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NEMA STANDARDS PUBLICATION NO. IB 4

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Determination of Amperehour and Watthour Capacity of Lead-Acid Industrial Storage Batteries for Stationary Service

NEMA

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

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NEMA IB 4-1987

IB 4

DETERMINATION OF AMEREHOUR AND WATTHOUR CAPACITY OF LEAD-ACID INDUSTRIAL STORAGE BATTERIES FOR STATIONARY SERVICE

Published by

National Electrical Manufacturers Association
2101 L Street, N.W.
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Foreword

The purpose of this Standards Publication is to provide the users and manufacturers of lead-acid industrial storage batteries for stationary applications a standard testing procedure to determine constant power and constant current performance.

User input has been considered throughout the development of this Standards Publication.

This standard has been developed by the Industrial Battery and Charger Section of NEMA which periodically reviews it for any revisions necessary to keep it up-to-date with advancing technology. Comments or proposed revisions are welcomed and should be submitted to:

Manager, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, D.C. 20037

This 1987 edition revises and supersedes IB 4-1979.

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Scope

This Standards Publication covers performance requirements, test conditions, and methods for determining the capacity of lead-acid industrial storage batteries for stationary service when installed as a source of standby power.

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DETERMINATION OF AMPEREHOUR AND WATTHOUR CAPACITY OF LEAD-ACID INDUSTRIAL STORAGE BATTERIES FOR STATIONARY SERVICE

Section 1

REFERENCED STANDARDS AND DEFINITIONS

1.1 REFERENCED STANDARDS

The following publication is adopted in whole or in part, as indicated, by reference in this Standards Publication.

National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, D.C. 20037

IB 1-1982 *Definitions and Precautionary Labels for Lead-Acid Industrial Storage Batteries*

1.2 DEFINITIONS

The terms contained in this Standards Publication shall be defined in accordance with NEMA IB 1 as applicable.
NEMA Standard 11-19-1987.

Section 2

PERFORMANCE

2.1 PERFORMANCE REQUIREMENTS

The following performance requirements shall apply:

2.1.1 The manufacturer's published ratings shall be used to determine the capacity of a complete battery or of cells that are selected to represent the complete battery.
NEMA Standard 11-19-1987.

2.1.2 A new battery shall deliver a minimum of 90 percent of its rated capacity (85 percent if dry charged or dry uncharged) when tested in accordance with Section 4.
NEMA Standard 11-19-1987.

2.1.3 The useful life of a battery shall be completed when the rated capacity falls below 80 percent, when tested in accordance with 4.1 and 4.2.
NEMA Standard 11-19-1987.

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Section 3

TEST CONDITIONS

3.1 DRY UNCHARGED OR DRY CHARGED BATTERIES

A dry uncharged or dry charged battery shall be filled with electrolyte and charged in accordance with the manufacturer's published instructions.

NEMA Standard 11-19-1987.

3.2 STATE OF CHARGE

Batteries shall be fully charged in accordance with the manufacturer's published instructions prior to the start of the test discharge.

NEMA Standard 11-19-1987.

3.3 VOLTAGE

The final discharge voltage of the battery shall equal the specified final voltage per cell times the number of cells. The battery voltage shall be measured at the post of the terminal cells, excluding the battery terminal cables, but including cell-to-cell connectors.

NEMA Standard 11-19-1987.

3.4 ELECTROLYTE LEVELS

The electrolyte level shall be adjusted in accordance with the manufacturer's published instructions.

NEMA Standard 11-19-1987.

3.5 ELECTRICAL CONNECTIONS

All electrical connections shall be made in accordance with the manufacturer's published instructions and shall be clean and tight.

NEMA Standard 11-19-1987.

3.6 TEMPERATURE

The electrolyte temperature during charging shall be within the range of 65 °F (18.3 °C) through 115 °F (46.1 °C).

The ambient temperature during a test discharge shall be within the range of 63 °F (17.2 °C) through 91 °F (32.8 °C).

The electrolyte temperature of all cells at the start of a test discharge shall be within the range of 63 °F (17.2 °C) through 91 °F (32.8 °C).

NEMA Standard 11-19-1987.

The cell-to-cell temperature variation should not exceed 6 °F (3.3 °C).

