Status on safety of large lithium-ion batteries in Japan

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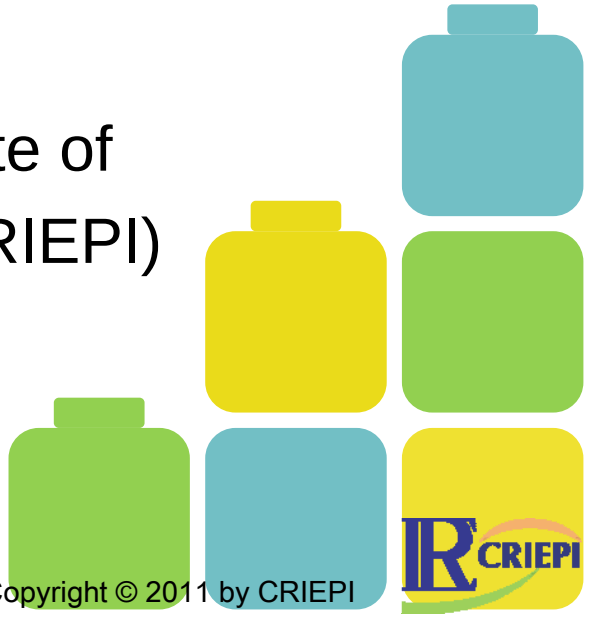
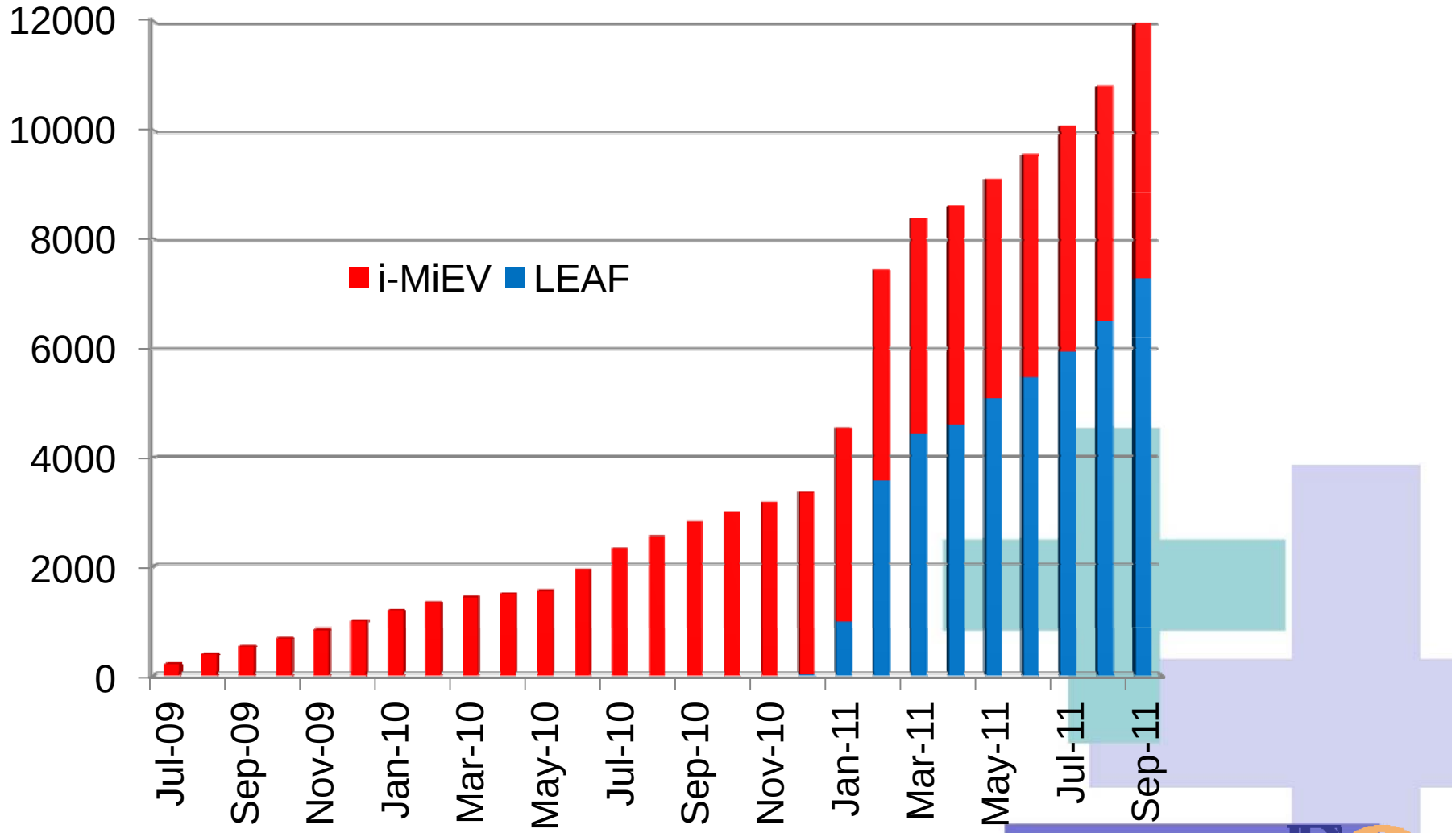


