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Impact of Different Laboratory Test Conditions on Float Charging Life at Elevated Temperatures for VRLA Batteries

Henry Zhu / Hong Cai

21st ABC, Sabah, Malaysia
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Test Conditions & Features	
Drying Oven	Temperature controlled. No humidity control; humidity fluctuates with ambient conditions.
Water Bath	Temperature controlled by immersion in water. Batteries partially immersed, with terminals / top surface exposed.

Defined Testing Conditions for Accelerated Life/Endurance Testing at Elevated Temperatures in Standards

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Norma	Test Condition	Applicable Batteries
SAE (J2801,J240…)	water bath	SLI flooded/AGM
VDA 2010-03		SLI AGM
VW 75073-2020		SLI AGM/EFB
GMW 3092-2007		SLI
IEEE 535-2013	no definition of heating media, no definition of R.H	flooded standby
GB/T/ 19638.1-2014		VRLA standby battery
5008.1-2013		SLI
22473.1-2021		ESS battery
BS 6290-1997	hot air enclosure, no definition of R.H	VRLA standby battery
JISC 8704-2-1 2006	hot air enclosure, R.H＜35%	VRLA industry battery
EN 61056-1	hot air enclosure, R.H＜36%	
IEC 60896-21	hot air enclosure, R.H＜35%	VRLA standby battery

VRLA Float Life Test (A) Comparison: Water Bath vs. Drying Oven

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Test Standard： IEC 60896

Test Conditions：

- ✓ Temperature: at 55±2℃
- ✓ Test Duration: 42 days = 1 test unit (cycle)

  after each test unit (cycle), C_3 is checked, testing continues until C_3 reaches less than 80% of initial capacity
- ✓ Relative Humidity (RH): recorded but not controlled

  -- drying oven RH: 5%~15%;

  -- water bath ambient RH (above bath): ~65%;
- ✓ Float Voltage: 2.27V ± 0.01V/cell

Test Units： 2V 200Ah (C10) AGM VRLA cells with ABS containers

- ✓ Water Bath: 6 units (designated WA1-WA6)
- ✓ Drying Oven: 6 units (designated DA1-DA6)

Monitored Parameters： Battery weight change (water loss), internal resistance change, C_3 capacity.

Results： Presented in Figure 1.2.3

VRLA Float Life Test (A): Water Bath vs. Drying Oven Comparison

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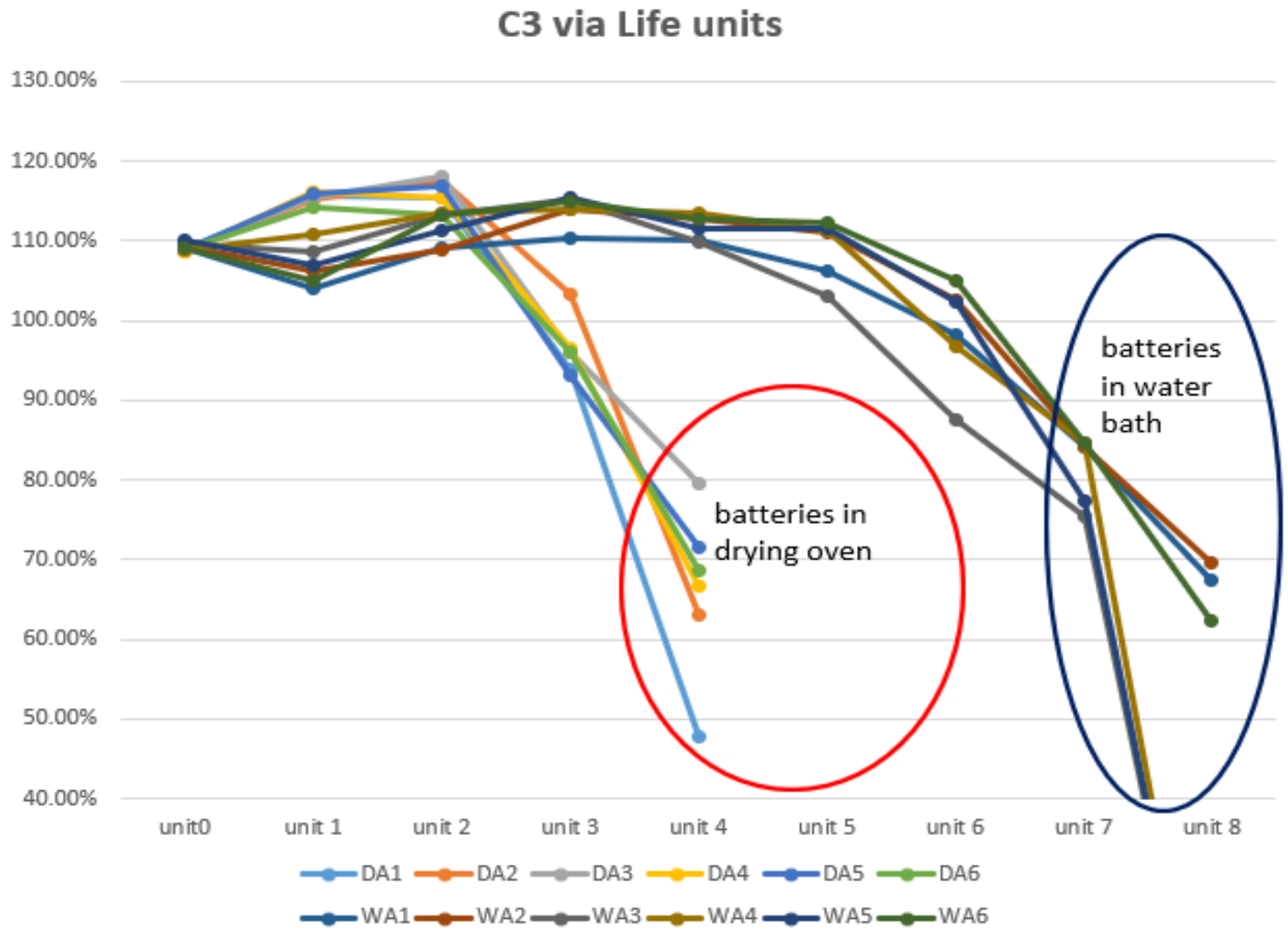
Fig. 1