Authorized Engineering Information 11-19-1987.

3.7 SPECIFIC GRAVITY

The specific gravity of the electrolyte of a fully charged battery, when corrected to 77 °F (25 °C) and with the electrolyte at the maximum level, shall be within the range shown on the battery nameplate or in the manufacturer's published instructions. If the specific gravity of the electrolyte of any fully charged cell is not within the specified range just prior to starting tests, the electrolyte shall be adjusted in accordance with the manufacturer's published instructions.

NEMA Standard 11-19-1987.

The specific gravity of the electrolyte may be corrected to a temperature of 77 °F (25 °C) by adding 0.001 specific gravity units (one point) to the specific gravity reading for every 3 °F (1.67 °C) of electrolyte temperature above 77 °F (25 °C) and by subtracting a like amount for every 3 °F (1.67 °C) below 77 °F (25 °C).

Authorized Engineering Information 11-19-1987.

3.8 SEQUENCE OF READINGS

All voltage, specific gravity, and temperature readings shall be taken from the positive terminal cell to the negative terminal cell, recorded in series, and numbered.

NEMA Standard 11-19-1987.

3.9 TEST EQUIPMENT

All equipment shall be clean, in good working order, and calibrated.

3.9.1 Thermometers

Thermometers shall be graduated so that each scale division will represent not more than 2 °F (1.1 °C) and shall have an accuracy of at least plus or minus 1 °F (0.56 °C).

NEMA Standard 11-19-1987.

3.9.2 Hydrometers

Hydrometers shall be graduated so that each scale division will represent not more than 0.005 units of specific gravity (5 points) and shall have an accuracy of at least plus or minus 0.0025 units of specific gravity.

NEMA Standard 11-19-1987.

3.9.3 Voltmeters

Meter accuracy shall be a minimum of 0.5 percent of full-scale value with a minimum resistance of 1000 ohms per volt.

The range of the voltmeter used shall be such that normal values will be indicated in the upper one-third of the scale.

Galvanometer-type voltmeter graduations shall be in accordance with Table 3-1.

NEMA Standard 11-19-1987.

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Table 3-1
GALVANOMETER-TYPE
VOLTMETER GRADUATIONS

Voltage Range, Volts	Maximum Voltage Per Scale Division, Volts
0 to 3	0.02
3 to 15	0.1
15 to 75	0.2
75 to 150	1.0

3.9.4 Galvanometer-type ammeters shall be graduated to have a minimum of 100 scale divisions. Ammeters shall be used with an appropriate shunt so that current readings will fall in the upper third of the meter scale. The meter and shunt, including shunt leads, shall have an accuracy of at least 0.5 percent of full-scale value.

NEMA Standard 11-19-1987.

3.9.5 The size of the shunt used during a discharge shall have a current rating between the discharge rate and 1.5 times the discharge rate in amperes. The accuracy of shunts shall be within 0.5 percent of full value.

NEMA Standard 11-19-1987.

3.9.6 Timing devices shall be accurate within plus-or-minus one-half percent of the specified discharge time.

NEMA Standard 11-19-1987.

Section 4
TEST METHODS

4.1 CONSTANT CURRENT

The following test methods shall apply to determine actual capacity to a final voltage when batteries are discharged at a constant current, or if a particular percentage of rated capacity is equalled or exceeded.

NEMA Standard 11-19-1987.

4.1.1 The float voltage and specific gravity of all cells shall be recorded just prior to the start of discharge.

NEMA Standard 11-19-1987.

When the battery design does not permit readings to be made on individual cells, the manufacturer should be consulted.

Authorized Engineering Information 11-19-1987.

4.1.2 The specific gravity and temperature of every sixth cell of a complete battery, or of all cells selected to represent a complete battery, shall be recorded just prior to the start of the discharge (see 3.8).

NEMA Standard 11-19-1987.

When the battery design does not permit readings to be made on individual cells, the manufacturer should be consulted.

Authorized Engineering Information 11-19-1987.

4.1.3 The charger shall be disconnected from the battery prior to the test discharge.

NEMA Standard 11-19-1987.

4.1.4 When all of the requirements of 3.1 through 3.9 and 4.1.1 through 4.1.3 have been met, the test discharge shall be initiated.

NEMA Standard 11-19-1987.