Outline

- Li-ion for EV & Stationary in Japan
  - EV sales volume in Japan
  - Unfavorable / Favorable conditions for EV
  - Stationary Li-ion “Boom” after 3.11
- Challenge to safe Li-ion battery
  - Choice of electrode materials for EV
  - New material approach in National Project (NEDO)
- Our approach
  - Pure polymer & Li-metal free “Li-ion battery”
  - Forced destruction test in NEDO project
- Summary

EV total sales in Japan



Unfavorable condition for EV

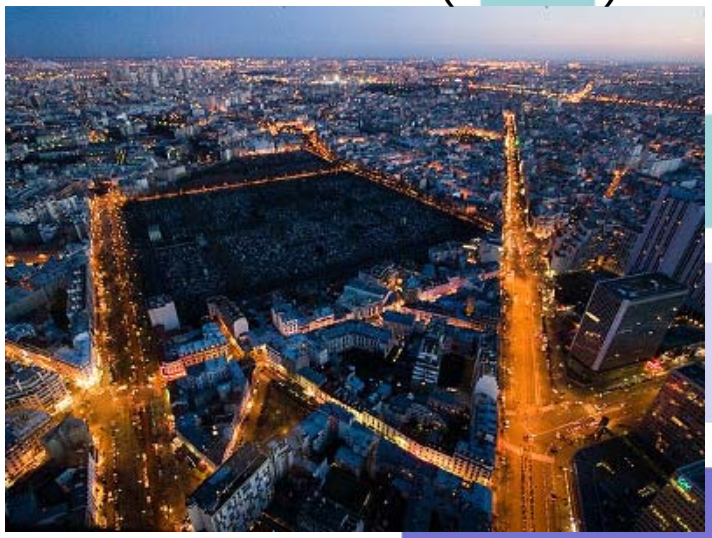
- Deficiency in electricity after 3.11
  - Actual rotation blackout in Tokyo
  - Save on electricity: 1st priority in Japan
  - No TVCF about EV until August

Donation from French Red Cross : €13M

"Merci pour support"

Earthquake & Tsunami(11/Mar)

Rotation Blackout(15/Mar)



Favorable Wind

- EV : Recognized as also EPS*
- Strong adverse wind to Nuclear power generation
  - Limited fuel choice: Fossil fuel →1st Priority
  - EV: Still lower CO_2 emission than oil
- 2nd use of EV battery →Target : Smart grid

LEAF to Home

Ref : NISSAN Web Site

*Emergency Power System

Released Stationary Li-ion after The Earthquake in Japan

KOKAM(Korea)

2.5 kWh/ €18900

BYD(China)

2.4 kWh/ € 8000

SONY

300 Wh/ € 1500

NEC

6 kWh/ € 25000

PANASONIC

3.2 kWh/ € 16800

TOSHIBA

1.6 kWh/ € 15000

Bad New for NaS*, Warning for Li-ion?

- NaS(NGK): Fire accident on 21th/Sep.
- Control fire: 2 weeks with “Sand”
- NGK
  - Stop production of NaS
  - Recommend to stop operation of NaS

- Li-ion can’t substitute such huge capacity immediately.
- But, should be in the future?
- If so, Li-ion for EV=Li-ion for LL**??

Introduction of 80MW NaS to Tohoku Electric Power Company

Planed Jan/12
Suspended Apr/12

*Sodium Sulfur Battery
**Load Leveling

Li-ion Cell Size History in Japan

- 1990's: Challenge to 100 Ah
  - SONY: Cylindrical (1996 NISSAN Prairie)
  - Panasonic: Cylindrical (2000, NEDO)
  - GSY*: Rolled Prismatic (2000, NEDO)
  - MHI**: Prismatic (2003)

  →All 100Ah cells disappeared
- 2000's: Safety is 1st priority for practical use
  - GSY: 50 Ah Prismatic (2009, Mitsubishi i-MiEV)
  - AESC***: 30 Ah Laminate (2010, Nissan LEAF)
  - TOSHIBA: 20 Ah Prismatic (2011, Honda EV-Bike)
  - MHI: 50 Ah Prismatic (2010, LL for 100 kW PV)