VRLA Float Life Test (A): Water Bath vs. Drying Oven Comparison

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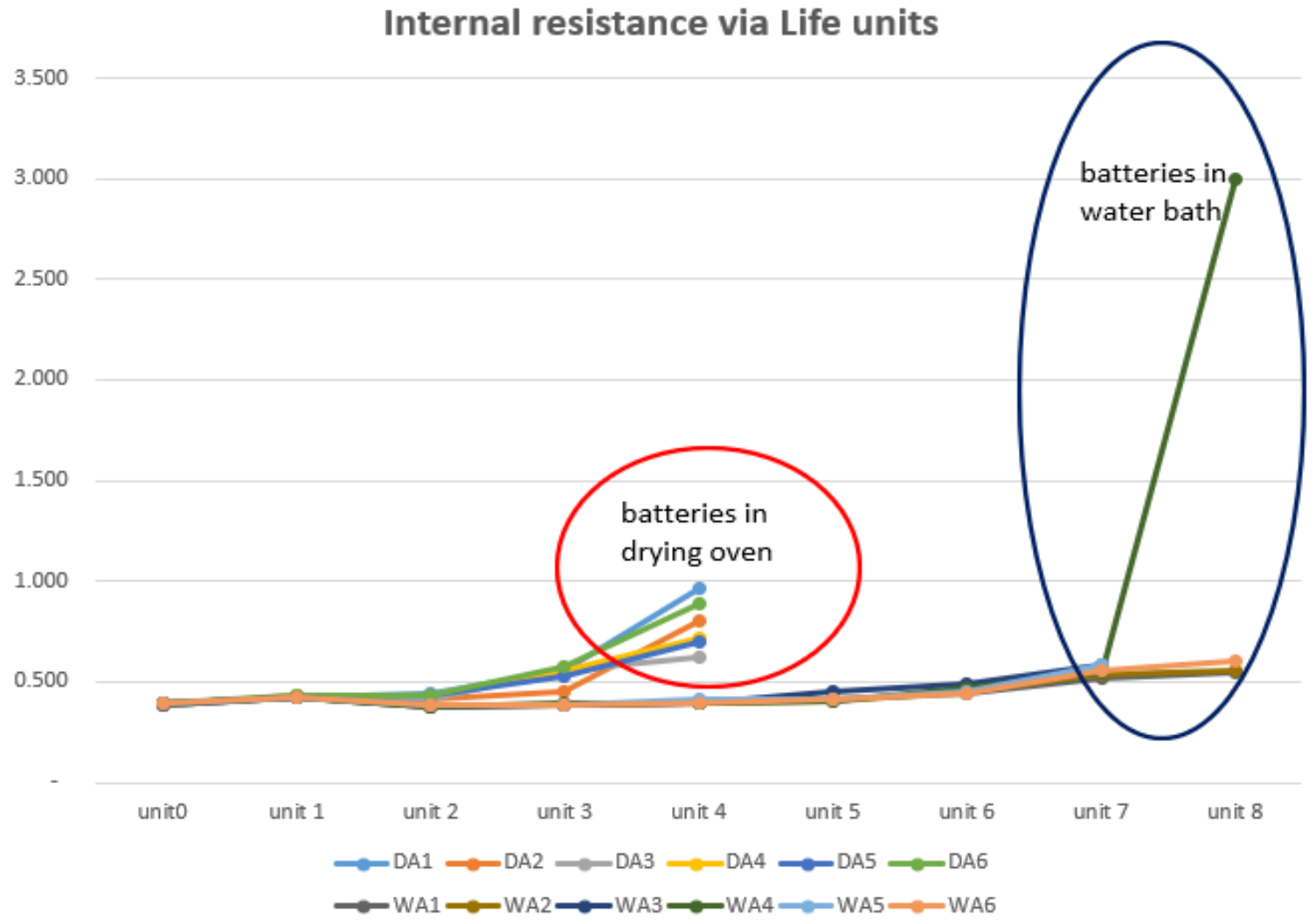
Fig. 2



