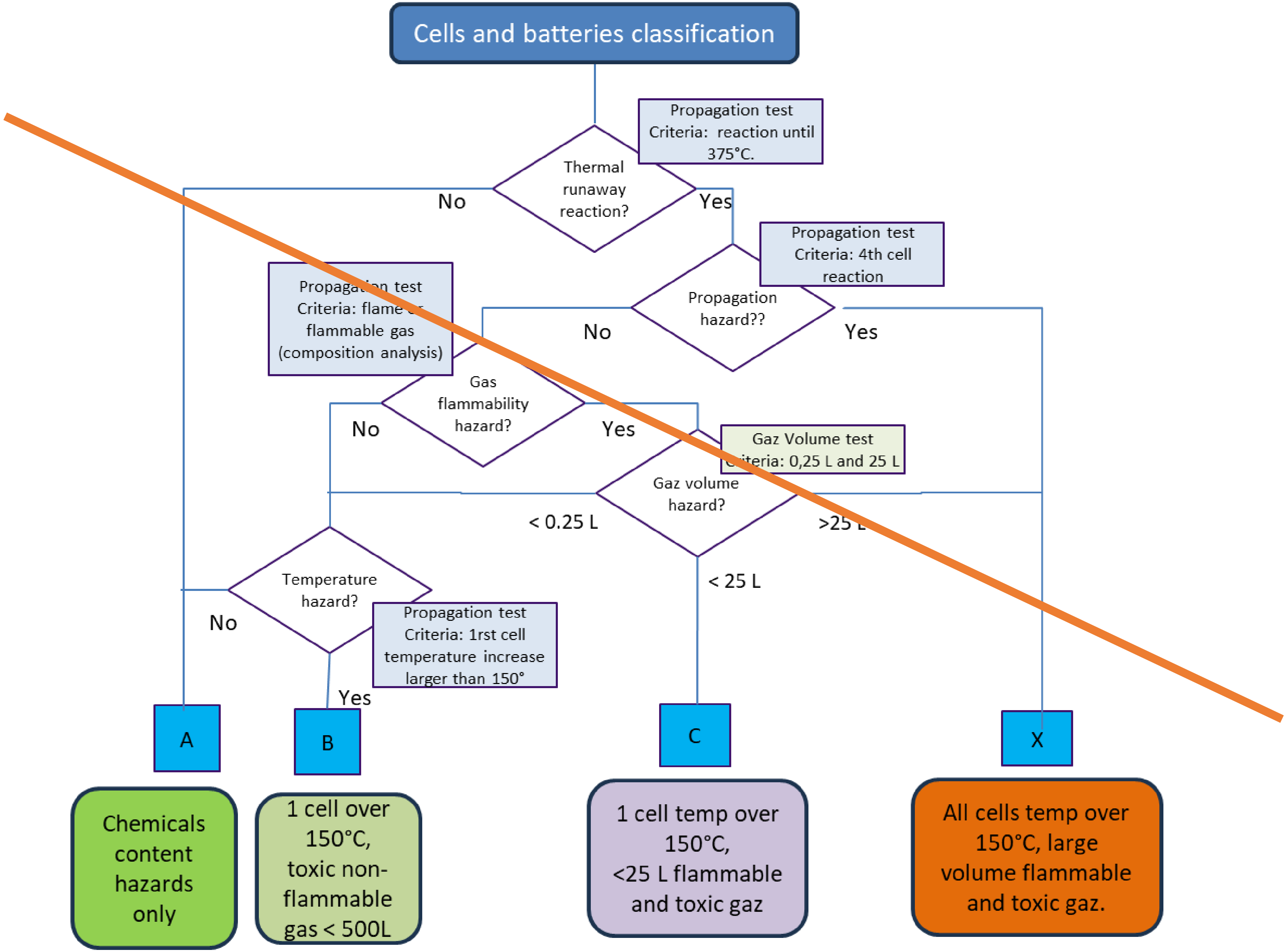
- T9 Propagationtest
- T10 cell-Gas volumne
- T11 Battery-Propagation
- T12 Batterie-Gasvolumne
- T13 Gas-flammability