4.1.5 When the average electrolyte temperature, as determined in 4.1.2, is not 77 °F (25 °C), a correction factor as shown in Table 4-1 or Table 4-2 shall be applied.

NEMA Standard 11-19-1987.

4.1.6 The test discharge shall be conducted with a constant current load equal to the manufacturer's rating of the battery for the selected duration and final voltage.

4.1.6.1 TEST LENGTH ONE HOUR OR LESS

For a test duration one hour or less, the discharge current shall be corrected for temperature as follows:

$$\text{Discharge Amperes} = \frac{\text{Rated Amperes}}{K_t}$$

Where K_t is the discharge current correction factor for the initial average electrolyte temperature, as shown in Table 4-1.

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Table 4-1
DISCHARGE RATE CORRECTION FACTORS K_t FOR TEMPERATURES AT VARIANCES TO STANDARD 77°F (25°C) FOR TEST DURATIONS OF ONE HOUR OR LESS

Initial Temperature (°F)	Initial Temperature (°C)	Factor K_t
62	16.7	1.098
63	17.2	1.092
64	17.8	1.086
65	18.3	1.080
66	18.9	1.072
67	19.4	1.064
68	20.0	1.056
69	20.6	1.048
70	21.1	1.040
71	21.7	1.034
72	22.2	1.029
73	22.8	1.023
74	23.4	1.017
75	23.9	1.011
76	24.5	1.006
77	25.0	1.000
78	25.6	0.994
79	26.1	0.987
80	26.7	0.980
81	27.2	0.976
82	27.8	0.972
83	28.3	0.968
84	28.9	0.964
85	29.4	0.960
86	30.0	0.956
87	30.6	0.952
88	31.1	0.948
89	31.6	0.944
90	32.2	0.940
91	32.8	0.938
92	33.4	0.936

Table 4-2
DISCHARGE TIME CORRECTION FACTORS K_t FOR TEMPERATURES AT VARIANCES TO STANDARD 77°F (25°C) FOR TEST DURATIONS GREATER THAN ONE HOUR

Initial Temperature (°F)	Initial Temperature (°C)	K_t Factor for Discharge Time Above 1 Hr. through 3 Hrs.	K_t Factor for Discharge Time Above 3 Hrs. through 8 Hrs.
62	16.7	1.063	1.045
63	17.2	1.059	1.042
64	17.8	1.055	1.039
65	18.3	1.050	1.036
66	18.9	1.046	1.033
67	19.4	1.042	1.030
68	20.0	1.038	1.027
69	20.6	1.033	1.024
70	21.1	1.029	1.021
71	21.7	1.025	1.018
72	22.2	1.021	1.015
73	22.8	1.016	1.012
74	23.4	1.012	1.009
75	23.9	1.008	1.006
76	24.5	1.004	1.003
77	25.0	1.000	1.000
78	25.6	0.997	0.998
79	26.1	0.994	0.996
80	26.7	0.991	0.994
81	27.2	0.988	0.992
82	27.8	0.985	0.990
83	28.3	0.983	0.988
84	28.9	0.980	0.986
85	29.4	0.977	0.984
86	30.0	0.974	0.982
87	30.6	0.971	0.980
88	31.1	0.968	0.979
89	31.6	0.966	0.977
90	32.2	0.963	0.975
91	32.8	0.960	0.973
92	33.4	0.957	0.971

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4.1.6.2 TEST LENGTH GREATER THAN ONE HOUR

For a test duration greater than one hour, the discharge time shall be corrected for temperature as follows:

$$\text{Discharge Time} = \frac{\text{Rated Time}}{K_t}$$

Where K_t is the discharge time correction for the initial average electrolyte temperature as shown in Table 4-2.

NEMA Standard 11-19-1987.

The manufacturer should be consulted for discharges longer than eight hours.

Authorized Engineering Information 11-19-1987.

4.1.7 The discharge current shall be maintained within plus or minus 1 percent of the selected ampere discharge rate until:

4.1.7.1 The battery terminal voltage falls to a value equal to the minimum specified average voltage per cell times the number of cells (actual capacity), or

4.1.7.2 The temperature corrected discharge time has elapsed, but battery terminal voltage is greater than the specified minimum.