VRLA Float Life Test (A): Water Bath vs. Drying Oven Comparison

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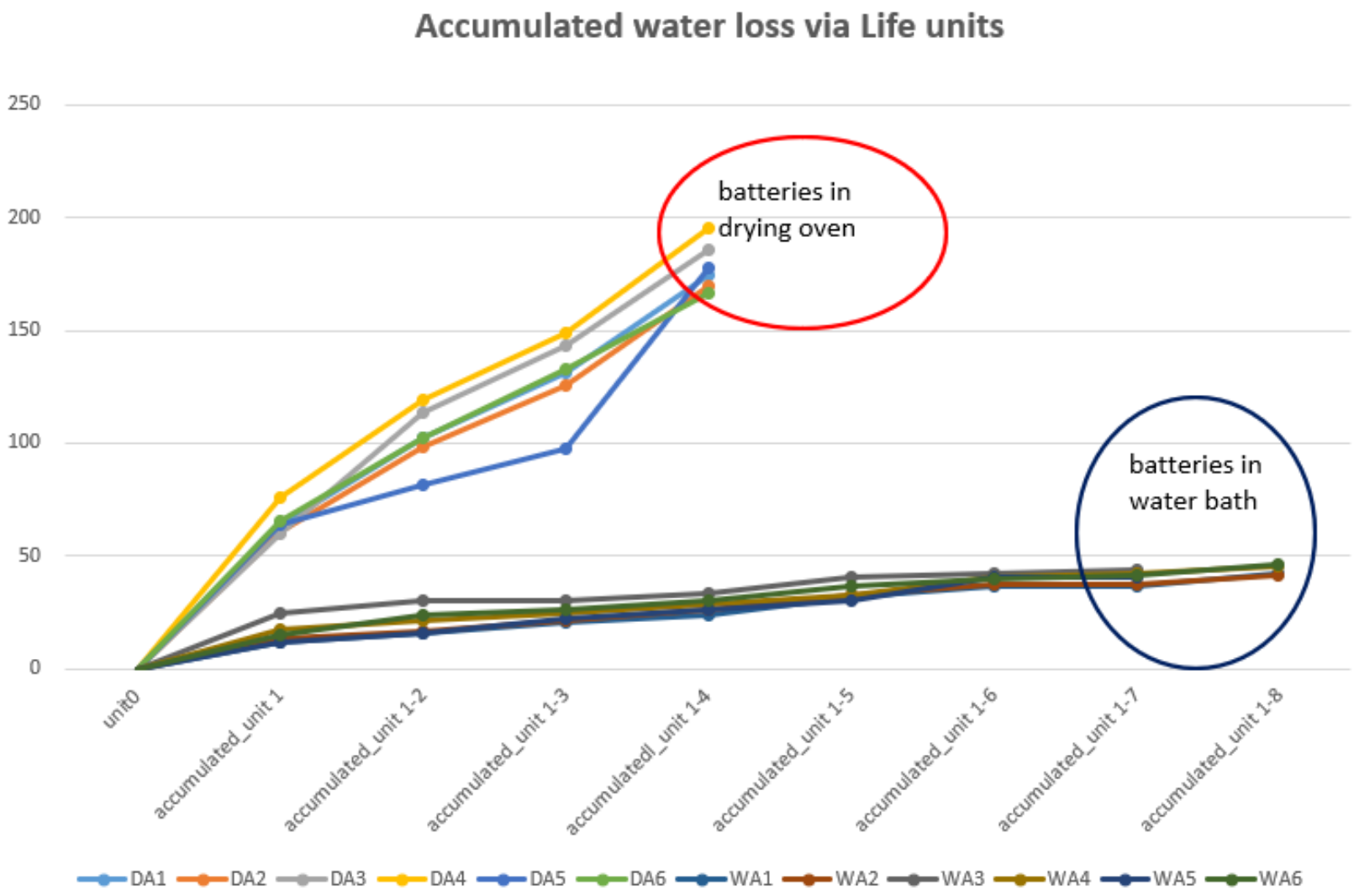
Fig. 3



