Spec. No.	INR21700-33J	Version No.	Tentative

Specification of Product

1. Customer :

2. Product : Lithium-ion Rechargeable Cell

3. SDI Model : INR21700-33J

4. Approved by

Division			
Signature			
Date	/ /	/ /	/ /

5. Date of Application (YY/MM/DD) : 17/MM/DD

6. Supplier : **SAMSUNG SDI Co., Ltd.**
Battery Business Division

Issued	Checked	Approved

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1. Scope

This product specification has been prepared to specify the rechargeable lithium-ion cell ('cell') to be supplied to Tesla Motors, Inc. by Samsung SDI Co., Ltd. pursuant to the parties' Supply Agreement dated July 7, 2016.

2. Description and Model

2.1 Description Cell (lithium-ion rechargeable cell)

2.2 Model INR21700-33J

3. Nominal specifications

Item	Specification
3.1 Standard discharge capacity	Typ 3,270mAh, Typ 12.0Wh Min 11.4Wh - Charge: 0.5C(1600mA),4.2V, 0.02C(64mA) cut-off @ RT - Discharge : 0.2C(640mA), 3.0V cutoff @ RT * 1C = 3,200mA
3.2 Rated discharge energy	Typ 11.4Wh Min. 10.83Wh - Charge: CP E/2 to 4.1V then CV 4.1V 0.05C (160mA) cut off rest 10min @23±3ºC - Discharge : CP E/2, 3.0V cut-off rest 10min @23±3ºC Lot mean Typ energy: 11.28 Wh Lot size: 10k cells
3.3 Charging voltage (1*)	4.10V
3.4 Nominal voltage	3.56V (Rated discharge energy condition)
3.5 Charging method	CP-CV (constant voltage with limited current)
3.6 C-rate	1C-rate: 3,200mA
3.7 Usable voltage	Refer to Table 1
3.8 Usable current	Refer to Table 2
3.9 Discharge cut-off voltage	3.00V
3.10 Cell weight	62.0±1.5g
3.11 Cell dimension (W/O tube, W/O Washer)	Refer to cell drawing Appendix. 1 Max. height to top : 70.15mm Max. height to crimping : 70.15mm Max. upper diameter : 21.1mm

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3.12 Operating temperature (1*) (Cell surface temperature)	Charge : 0 to 60ºC Discharge: -20 to 60ºC According to recommended cell usage range of the Table1 & 2
3.13 Storage temperature (2*)	1 year : -20~23ºC 3 months : -20~45ºC 1 month : -20~60ºC 1 week : -30~60ºC 1 day : -40~60ºC

Note (1): INR21700-33J (B33J) has the recommended usage range of voltage and power as below :

4. Outline dimensions

See Appendix 1.

5. Standard test conditions

5.1 Environmental conditions

Unless otherwise specified, all tests stated in this specification are conducted at temperature 23±3ºC and humidity under 65%.
This condition refers to the room temperature (RT) conditions.

5.2 Measuring equipment

(1) Ammeter and Voltmeter
The ammeter should have an accuracy of the grade 0.5mA or higher.
The voltmeter should have an accuracy of the grade 0.5mV or higher.

(2) Slide caliper
The slide caliper should have 0.05 mm scale or higher.

(3) Impedance meter
The impedance meter with AC 1kHz should be used.

(4) Weighing machine
The weighing machine should have an accuracy of the grade 0.001g or higher

6. Characteristics

6.1 Standard charge

This "Standard charge" means charging the cell with charge current 1,600mA and constant voltage 4.2V at 23ºC, 64mA cut off.

6.2 Standard discharge capacity

The standard discharge capacity is the initial discharge capacity of the cell, which is measured with discharge current of 640mA with 3.0V cut-off at 23ºC within 1 hour after the Standard charge. In this case the minimum capacity of the standard discharge capacity is 3,270mAh and the minimum energy of the standard discharge is 12.0Wh in warranty.

Standard discharge capacity ≥ 3,270mAh
Standard discharge energy ≥ 12.0Wh

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6.3 Rated discharge energy

The rated energy is the initial discharge energy of the cell, which is measured with constant discharge power of E/2 with 3.0V cut-off at 23ºC within 1 hour after the charge with constant energy of E/2 to 4.1V then charged to constant voltage 4.1V at 23ºC, 160mA cutoff.
In this case, the energy of the rated discharge energy should be at least 10.83Wh.

Minimum rated discharge energy = 10.83Wh

6.4.1 Initial internal impedance (AC resistance)

Initial internal impedance measured at AC 1kHz after Standard charge.