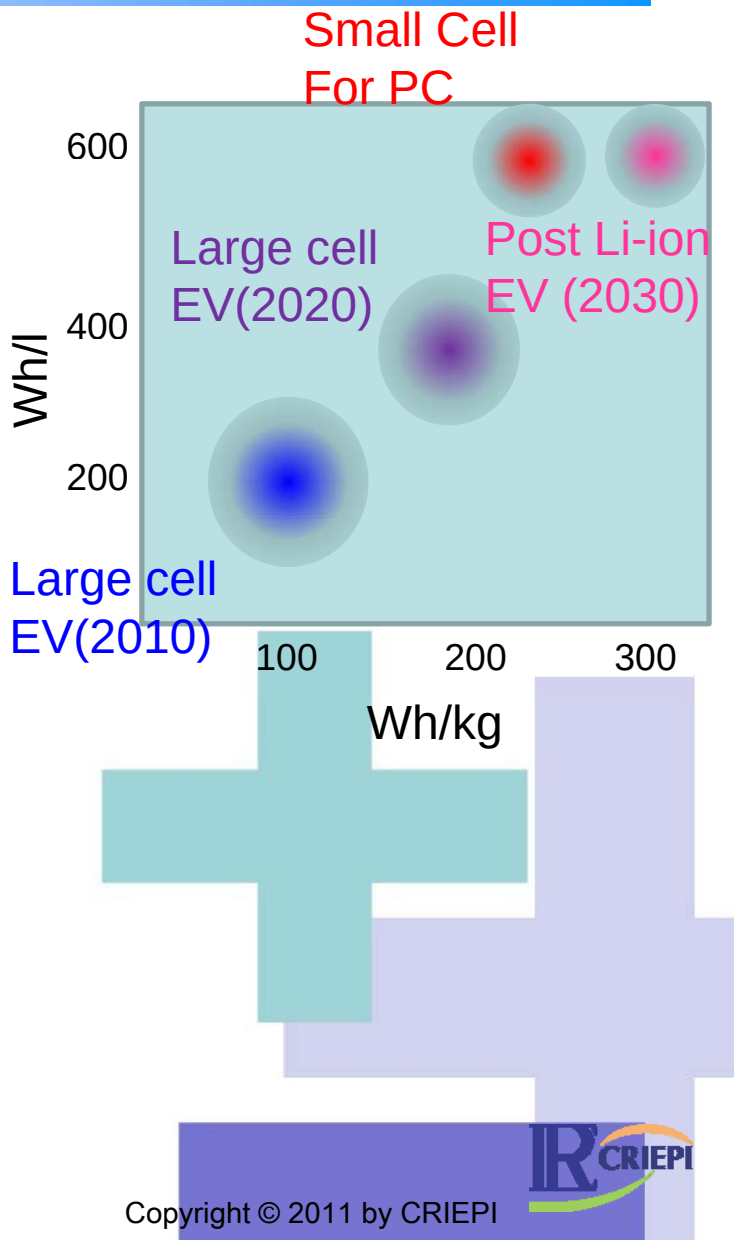
Panasonic (NEDO)
100Ah x 8 module

MHI 100Ah

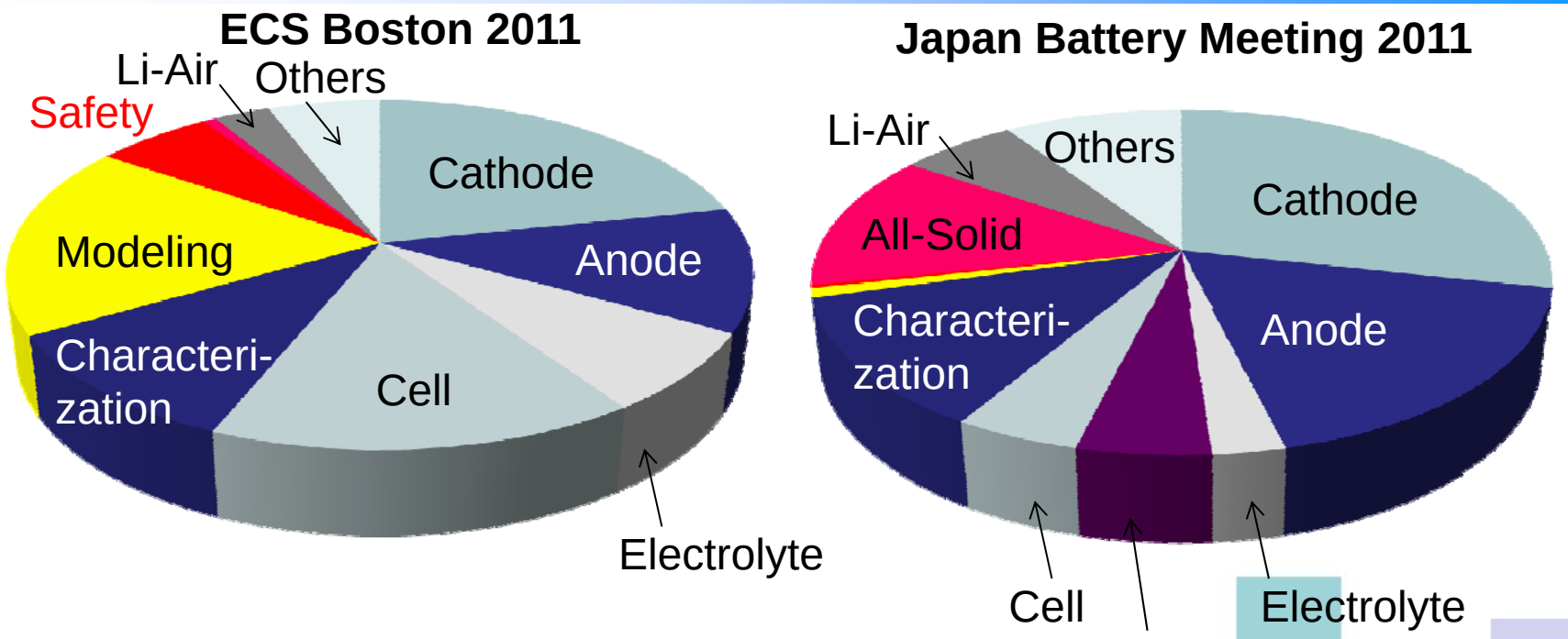
*GS-Yuasa
**Mitsubishi Heavy Industrial
***Automotive Energy Supply Corporation
(Joint company of NEC&NISSAN)