VRLA Float Life Test (P): Water Bath vs. Drying Oven Comparison

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Test Unit:

- ✓ 2 × 12 V 110 Ah (C10) AGM cells with PP containers
- ✓ 2 units in water bath (designated WP1-WP2)
- ✓ 2 units in drying oven (designated DP1-DP2)

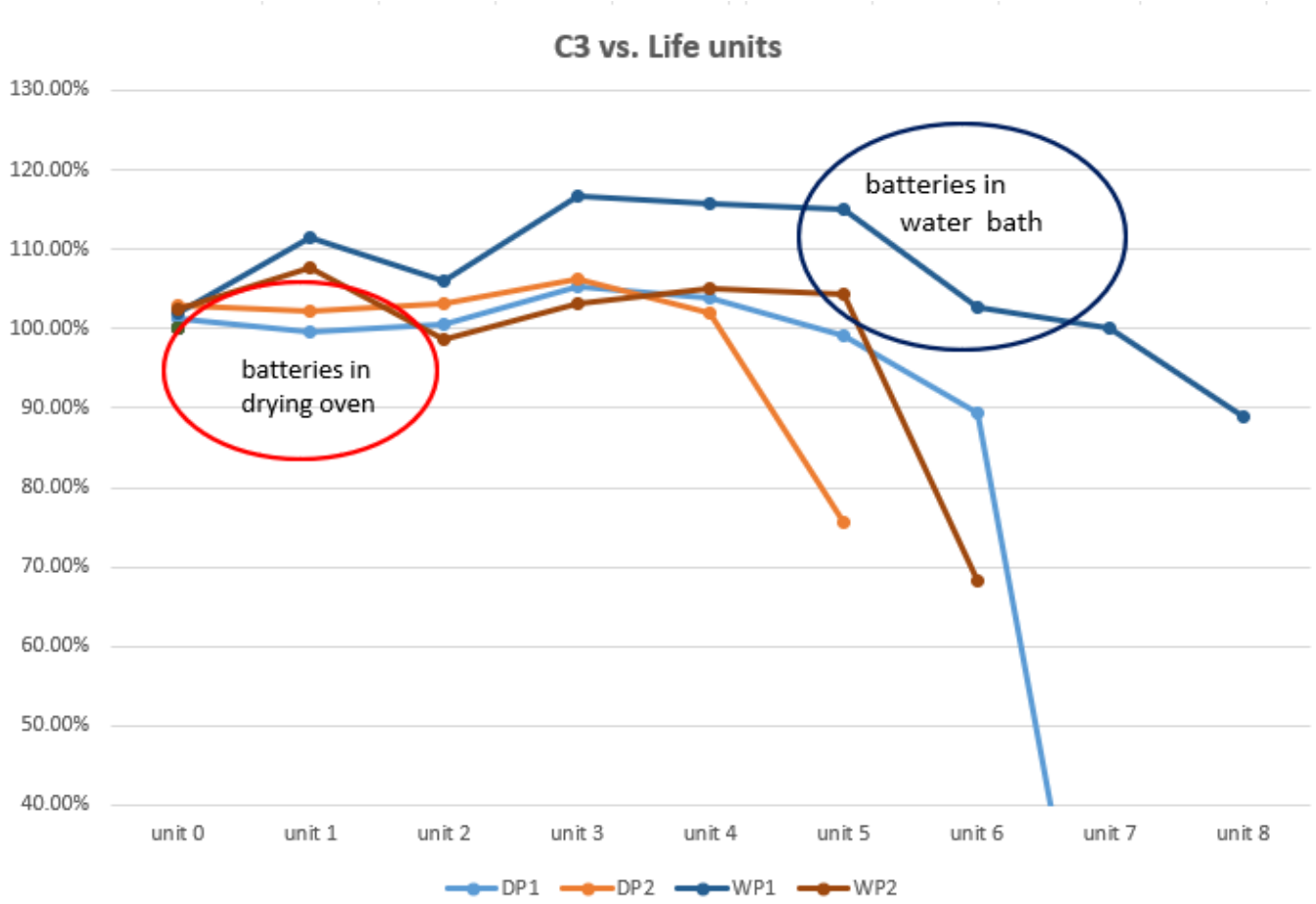
Monitoring Parameters:

1. Water loss (weight change)
2. Internal resistance change
3. C_3 capacity

Results:

Performance trends shown in Figures 4, 5, and 6

Fig. 4



VRLA Float Life Test (P): Water Bath vs. Drying Oven Comparison

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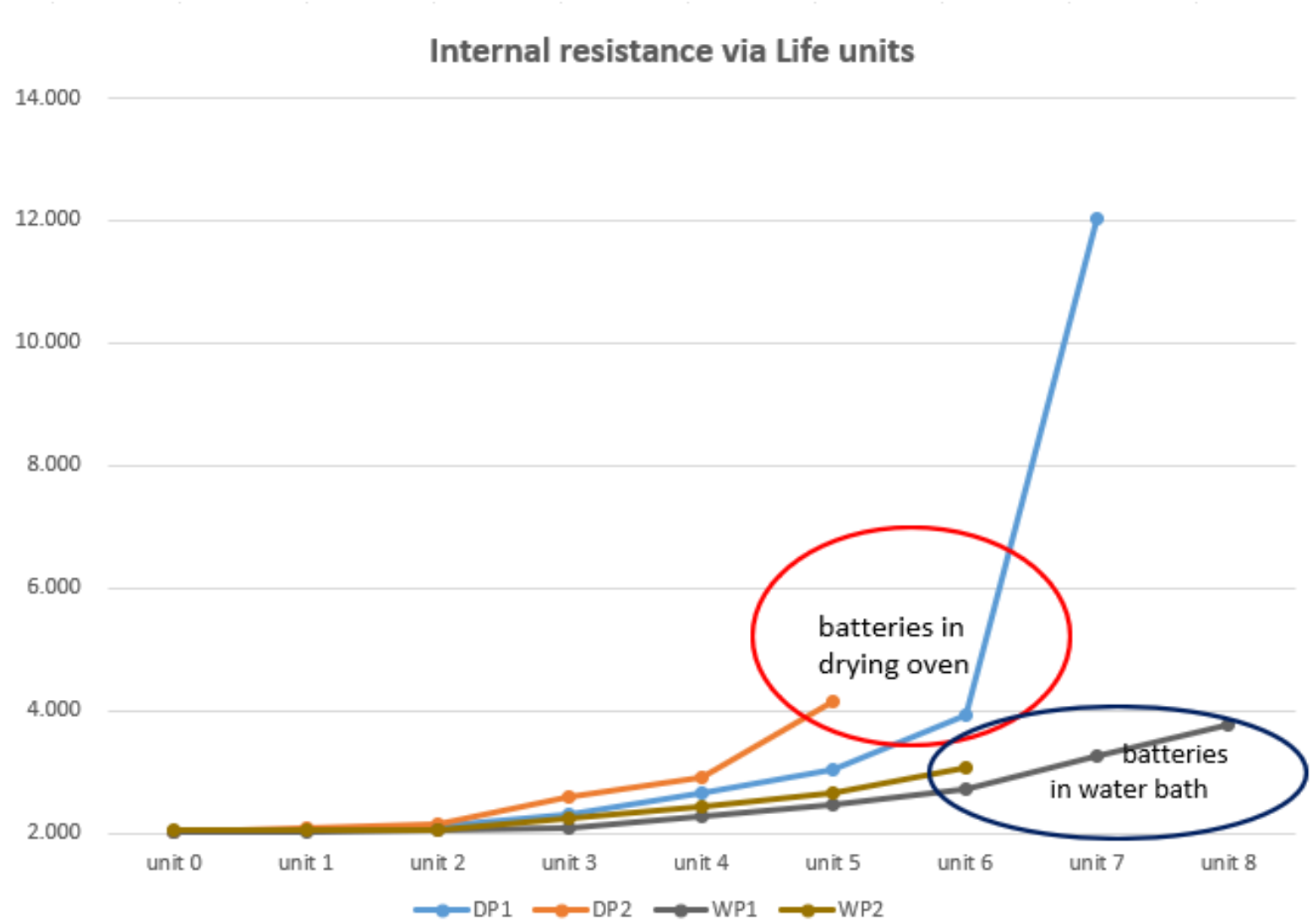
Fig. 5



