PERMA.BATTERIES
Solutions d'autonomie solaire

Revision 2.0 (11.2022)

NICKEL-IRON BATTERIES

PB SERIES (100-1200 Ah)

Commissioning and maintenance

Foreword

Dear customer,

Thank you for choosing Nickel-Iron batteries. Ni-Fe batteries are extremely robust and long-lasting.Regular,scrupulous maintenance will ensure their long service life.

Please read this documentation carefully before commissioning your batteries.

contact@perma-batteries.com
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This documentation contains important information on the use and maintenance of Nickel-Iron batteries. Failure to comply with the following instructions may have serious consequences for battery performance and service life.

PERMA-BATTERIES reserves the right to modify the content of this documentation at any time.

PERMA-BATTERIES is not responsible for any errors that may be contained in this documentation.

PERMA-BATTERIES is not liable for direct damages arising from the use of this documentation.

Please keep this documentation readily available for anyone who needs to work on the batteries.

For further information, please contact us by email :
contact@perma-batteries.com

or by phone Monday to Friday, 9am to 6pm:
+1 (415) 818-0845

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A. Features and operation

1.1 Design :

Nickel-iron batteries have a so-called "pocket-plate" design, where the reagents used for the electrodes are encapsulated in powder form in thin micro-perforated plates, then assembled together to obtain the desired capacity.

The "positive" plate contains nickel hydroxide (NiOH), while the "negative" plate contains iron oxide (FeOH). The design remains faithful to Thomas Edison's original 1901 patent. The electrolyte is an aqueous solution of potash (KOH) at around 20% by volume, and lithium at around 5% by volume.

Fig.1. Internal design of a Ni-Fe battery.

This type of design offers superior mechanical strength and excellent robustness of the internal components. The exceptional longevity of NiFe batteries can be explained chemically. Structural degradation of the components (iron and nickel electrodes) is prevented by an alkaline electrolyte that does not attack metals, ensuring decades of long life and robust operation.

Electrochemical reactions can be summarized in the following equation:

$$3Fe+8NiOOH+4H_2O \rightleftharpoons 8Ni(OH)_2+Fe_3O_4$$

(discharge is read from left to right, recharge from right to left)

Furthermore, the operation of an alkaline battery such as a nickel-iron battery relies on an electrolyte that does not recombine with the reactants during cycling, unlike lead-acid batteries (PbSO4 & H2SO4). The chemical role of the electrolyte in a Ni-Fe battery is solely to enable ionic conductivity between the cells through OH- exchange. As a result, the density of the electrolyte in a Nickel-Iron battery remains unchanged, and the risk of stratification due to partial states of charge is eliminated, enabling subsequent capacity additions.

1.2 Capacity & voltage :

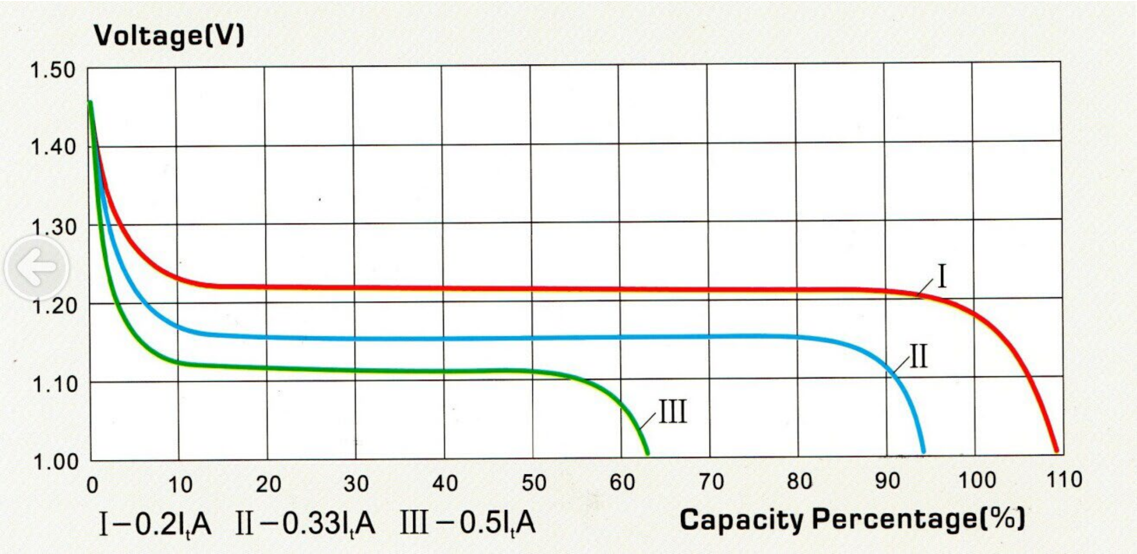
The capacity of a Ni-Fe battery is expressed in Ah (ampere-hours), at 20°C +/- 5° C, and corresponds to the amount of energy recoverable under a 0.2 ItA charge for 5 hours (i.e. a discharge current of C/5), after having been ế fully charged for 8 hours at 0.2 ItA.