Safety Concept of EV Battery

- 2010: 100 Wh/kg
  - “Conservative” material choice: $LiMn_2O_4$, Graphite, $Li_4Ti_5O_{12}$
  - Not so high energy density
  - Not so large cell
- 2020: 200 Wh/kg
  - High Cap. Anode/Cathode
  - Electrolyte Modification
- 2030: >300 Wh/kg
  - Solvent free (TOYOTA)



Difference in Position of Safety : Donor or Acceptor?



- US(ECS) : Li-ion Acceptor
  - Cell safety and modeling are their interest
- Japan : Li-ion Donor
  - “Expected” safe materials (Ionic Liquid, Solid Electrolyte) are our interest

National Project concerning Safety

No specific national project about safety in Japan

1. Expected safe materials: Mainly focused on electrolyte
   - Solid electrolyte(Inorganic/Glass/Polymer)
   - Ionic liquid
   - Flame retardant electrolyte
   - Ceramic coated separator/electrode
2. Safety test: Battery for PHEV (10 Ah class)
   - Cell/Module/System: JARI
   - Forced destruction test: CRIEPI
3. Discussion on Regulation
   - Li-ion for residential (Tokyo Fire Department)

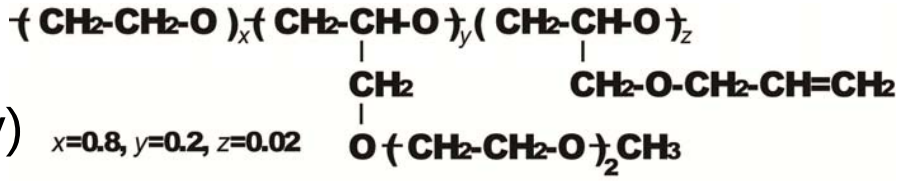
Our approach

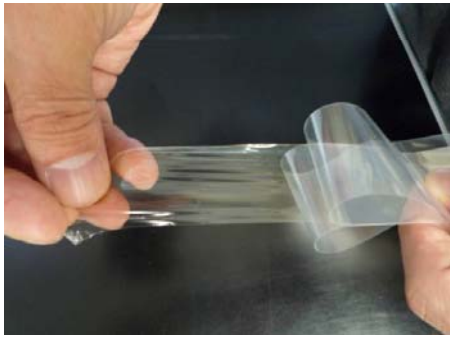
- Solution for the safe battery
- Estimation of event in abuse condition

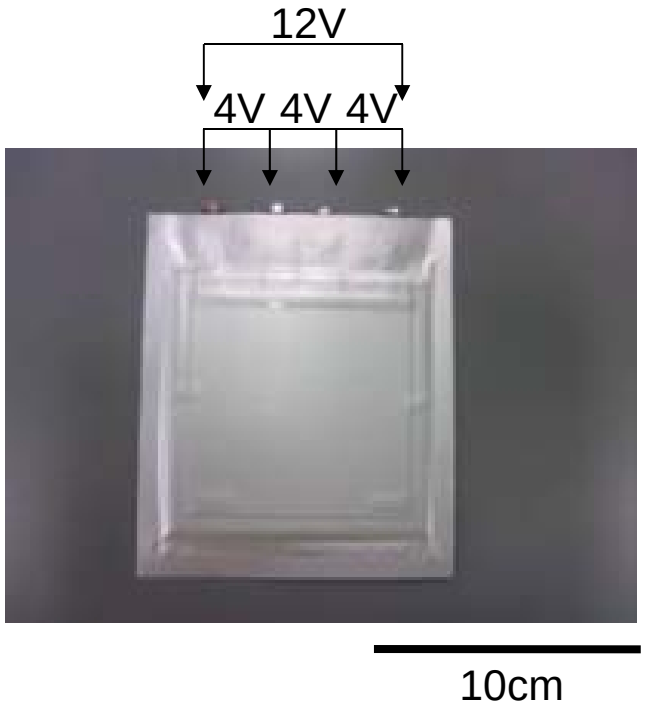
Solvent-free & Metal-free Lithium-ion Polymer Battery
[Graphite |SPE | $LiNi_{1/3}Mn_{1/3}Co_{1/3}O_2$]x3 stack in one package