Minimum safety requirements for cells/batteries in use

≠

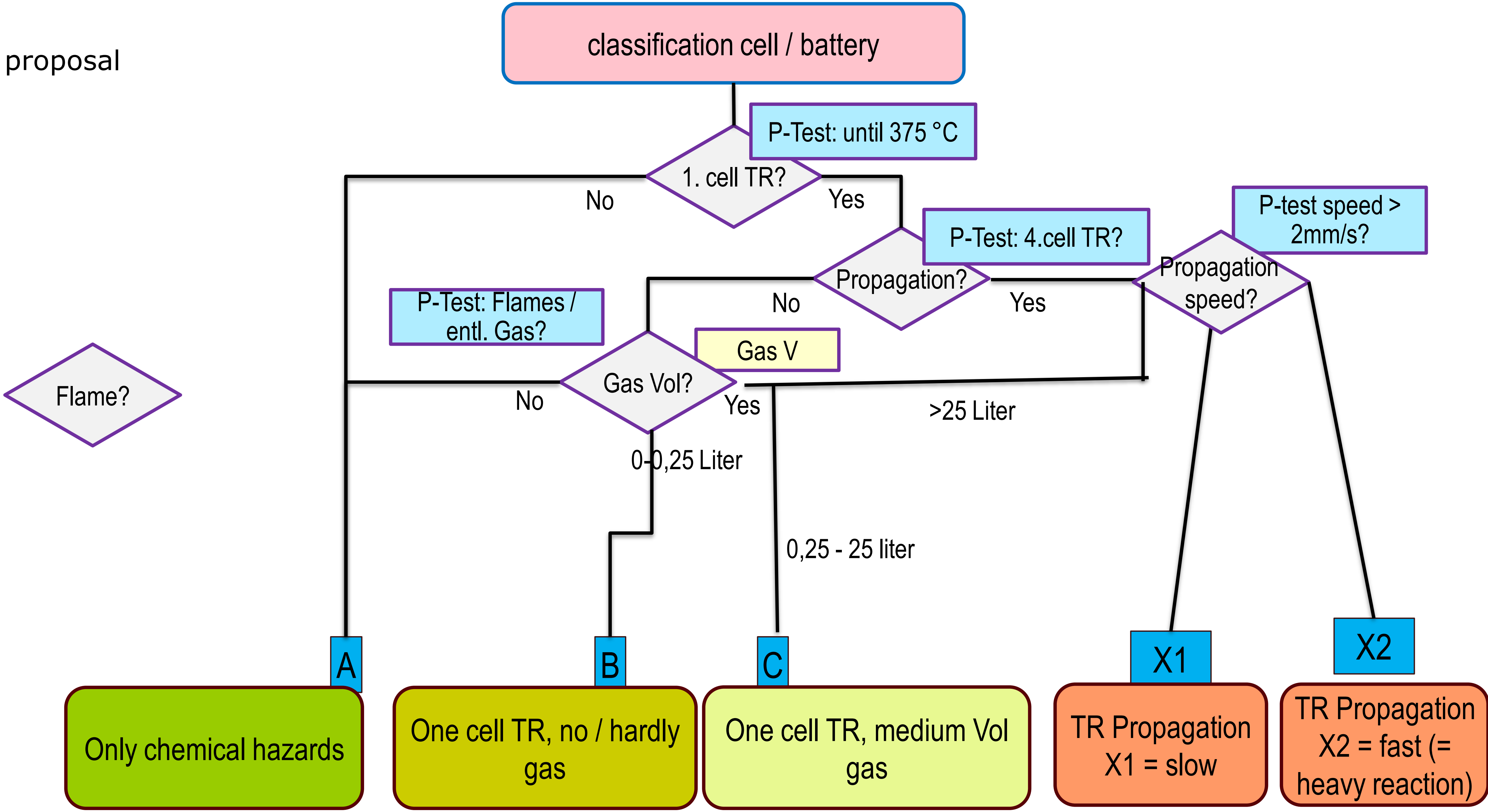
consequences / impact by therm.runaway

There should not be a conseqent numbering (T.9 ff) but a new chapter



Cells and batteries classification
Propagation test
Criteria: reaction until 375°C.
Thermal runaway reaction?
No
Yes
Propagation test
Criteria: 4th cell reaction
Propagation hazard??
No
Yes
flammable gas
(composition analysis)
Gas flammability hazard?
No
Yes
Gaz Volume test
Gaz volume hazard?
< 0.25 L
< 25 L
Temperature hazard?
No
Yes
Propagation test
Criteria: 1rst cell temperature increase larger than 150°
A
B
C
X
Chemicals content hazards only
1 cell over 150°C, toxic non-flammable gas < 500L
1 cell temp over 150°C, <25 L flammable and toxic gaz
All cells temp over 150°C, large volume flammable and toxic gaz.