Initial internal impedance = 29±5 mΩ

6.4.2 DC impedance

DC impedance is measured at 50% SOC(state of charge) state.
After Standard charge, discharge with constant current of 1,600mA for 1hr followed by 30min rest time (Check voltage at this time – V1). Discharge with constant current of 1,600mA for 30sec (and check voltage at 10sec – V2)

Initial DC impedance = (V1-V2)[mV] / 1600[mA] = 40±10 mΩ

6.4.3 DC impedance growth (DCR (%) increase)

DC impedance growth means % increased DC impedance after cycle or storage test compared with initial DC impedance

DCR (%) increase = [(*DCR(f) / **DCR(i))-1] x 100

* DCR(i) : initial DC impedance, **DCR(f) : DC impedance after cycle or storage test

6.5 Temperature dependence of discharge capacity

Discharge capacity comparison at each temperature, measured with discharge constant current 640mA and 3.0V cut-off with follow temperature after the Standard charging at 23ºC.

Note: If the charge temperature and discharge temperature is not the same, the interval for temperature change is 3 hours.

Charge temperature	Discharge temperature			
23ºC	-10ºC	0ºC	23ºC	45ºC
Relative capacity	50%	70%	100%	100%

Typical capacity (3,270mAh) is 100% Percentage as an index of the relative capacity.

6.6 Temperature dependence of charge capacity

Discharge capacity comparison according to the charging temperature, measured with constant current discharge at 23ºC with 640mA and 3.0V cut-off after charged by CC-CV 0.5C, 4.2V, 0.02C (64mA) cut-off at the following temperature.

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	Charge temperature			Discharge temperature
	0ºC	23ºC	45ºC	23ºC
Relative capacity	80%	100%	100%	

Note: If charge temperature and discharge temperature is not the same, the interval for temperature change is 3 hours.
Typical capacity (3,270mAh) is 100% Percentage as an index of the relative capacity.

6.7 Charge rate capabilities

Discharge capacity is measured with constant current 640mA and 3.0V cut-off after the cell is charged with 4.2V as follows.

	Charge Condition		
Current	0.2C (640mA)	0.5C (1,600mA)	1.0C (3,200mA)
Cut-off	7h or 0.05C	3.0h or 0.05C	2.5h or 0.05C
Relative discharge capacity	100%	95%	90%

Note: Percentage as an index of the capacity at 23ºC (=3,270mAh) is 100%.

6.8 Discharge rate capabilities

Discharge capacity according the discharging current is measured with 3.0V cut-off after the standard charge is as follows,

	Discharge Condition			
Current	0.2C (640mA)	0.5C (1,600mA)	1C (3,200mA)	2C (6,400mA)
Relative capacity	100%	95%	90%	80%

Note: Typical capacity(3,270mAh) is 100% as an index of the relative capacity.

6.9 Cycle life performance

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Temperature		23ºC	40ºC
Condition	Charge (CC-CV)	1600mA (0.5C), 4.1 V, 160mA (0.05C) Cut-off	
	Discharge (CC)	1600mA (0.5C), 3.0V Cut-off	
	Rest	10minutes	
Assurance standards		75% @2000cycle	75% @2000cycle
DC-IR (%) increase		20% @1500cycle	20% @1500cycle

Note: Capacity of first cycle is considered as 100% of the relative capacity.

6.9.1 Standard cycle life at room temperature with 4.1V

Each cycle is an interval between the charge current 1600mA and constant voltage 4.1V at 23ºC, with 160mA cutoff and the 1,600mA discharge of current with 3.0V cut-off. Both of DCR(i) and DCR(f) should be measured at 23ºC

As a assurance standards,
Capacity after 2000cycles.

Capacity ≥ 75% of the capacity of first cycle
DCR(%) increase ≤ TBD

6.9.2 Cycle life at high temperature of 40ºC

Each cycle is an interval between the charge current 1600mA and constant voltage 4.1V at 40ºC, with 160mA cutoff and the 1,600mA discharge of current with 3.0V cut-off. Both of DCR(i) and DCR(f) should be measured at 40ºC

As a assurance standards,
Capacity after 2000cycles.

Capacity ≥ 75% of the capacity of first cycle
DCR(%) increase ≤ TBD

6.10. Storage performance

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Storage Temperature		23ºC	40ºC	55ºC
Capacity Check condition	Charge (CC-CV)	1600mA (0.5C), 4.1 V, 160mA (0.05C) Cut-off at 23ºC		
	Discharge (CC)	1600mA (0.5C), 3.0V Cut-off at 23ºC		
	Rest	10minutes		
Storage period		365 days	365 days	30 days
Recovery		95% of initial capacity	90% of initial capacity	90% of initial capacity
DC-IR (%) increase In 6months		15%	25%	35%

6.10.1 Storage characteristics at 23ºC

Measured the cell initial capacity with discharge constant current 1,600mA and 3.0V cut-off after the charge with current of 1,600mA and constant voltage 4.1V at 23ºC, 160mA cutoff

Storage the cell for 365 days at 23ºC after the charge with current of 1,600mA and constant voltage 4.1V at 23ºC, 160mA cutoff

After that, measure the recoverable capacity with the same condition of initial capacity check.

Capacity recovery(after the storage) ≥ 95% of initial capacity
DCR(%) increase ≤ 15% in 6months

6.10.2 Storage characteristics at 40ºC

Measured the cell initial capacity with discharge constant current 1,600mA and 3.0V cut-off after the charge with current of 1,600mA and constant voltage 4.1V at 23ºC, 160mA cutoff

Storage the cell for 365 days at 40ºC after the charge with current of 1,600mA and constant voltage 4.1V at 23ºC, 160mA cutoff

After that, measure the recoverable capacity with the same condition of initial capacity check.