NEMA Standard 11-19-1987.

4.1.8 Individual cell voltages and battery terminal voltages shall be monitored throughout the test duration. At the end of the discharge period (see 4.1.7.1 and 4.1.7.2) prior to disconnecting the load, individual cell voltages and battery terminal voltage shall be recorded.

NEMA Standard 11-19-1987.

4.1.9 If an individual cell is approaching reversal of its polarity (plus 1 V or less), but the terminal voltage has not yet reached its lower test limit, the test should be continued with a jumper across the weak cell. The jumper connection should be made away from the cell to avoid arcing near the cell. The new minimum terminal voltage should be determined based on the remaining cells. Any cell removed from the test should be considered as not having met the performance requirements.

Authorized Engineering Information 11-19-1987.

4.1.10 At the completion of the test discharge, the temperature and specific gravity of the electrolyte of every sixth cell shall be recorded where there are more than 12 cells discharged in one circuit.

NEMA Standard 11-19-1987.

4.1.11 The battery shall be recharged in accordance with the manufacturer's instructions.

NEMA Standard 11-19-1987.

4.1.12 The battery capacity shall be determined as follows:

4.1.12.1 TEST LENGTH ONE HOUR OR LESS

$$\text{Percent Capacity at } 77\,^{\circ}\text{F } (25\,^{\circ}\text{C}) = \frac{t_a}{t_r} \times 100$$

Where —

t_a is the actual duration of the test to the minimum specified terminal voltage (see 4.1.7.1).

t_r is the rated time to final voltage.

4.1.12.2 TEST LENGTH GREATER THAN ONE HOUR

$$\text{Percent Capacity at } 77\,^{\circ}\text{F } (25\,^{\circ}\text{C}) = \frac{t_a}{t_c} \times 100$$

Where —

t_a is the actual duration of the test to the minimum specified terminal voltage (see 4.1.7.1).

t_c is the temperature corrected time to minimum specified terminal voltage (see 4.1.7.2).

NEMA Standard 11-19-1987.

The manufacturer should be consulted for discharges longer than eight hours.

Authorized Engineering Information 11-19-1987.

4.1.13 If the battery fails to meet the requirements of 2.1.3, the battery shall be retested in accordance with the test conditions and test methods of Section 3 and Section 4.

If the battery fails the second series of tests, it shall be considered as not conforming to this standard.

NEMA Standard 11-19-1987.

4.2 CONSTANT POWER

The following test methods shall apply to determine actual capacity to a final voltage when batteries are discharged at a constant power, or if a particular percentage of rated capacity is equalled or exceeded.

4.2.1 The float voltage and specific gravity of all cells shall be recorded just prior to the start of discharge.

NEMA Standard 11-19-1987.

When the battery design does not permit readings to be made on individual cells, the manufacturer should be consulted.

Authorized Engineering Information 11-19-1987.

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4.2.2 The specific gravity and temperature of every sixth cell of a complete battery, or of all cells selected to represent a complete battery, shall be recorded just prior to the start of the discharge (see 3.8).

NEMA Standard 11-19-1987.

When the battery design does not permit readings to be made on individual cells, the manufacturer should be consulted.

Authorized Engineering Information 11-19-1987.

4.2.3 The charger shall be disconnected from the battery prior to the test discharge.

NEMA Standard 11-19-1987.

4.2.4 When all of the requirements of 3.1 through 3.9 and 4.1.1 through 4.1.3 have been met, the test discharge shall be initiated.

NEMA Standard 11-19-1987.

4.2.5 When the average electrolyte temperature, as determined in 4.1.2, is not 77 °F (25 °C), a correction factor as shown in Table 4-1 or Table 4-2 shall be applied.

NEMA Standard 11-19-1987.

4.2.6 The test discharge shall be conducted with a constant power load equal to the manufacturer's rating of the battery for the selected duration and final voltage.

4.2.6.1 TEST LENGTH ONE HOUR OR LESS

For a test duration one hour or less, the discharge power shall be corrected for temperature as follows:

$$\text{Discharge Watts} = \frac{\text{Rated Watts}}{K_t}$$

Where K_t is the discharge power correction factor for the initial average electrolyte temperature, as shown in Table 4-1.