The open circuit voltage (OCV) of a fully charged Nickel-Iron cell is between 1.3 and 1.5V (typical value 1.45V per cell). This value depends not only on the time elapsed after reaching full charge (self-discharge rate), but also on other variables such as temperature, discharge current, and the cell's internal resistance.

The nominal voltage (vEMF) of a Nickel-Iron cell corresponds to the potential difference between the electrodes, and is approximately 1.2V per cell. Consequently, the nominal voltage of a Ni-Fe battery bank will be **N x 1.2V** (where N represents the number of cells).

The capacity of a Ni-Fe cell varies according to the discharge current used. The higher the discharge current, the lower the actual capacity.

Fig 2: Capacitance curves as a function of discharge current (C/5, C/3, C/2).

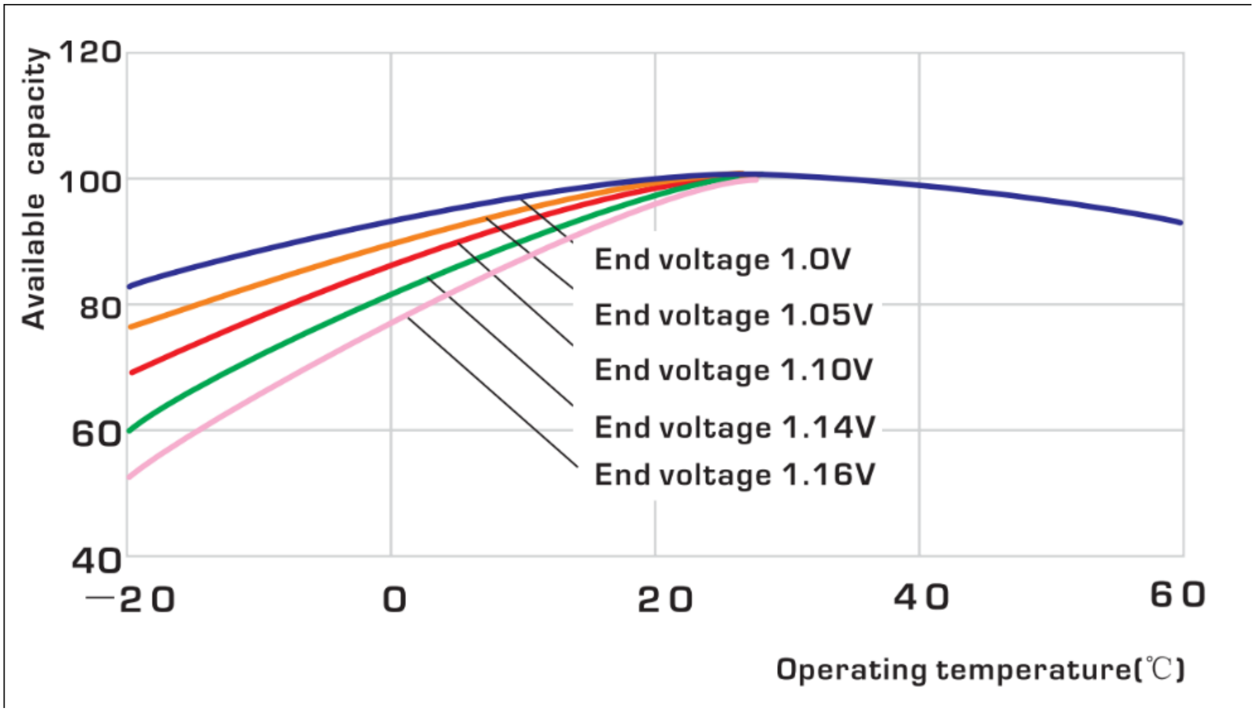


Although Ni-Fe is capable of withstanding peak discharge currents of up to C/4, given its intrinsically high internal resistance (low solubility of Fe & Ni electrodes), optimum performance will be obtained with slow discharges (C/15 to C/20), which is compatible with stationary applications where sustained inrush currents are rare (isolated sites, or hybrid applications).