Capacity recovery(after the storage) ≥ 90% of initial capacity
DCR(%) increase ≤ 25% in 6months

6.10.3 Storage characteristics at 55ºC

Measured the cell initial capacity with discharge constant current 1,600mA and 3.0V cut-off after the charge with current of 1,600mA and constant voltage 4.1V at 23ºC, 160mA cutoff

Storage the cell for 30 days at 55ºC after the charge with current of 1,600mA and constant voltage 4.1V at 23ºC, 160mA cutoff

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After that, measure the recoverable capacity with the same condition of initial capacity check.

Capacity recovery(after the storage) ≥ 90% of initial capacity
DCR(%) increase ≤ 35% in 6months

6.10.4. Long term storage.

In case of long term cell storage (3 months or more), It is strongly recommended that cells are stored in dry place and at temperature below 25ºC.

6.11 Status of the cell as of ex-factory or outgoing inspection

The cell should be shipped in 30% charged state. In this case, OCV is in range 3.560 ± 10mV.

7. Mechanical Characteristics

7.1 Drop Test

Test method: Each fully charged cell or battery is dropped three times from a height of 1.0 m onto a concrete floor. The cells or batteries are dropped so as to obtain impacts in random orientations. After the test, the sample shall be put on rest for a minimum of one hour and then a visual inspection shall be performed.

Criteria: No fire, no explosion
(Test shall be performed with the following criteria IEC 62133)

7.2 Vibration Test

Test method: As to the UN transportation regulation (UN38.3), for each axis (X and Y axis with cylindrical cells) 7Hz→200Hz→7Hz for 15min,
repetition 12 times totally 3hours, the acceleration 1g during 7 to 18Hz and 8g (amplitude 1.6mm) up to 200Hz.

Criteria: No leakage, with less than 10mV of OCV drop

8. Safety

8.1 Overcharge Test

Test method: Overcharge a cell which begins at the standard charge condition with 12V and 3C (9,900mA) at 23ºC for 7 hours.

Criteria: No fire, and no explosion.

Frequency: This test and report (including raw data) shall be available upon request.

The overcharge test shall be performed with the UL1642 Rev. in 2013 standard.

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8.2 External short-circuit test

Test method: Fully rated charged cell is to be short-circuited by connecting the positive and negative terminals of the battery with a circuit load having a resistance load of 80 ±20 mΩ. The battery is to discharge until a fire or explosion is obtained, or until it has reached a completely discharged state of less than 0.2 V and the battery case temperature has returned to ±10ºC of ambient temperature. The return to near ambient of the battery (cell) casing in an indication of ultimate results.

Tests are to be conducted at 20 ±5ºC and at 55 ±5ºC.

Criteria: No fire, and no explosion.

Frequency: This test and report (including raw data of the battery case temperature) shall be available upon request.

The external short-circuit test shall be performed with the UL1642 Rev. in 2013 standard.

8.3 Forced discharge test

Test method: A discharged cell is subjected to a reverse charge at 1.0C(3,300mA) for 90 min at 23ºC.

Criteria: No fire, and no explosion.

Frequency: This test and report (including raw data of cell voltage) shall be available upon request.

The forced discharge test shall be performed with the IEC62133 2nd edition standard

8.4 Hot oven test

Test method: A standard charged cell at 20±5ºC shall be placed in an oven at 20±5ºC The oven shall be heated at 5ºC per minute up to 130ºC remain for 10 minutes. The cell shall return to 20±5ºC and then be examined.

Criteria: No fire, and no explosion for 10minutes

Frequency: This test and report shall be available upon request.

The hot oven test shall be performed with the UL1642 Rev. in 2013 standard.

8.5 Radiant heater test

Test method: A standard charged cell assembled into the cell stand shall be pre-heated to 40±5ºC. This assembly shall be inserted into a cylinder of metal which has been preheated to 650±5ºC, until the cell goes into thermal runaway.

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Criteria: The cell shall be visually examined and no holes found on the side of the cell.

Frequency: This test and report (including high quality images) shall be performed once per month with sample size of at least five.

Note: The goal shall be for thermal runaway to create no holes in the bottom face of the cell though it is acceptable.

9. Certification

This product fully complies with the UL1642 Rev. in 2013 and UN38.3 2013, Rev.5, Amend.2 standard.
Revision (No.36, 2008) of the Ministerial Ordinance for Determining Technical Standards for Electrical Appliances (No.85, 1962) was also complied.
This product is guaranteed EU battery directive 2006/64/EC.

10. Warranty

The warranty with respect to cells is set forth in Section 10 of the Agreement.

11. Transportation information

This product was tested and found to be in conformity with UN test (Manual of Tests and Criteria Rev.4, Part III subsection 38.3) for allowing shipping of the cells.