VRLA Float Life Test (P): Water Bath vs. Drying Oven Comparison

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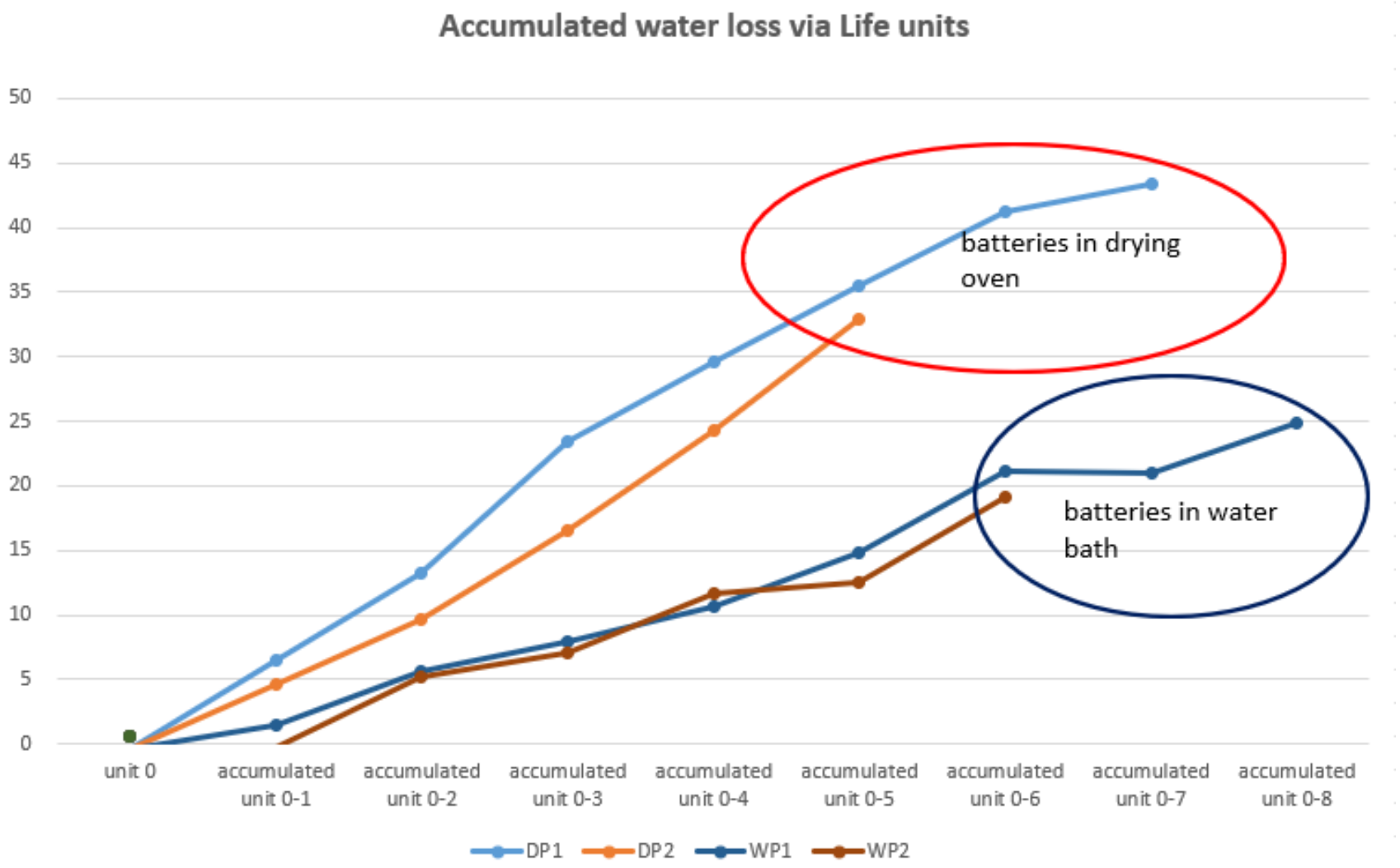
Fig. 6



Results

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- ✓ Life in water bath conditions is significantly longer.
- ✓ Water loss in water bath conditions is significantly lower.
- ✓ The increase in internal resistance under water bath conditions is significantly slower.
- ✓ Variations in water bath tests are significantly smaller (both between batches and among samples within the same batch).
- ✓ These results are consistent across both AGM and gel batteries, as well as for both ABS and PP materials; they also apply to both 2V cells and 12V batteries.
- ✓ The results are based on 7 batches of tests, with a sample size of 25 pieces per batch (totaling 50 pieces) :

Test batch	1	2	3	4	5	6	7
Sample size	6*2	4*2	1*2	2*2	6*2	3*2	3*2
Plastic material	ABS	PP	PP	ABS	ABS	PP	ABS
Type of VRLA	AGM	AGM	AGM	gel	gel	AGM	AGM
Voltage (V)	2	12	12	2	2	12	2

Correlating test results with field performance

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Our field investigation data show performance consistently superior to drying oven tests yet slightly inferior to water bath tests.

This performance gap is likely attributable to RH levels encountered in actual service conditions:

- desert climate: R.H ＜20%
- Normal European weather condition: R.H 42%~70%
- clouds/fog: R.H ~100%
- humid air: R.H ~80%
- Wuhan: R.H 45%~90%

Batteries used in most standby applications are typically installed indoors and are less likely to encounter the extremely low humidity environments simulated in drying oven tests, which result in increased water loss.

Result discussion (Ⅰ)

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Humidity in a drying oven is influenced by several factors:

a. Outdoor humidity and temperature;

b. Indoor conditions: temperature and indoor humidity (when the air conditioner is switched on, or when water tanks are nearby, indoor humidity may differ significantly from outdoor humidity);

c. Sealing and air exchange of the drying oven;

d. The humidity in a drying oven at 55°C fluctuates between 5% and 15% RH, depending on environmental humidity.