New proposal



BAM will provide data to show different levels of propagation speed are needed

Cornerstones of proposal February 2025

Manual of tests and criteria:

Testing: (general)

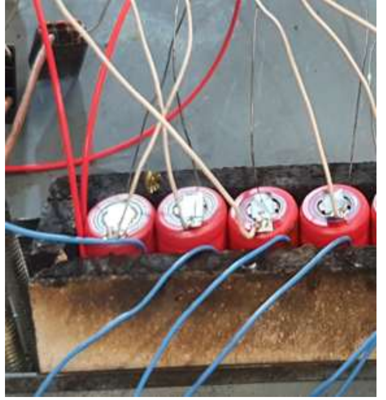
- 3 repetitions (until 3 valid result

- All tests until TR or 375°C

- Assembled battery (electrically connected) from classification tested cells needs no re-testing, when it has been verified that there is no higher hazard (through connecting)

  In this respect design characteristics include:
  - Overcurrent, overchrage, overdischarge
  - Thermally relevant battery material
  - Electrical connection causing heat transfer

Cornerstones of proposal February 2025



T.9 Cell Propagation Test

- 4 cells of a type in an row
- Placed in a cell holder (all 6 sides closed), preventing ejection of cell core
- Heater on first cell
- Minimum heating rate 10°C/min (can be increased if needed for larger cells)

Results form the test:

a) Presence of flame

- Proof by video recording

b) Test criteria for cell/battery ability to go into TR (inherent safe cells/batteries)

- Result from Propagation Test
- If first cell (100% SoC) does not go into TR until surface temperature 375°C (remained for 1 minute)
- (or heater energy > 2x energy of cell) tbd

Cornerstones of proposal February 2025

c) Maximum temperature (not needed for classification criteria in this draft)

- Thermocouples

d) Progagation from cell to cell (yes/no)

- When 4th cell goes into TR

[e) Propagation speed (not needed for classification criteria in this draft)]

Definition of TR:

150°C T jump (tbd!) clear definition missing in paper

This would exempt too many LFP cells = start T 230°C, T max ca. 400°C

Better: 20°C/20s or 30°C/30s

Cornerstones of proposal February 2025

T.10 Cell gas volumne Test

- 1 cell, initiation as in propagation test
- Complete Gas collected in a test chamber (tight) with N_2 or Ar atmosphere (=> no combustion of gas)
- Test protocol not (yet) described:
  - Gas pressure + temperature (time for stabilization)
  - Volumetric gauge

Results form the test:

a) Gas volume

- Expressed in liters at ambient (20°C?) temperature and pressure (1bar?)
- Or expressed in category:
  - No gas
  - 50 liters (100Wh)

[worst case approach UNTDG 62INF 14: 35%vol hydrogen, 30%vol CO and 30%vol organic carbonates (EC/DEC) and 4% HF]

Cornerstones of proposal February 2025

T.11 Battery Propagation Test

- Aim to identify propagation inside battery + from battery to battery
- Ignition of 1 cell (at a side position) same trigger method as T9 / or other
- Description: which is an appropriate cell
- Heating rate 10+/- 5°C
- ~~Until 350°C~~ (needs correction to 375°C)

Results form the test:

a) Presence of flame

- Proof by video recording
- Result: Battery does generate fire: yes / no

b) Maximum temperature (not needed for classification criteria in this draft)

- Thermocouples, T max which is held for 3 minutes
- Criteria: T max is < 150°C increase from when heater is stopped

Cornerstones of proposal February 2025

c) Progagation from cell to cell (yes/no)

- No propagation criteria:
  no surface temperature is > 100 °C, momentarily (?) spikes not > 200°C
  (surface at initiation cell excluded)

[d) Propagation speed (not needed for classification criteria in this draft)]

T.11b Alternative Battery Propagation Test

- Battery to battery propagation test (no more specified)
  - If battery casing is melting (e.g. plastics)
  - Or if there is no casing (e.g. module)
- **Only different criterion** for propagation: no propagation from battery to battery

Cornerstones of proposal February 2025

T.12 Battery gas volumne Test

a) Perform T.10 for 1 cell of the battery, multiply gas volumne with number of cells that have reacted in battery propagation test (or all if T.11 was not performed)
b) If cells cannot be separated: apply T.10 to full battery (i.e. in a chamber)
c) Use data from cell manufacturer, multiply gas volumne with number of cells that have reacted in battery propagation test or
d) multiply 0,5l/Wh with Wh of cells that have reacted in battery propagation test or

Results form the test:

a) Gas volume

- Expressed in liters at ambient (20°C?) temperature and pressure (1bar?)
- Or expressed in category:
  - No gas
  - 50 liters (ca. 100Wh)

Cornerstones of proposal February 2025

T.13 Cell gas flammability Test

a) Under discusion

Is this needed? Do we have tests that show, gas is sometimes not flammable?
Anyway, this will depend on the concentration. Very difficult.
Can we expect that this gas is always flammable (like the gas is always toxic)?
Instead only focus on the volume?