- No flammable vapor (Safety)
- Printing process (Large-scale)
- High-voltage stack (High energy density)
- No Li metal (Low production cost)

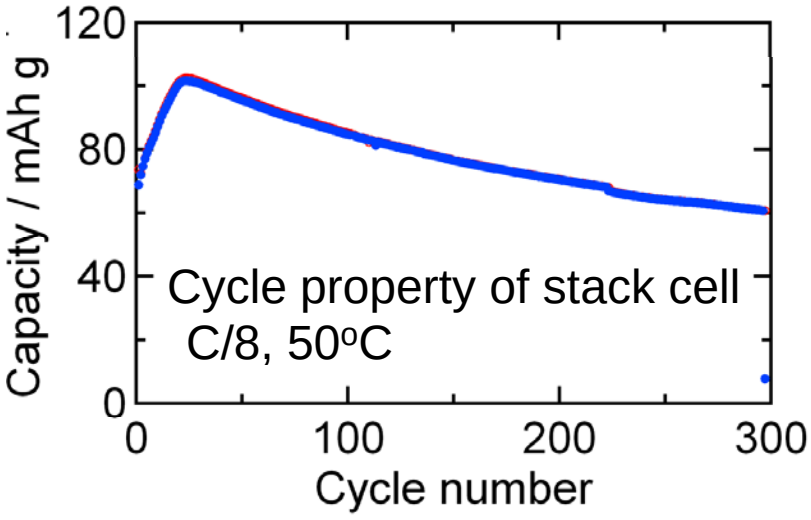
Solid Polymer Electrolyte(SPE)







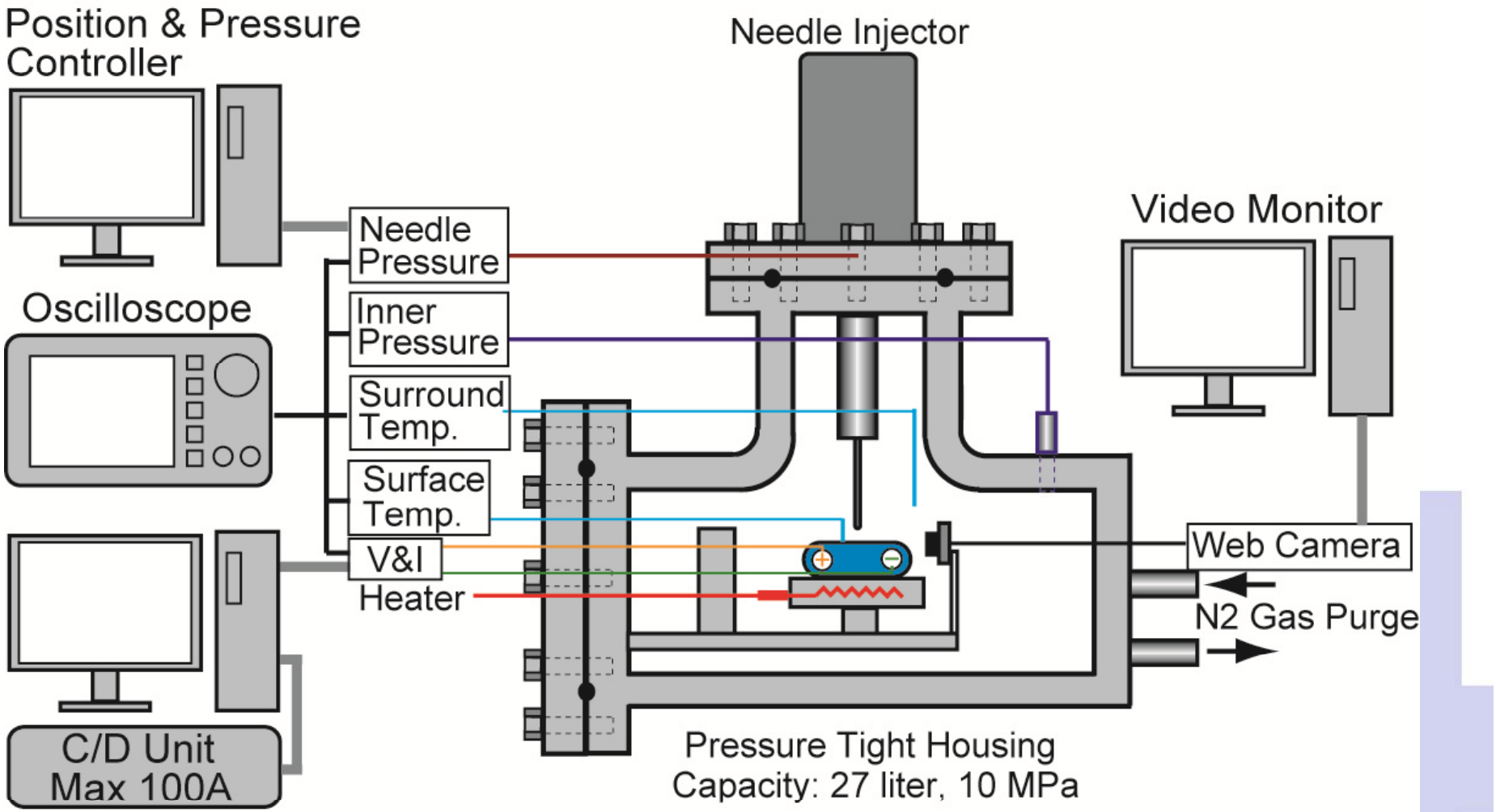
3 Stack 12 V battery (100cm^2)