1.3 Internal resistance and temperature

The internal resistance of a Ni-Fe battery depends not only on its state of charge (SOC), but also on the ambient temperature. Compared with the internal resistance of a fully charged Ni-Fe cell at 20°, internal resistance will be 20% higher at 50% SOC (when the battery is half empty). When the battery is 90% discharged, internal resistance will be 80% higher than when fully charged. Temperature also has a major impact on resistance. Below 0°, internal resistance will be 40% higher than at room temperature. These criteria therefore need to be taken into account for high inrush currents, which would cause a drop in battery voltage leading the inverter to disconnect, but having no consequences for either the batteries or the inverter.

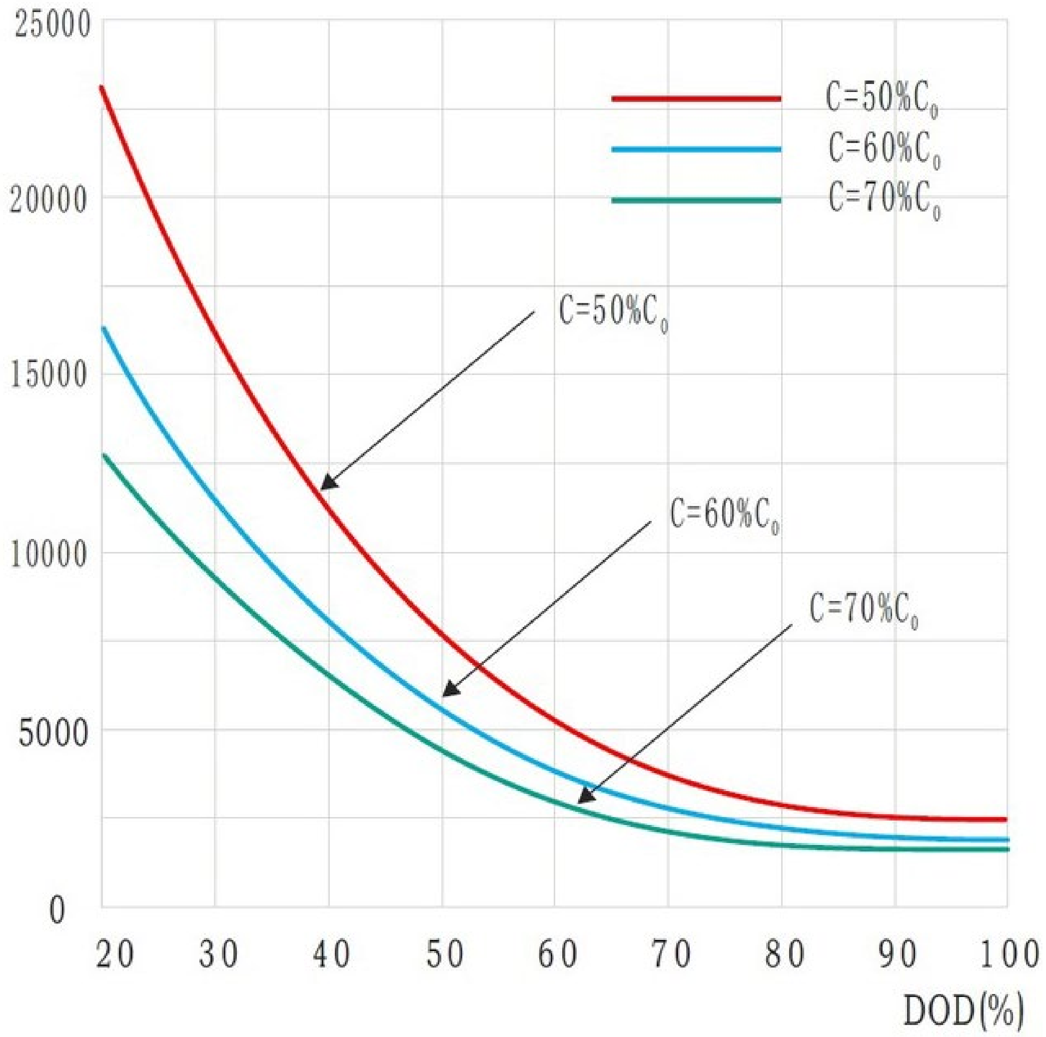
Fig.3 Available capacity as a function of temperature.