(see Figures 7, 8)

Result discussion (I)

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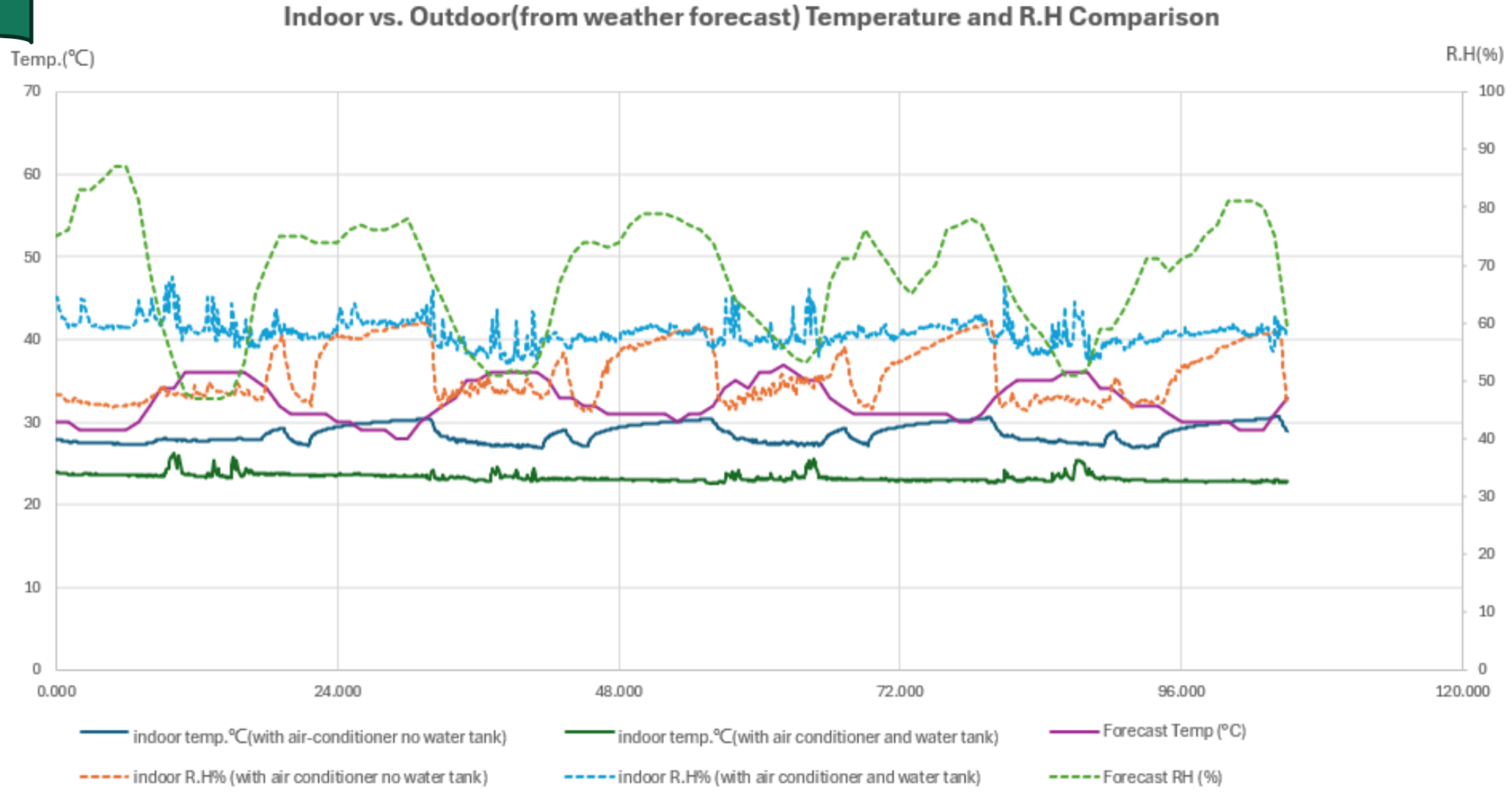
Fig. 7



Result discussion (Ⅰ)