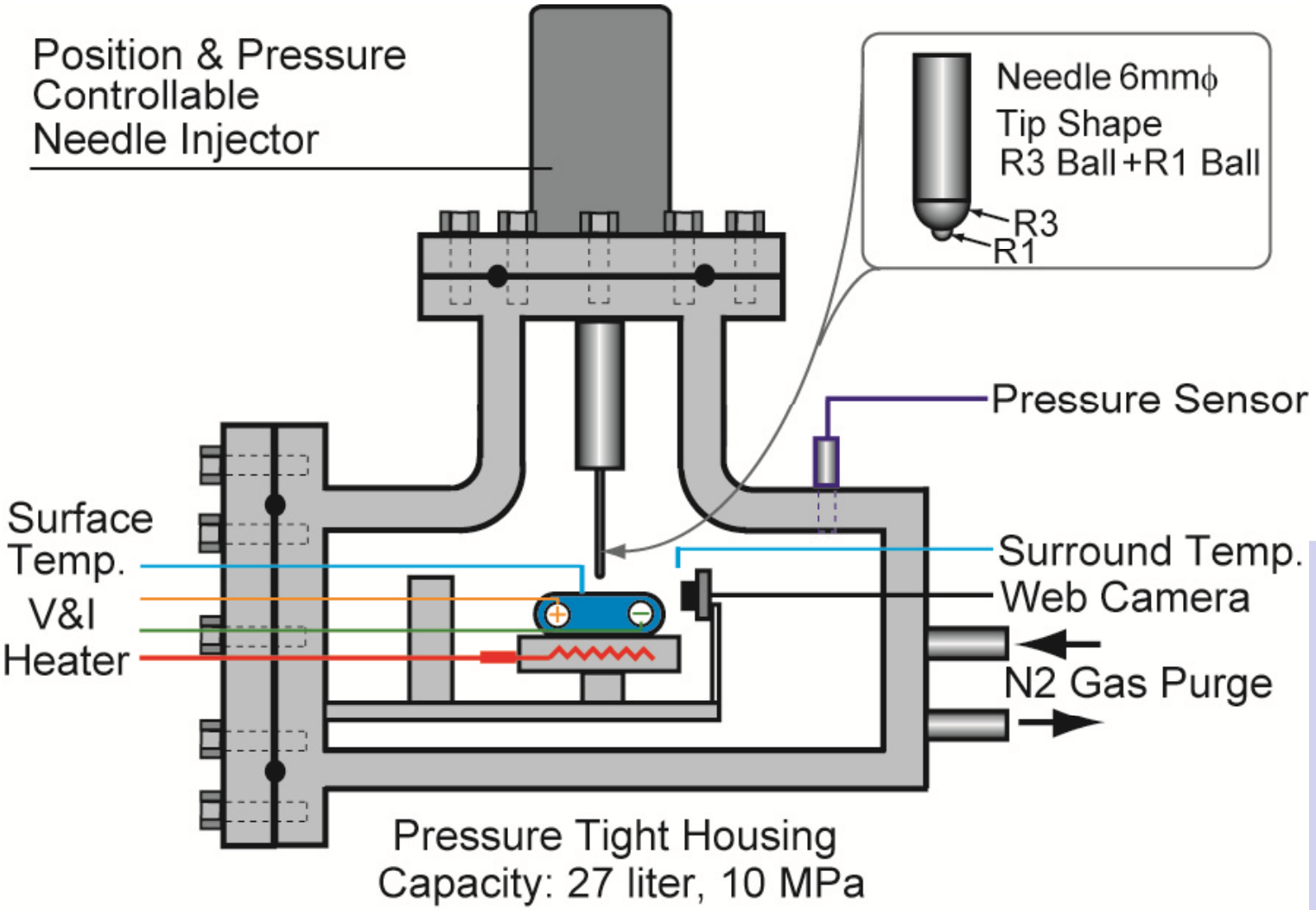
Proposed Safety Test

Test Type	Open Space Test	Accelerated Rate Calorimeter (ARC)	Forced Destruction using Pressure Vessel
Advantages	➢Simulate actual event ➢No size limitation ➢Various test ➢Visible	➢Precise Temp. of thermal runaway ➢Reaction rate estimation by Temp.	➢Precise pressure trace in event ➢Reaction rate estimation by pressure ➢Combine nail test ➢Visible
Drawbacks	➢Poor Quantitative comparison	➢Invisible ➢Size limitation ➢Difficult to nail/crash	➢Size limitation(<100Ah) ➢Can't simulate reaction with ambient air
Labs & Companies	SNL INERIS JARI	Thermal Hazards	CRIEPI