4.2.6.2 TEST LENGTH ONE HOUR OR LONGER

For a test duration one hour or longer, the discharge time shall be corrected for temperature as follows:

$$\text{Discharge Time} = \frac{\text{Rated Time}}{K_t}$$

Where K_t is the discharge time correction for the initial average electrolyte temperature as shown in Table 4-2.

NEMA Standard 11-19-1987.

The manufacturer should be consulted for discharges longer than eight hours.

Authorized Engineering Information 11-19-1987.

4.2.7 The discharge power shall be maintained within plus or minus one percent of the selected watts discharge rate until:

4.2.7.1 The battery terminal voltage falls to a value equal to the minimum specified average voltage per cell times the number of cells (actual capacity), or

4.2.7.2 The temperature corrected discharge time has elapsed, but battery terminal voltage is greater than the specified minimum.

NEMA Standard 11-19-1987.

4.2.8 Individual cell voltages and battery terminal voltages shall be monitored throughout the test duration. At the end of the discharge period (see 4.2.7.1 and 4.2.7.2) and prior to disconnecting the load, individual cell voltages and battery terminal voltage shall be recorded.

When the test is manually conducted, the voltage-current relationship shall be constantly monitored with continuous adjustment to the watts rate to ensure the accuracy of the test.

NEMA Standard 11-19-1987.

4.2.9 If an individual cell is approaching reversal of its polarity (plus 1 V or less), but the terminal voltage has not yet reached its lower test limit, the test should be continued with a jumper across the weak cell. The jumper connection should be made away from the cell to avoid arcing near the cell. The new minimum terminal voltage should be determined based on the remaining cells. Any cell removed from the test should be considered as not having met the performance requirements.

Authorized Engineering Information 11-19-1987.

4.2.10 At the completion of the test discharge, the temperature and specific gravity of the electrolyte of every sixth cell shall be recorded where there are more than 12 cells discharged in one circuit.

NEMA Standard 11-19-1987.

4.2.11 The battery shall be recharged in accordance with the manufacturer's instructions.

NEMA Standard 11-19-1987.

4.2.12 The battery capacity shall be determined as follows:

4.2.12.1 TEST LENGTH ONE HOUR OR LESS

$$\text{Percent Capacity at 77 °F (25 °C)} = \frac{t_a}{t_r} \times 100$$

Where —

t_a is the actual duration of the test to the minimum specified terminal voltage (see 4.1.7.1).

t_r is the rated time to final voltage.

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4.2.12.2 TEST LENGTH GREATER THAN ONE HOUR

$$\text{Percent Capacity at } 77\,^{\circ}\text{F } (25\,^{\circ}\text{C}) = \frac{t_a}{t_c} \times 100$$

Where —

t_a is the actual duration of the test to the minimum specified terminal voltage (see 4.1.7.1).

t_c is the temperature corrected time to minimum specified terminal voltage (see 4.1.7.2).

NEMA Standard 11-19-1987.

4.2.13 If the battery fails to meet the requirements of 2.1.3, the battery shall be retested in accordance with the test conditions and test methods of Section 3 and Section 4.

If the battery fails the second series of tests, it shall be considered as not conforming to this standard.

NEMA Standard 11-19-1987.

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Industrial and Battery Charger Section of the National Electrical Manufacturers Association

Member Companies

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Plymouth Meeting, PA 19462

Chloride Electro Networks
Caledonia, NY 14423

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Winston-Salem, NC 27117

East Penn Mfg. Company, Inc.
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Exide Corporation
Reading, PA 19612

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Industrial Products Group
Reading, PA 19603

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Langhorne, PA 19047

Hobart Brothers Company
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Battery Division
Milwaukee, WI 53212

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Skokie, IL 60076

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Kansas City, KS 66115

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NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status, are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below.

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard. *(Standardization Policies and Procedures, p. 1)*

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.
(Standardization Policies and Procedures, p. 2)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the standards publication may be capable of otherwise equivalent performance.
(Standardization Policies and Procedures, p. 9)

Classes of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Standardization Policies and Procedures, pp. 8 & 17)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote on the standard.
(Standardization Policies and Procedures, pp. 8 & 17)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment, and/or approval, and which has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon.
(Standardization Policies and Procedures, pp. 8 & 17)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

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