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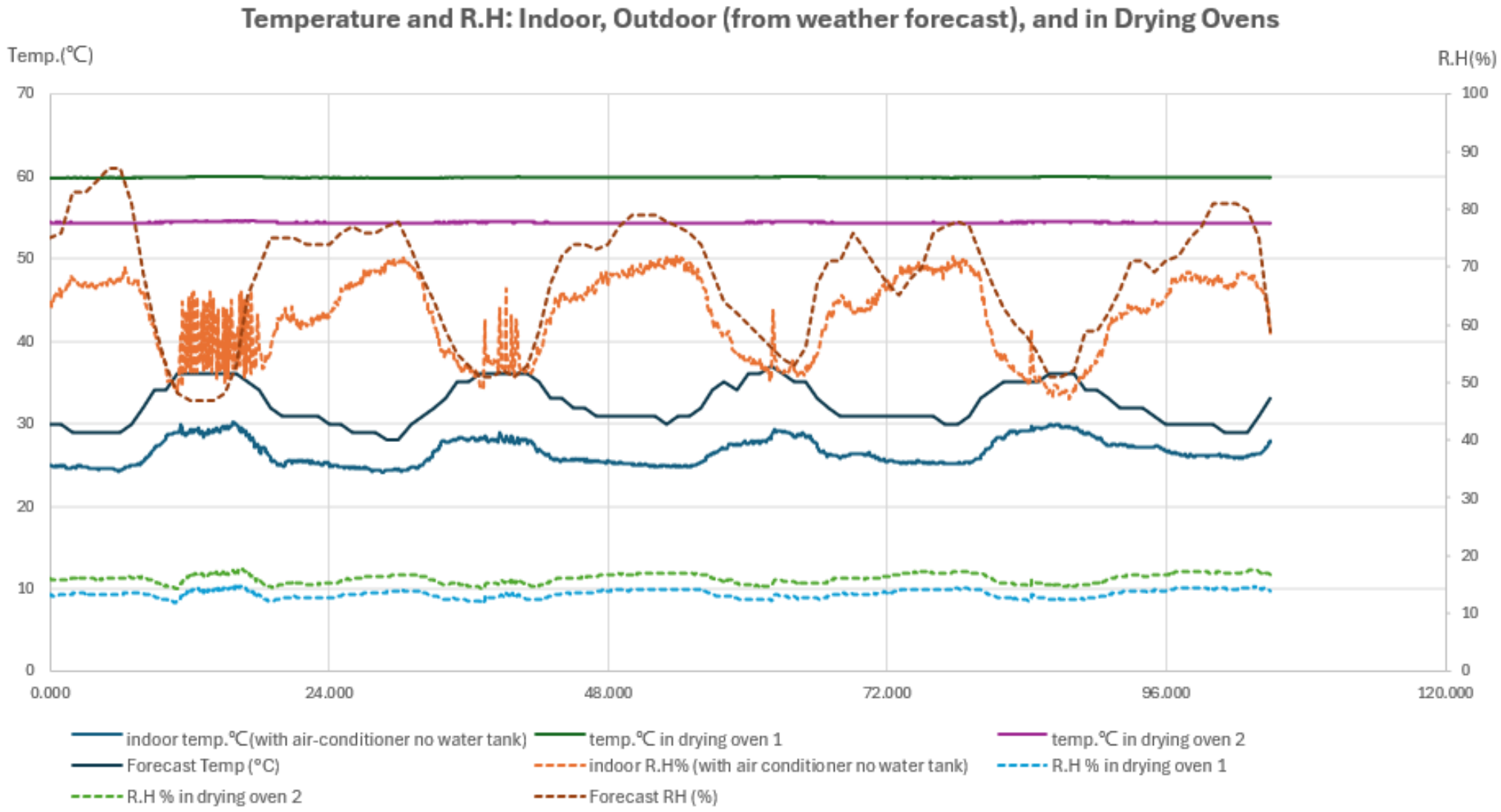
Fig. 8



Result discussion (Ⅱ)

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- ✓ Compared with flooded batteries, VRLA batteries (especially AGM types) are more sensitive to water loss, which is one of the major failure modes.
- ✓ Permeation of water vapor through battery container walls contributes to most water loss. This process depends on the concentration gradient of water vapor between the interior of the battery and the surrounding atmosphere. In drying oven tests, this gradient fluctuates more severely than in water bath tests.
- ✓ The humidity in a water bath at 55°C can be considered close to 100% RH (except at the top of the battery exposed to air).
- ✓ Humidity inside the battery is around 60% RH. Therefore, (R.H. interior – R.H. outside) is consistently positive and varies significantly in drying oven tests. Conversely, it remains consistently negative in water bath tests.

Conclusion

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- **Water bath**：Controlled test conditions provide an overly mild environment compared to field exposure. Test results are highly reliable and consistent, though may not fully represent real-world performance (typically outperforming field results).
- **Drying oven**：Uncontrolled relative humidity (R.H.) conditions. Test results exhibit significant variability and inconsistency, often underperforming compared to field results in most cases.
- **Climate Chamber (with Upper/Lower R.H. Control)**：

  Recommended specification: Maintain R.H. at 35% ±5% or ±10%

  (*Note: Current IEC standard specifies <35% R.H., EN standard <36% R.H., but neither defines a* ***minimum R.H. limit***).

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Thank you very much !

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