Li-ion Forced Destruction System

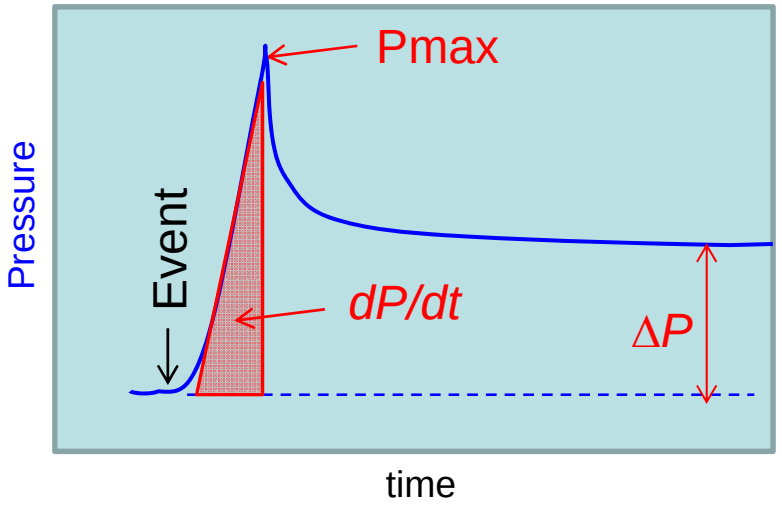


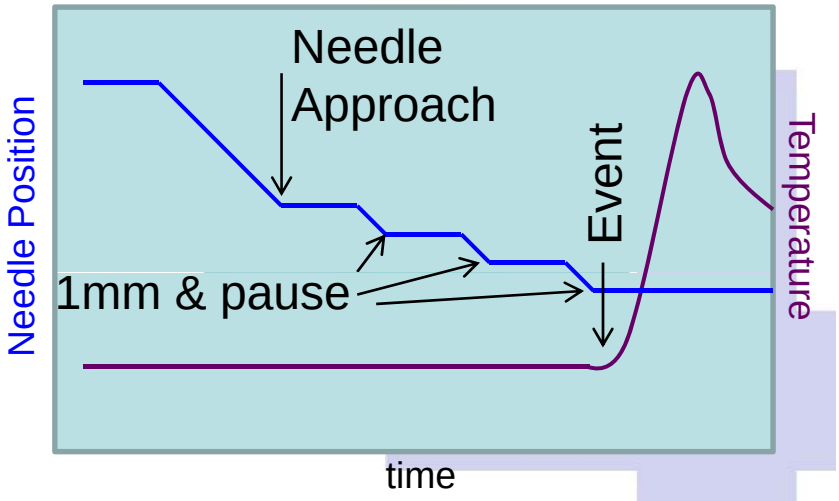
Schematic of Pressure Tight Housing



Proposed Forced Destruction Test

- Concept
  - Estimate maximum energy of cells in event
  - Not safety judgment
- Event in pressure tight housing
  - Max. pressure(*P*max) & *dP/dt* : Reaction rate estimation
  - Outgas volume estimation from the pressure before/after event (ΔP)
- Soft (blunt) & staircase Nailing
  - Simulate spot internal short circuit without using metal chip inside
- Goal
  - Compare fresh & cycled cell
  - Confirm cycled≒safe cell