38.3.7~~5~~ Cell and battery test summary

The following test summary shall be made available:

Cell or battery test summary in accordance with sub-section 38.3 of the *Manual of Tests and Criteria*	
The following information shall be provided in this test summary :	
(a)	Name of cell, battery, or product manufacturer, as applicable;
(b)	Cell, battery, or product manufacturer's contact information to include address, phone number, email address and website for more information;
(c)	Name of the test laboratory to include address, phone number, email address and website for more information;
(d)	A unique test report identification number;
(e)	Date of test report;
(f)	Description of cell or battery to include at a minimum: (i) Lithium ion, lithium metal or sodium ion cell or battery; (ii) Mass of cell or battery; (iii) Watt-hour rating, or lithium content; (iv) Physical description of the cell/battery; and (v) Cell or battery model number or, alternatively, if the test summary is established for a product containing a cell or battery, the product model number.
(g)	List of mandatory tests conducted under 38.3.4 and results (i.e., pass/fail)
(h)	If applied, list of tests conducted under 38.3.5 for categorization purpose;
(i)	If applied, SOC at which the cell or battery was tested according to 2.9.4.3 ;
(j~~h~~)	Reference to assembled battery testing requirements, if applicable (i.e. 38.3.3 (f) and 38.3.3 (g));
(k~~i~~)	Reference to the revised edition of the *Manual of Tests and Criteria* used and to amendments thereto, if any; and
(l~~j~~)	~~Signature with~~ Name and title of responsible person ~~signatory~~ as an indication of the validity of information provided

Include documentation of a voltage value, the cell/battery may display at the most to be at or below the SoC used for classification
=> Make controlling/checking possible

Detailled classification sheme for specific safety goals

		"Hazard points" Road	Air	P911	Example NMC 811	Example LFP	Example NMC 811 SoC 20%	Example SIB
Max Temperature	< 400°C	1	1	1		1 1 1	1 1 1	1 1 1
	< 800°C	2	2	5				
	> 800°C	3	3	10	3 3 10			
Flame	no	0	0	0		0 0 0	0 0 0	
	Little/spark	1	1	1				1 1 1
	heavy	3	6	6	3 6 6			
Gasvolumn	< 0,25l	1	1	1	1 1 1		1 1 1	1 1 1
	0,25 < x < 1l	2	10	2		2 10 2		
	> 1l	3	20	3				
Propagationspeed	no	0	0	0			0 0 0	
	slow	4	4	4		4 4 4		4 4 4
	fast	6	5	5	6 5 5			
Sum					13 15 22	7 15 7	2 2 2	7 4 7

cassifizierung depends on safety target!

This is not to propose another system, just to show that hazards depend on the views

Safety levels of packaging for LIBs + SIBs

SV 188

No dangerous goods packaging

SP636, P903, P909

dangerous goods packaging PGr II

P908

PGr II Insulation+ leakproof

Heat insulation = negative ?
Inner packaging = negative?

Gasreleases Sand as filling, **Spacing Separation compartments**

PGr I/II flameproof material

P911

PGr I flameproof + temperature proof <100°C

Protection FROM TR impact (mitigation)

Preventing TR Initiiation in transport:

Short circut protection, preventing from movement

Some more thoughts

- New divisions and UN number shall apply to all (current + new) battery types: Li-metal, Li-ion, NA-ion, solid state electrolyte, …
- Defective cells / batteries can also be assigned to their divisions, if known. Requirements will be defined in SP 376

SPs needed (packagings to be picked from page befre)

- SP 376
  - critically defective = **very <u>high statistical risk</u>** of TR
    => if division X1/2 are critically defective => P911/LP906,
  - Normal defective = **medium risk** of TR
    Packaging to prevent outside fire (non-flammable)
  - Leaking = P908

- SP 310 Prototypes : **medium statistical risk**, P910

- New SPXXX: If alkali metal is present => marking reactive with water

- SP 188 needs to be amended such that a single packaging with 30kg does not propagate to the next => Marking + Separation, Insulation is needed in case of X1/2