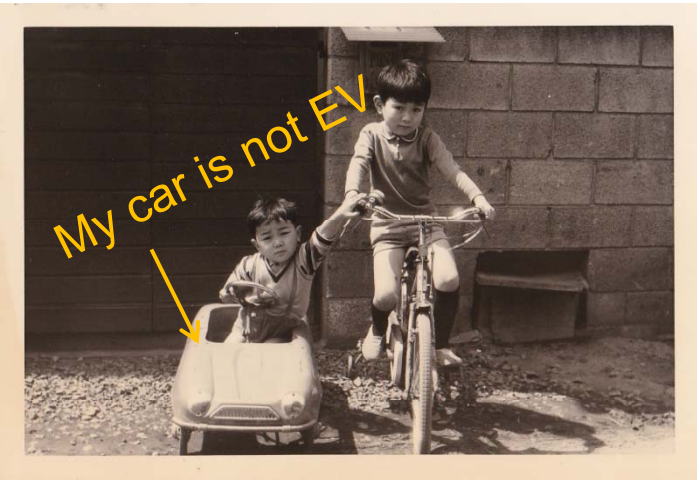


Summary : Li-ion for EV & Stationary-use in Japan

- Present
  - Conservative battery design in EV
    →Safety : Not so serious news at present in Japan
  - Stationary : Quick release after 3.11. Safety check is needed
    → Solvent free Li-ion polymer : Will be one solution
- Issues
  - Keep battery safety after cycles
    →Compare new & cycled cells using forced destruction test
- Higher energy density (for long distance EV)
  - High capacity electrodes : Lots of choice
  - Improvement of safety with high capacity electrodes
    → Electrolyte & interface design : Key technology for safety
- Innovative post Li-ion (>300 Wh/kg)
  - Academic approach, but very serious competition in Japan
  - No solution in organic liquid electrolyte?

Appendix: Science Museum in 1974

- My father explained the future technology of the 21th century
  - TV phone
  - Electric Vehicles



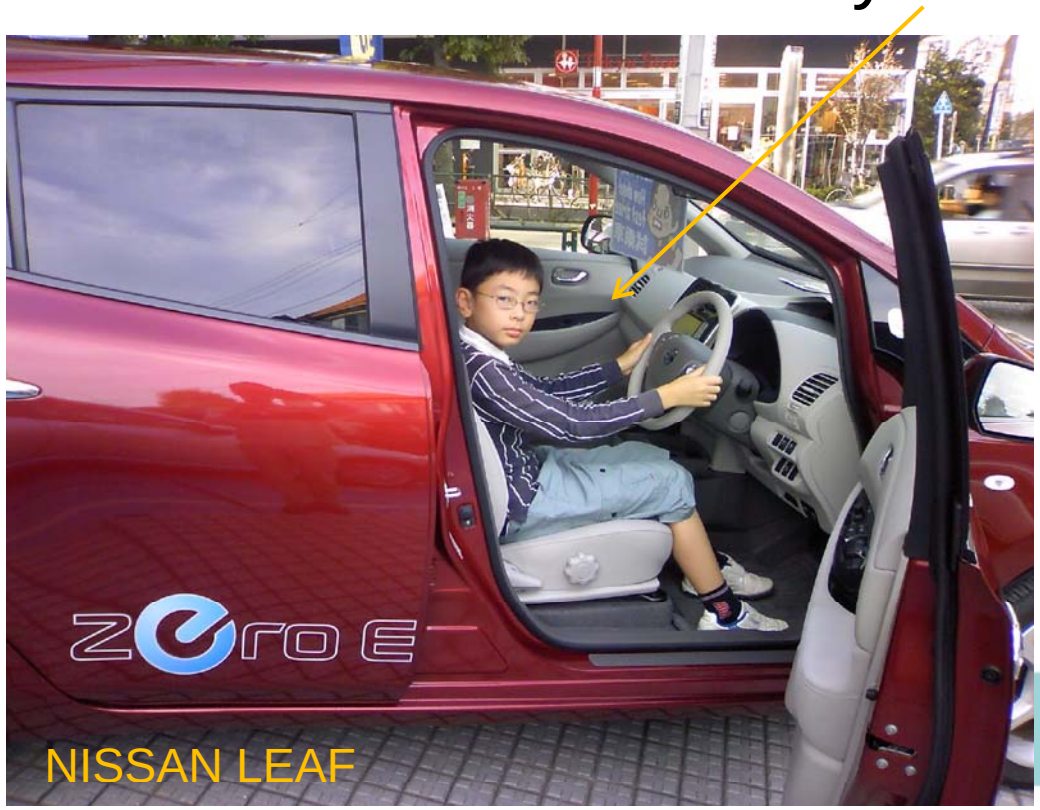
Now,

- I can enjoy “Video Chat” using smart phones.
- But, EV is just start running..

  →My father had told me a lie….

But, I still have a dream..

- I don’t want to tell a lie to my son again.



Merci.

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