1.4 Cyclability :

The regular cycling endurance of a Ni-Fe battery is very high, enabling it to achieve excellent cyclic endurance at medium DODs. The absence of death-substance phenomena due to the very low solubility of the elements means that operating times of several decades can be achieved at different EOLs (end-of-life).

Fig. 4 Cyclability at different EOLs (20°).



1.5 Load type :

Most MPPT controllers are designed to use the default settings for a lead-acid battery, but they also feature a "custom" battery type configuration, enabling customized charge voltages to be set for other battery technologies.

You will probably need to use the custom battery type on your charger to configure it correctly for your Nickel-Iron battery bank.

The **absorption/bulk** voltage of Nickel-Iron batteries is **1.65V per cell.**

You need to reach this voltage during the bulk charge cycle and maintain it during the absorption cycle to charge a Nickel-Iron battery correctly.

The absorption cycle should be based on time, not on an end-of-charge parameter on your charger.

The **float** voltage of Nickel-Iron batteries is **1.45V per cell.**

During the running-in procedure, it is quite normal to hear the electrolyte "bubbling" (small bubbles bursting at the surface).

1.6 Temperature compensation :

The dynamic temperature compensation value for a Ni-Fe cell is **-3mV/C°**. This value is entered in the MPPT controller parameters, to adapt the charging voltage to the ambient temperature.

Temperature compensation reduces the load voltage as the ambient temperature rises, and vice versa. As a result,

- If the absorption voltage is 1.65V per cell at 25° (i.e. **33V** at 25°), the voltage at 35° will be reduced by (35-25 x 3 x 20) / 1000 = 0.6V, i.e. (1.65x20)-0.6 = **32.4V (i.e. 1.62V per cell).**

- Conversely, at 0°, the voltage will be (25-0 x 3 x 20) / 1000 = 1.5V, i.e. (1.65X20)+1.5V = **34.5V (i.e. 1.72V per cell).**

This dynamic voltage adjustment should be carried out by an internal MPPT function, avoiding the need to manually adjust the parameter during temperature fluctuations, and enabling more efficient recharging.

1.7 Load currents :

The maximum charging currents with an MPPT regulator or a specific charger for a Nickel-Iron battery are as follows :

Load type	**Load current**	**Charging time (hours)**	**Reference temperature**
Normal	*0.2C5.A*	*8*	*20°*
Packaging	*0.2C5.A*	*12*	*20°*
Fast	*0.5C5.A*	*4*	*20°*

⚠ Fast charging in less than 4 hours is possible as long as the electrolyte and/or battery temperature does not exceed 40° C.

Capacity (in Ah)	**Minimum load current (C/20, in A)**	**Optimum load current (C/10, in A)**
100	5	10
200	10	20
300	15	30
400	20	40
500	25	50
600	30	60
700	35	70
800	40	80
900	45	90
1000	50	100
1100	55	110

1200	60	120

1.8 Equalizing load

Although not mandatory, an equalization charge every 6 months (or even once a year) helps maintain optimum performance. The equalization procedure consists of a full 10-hour forced charge at **1.65-1.70** per element at C/5, followed by a full discharge at C/5 down to 1.00VDC cut-off voltage.

1.9 Overall yield

The overall efficiency of a Ni-Fe cell depends on several factors, such as charging current, ambient temperature, SOC (state of charge) and internal resistance. The average efficiency of a Ni-Fe battery at 25° is **75%** (Wh). Generally speaking, high efficiencies (>80%) are achieved at relatively low SOC levels, and as the battery approaches full charge, efficiencies drop significantly.

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B. Installation & packaging

1.1 Delivery

Ni-Fe batteries are supplied pre-filled with electrolyte and do not normally need to be topped up during commissioning, provided that the level is close to the "MAX" line.

Visual inspection of the contents of the shipment must be carried out immediately upon receipt. The customer should take note of any visual indication of electrolyte spillage or leakage. Any evidence of spillage or leakage during shipment must be reported to PERMA-BATTERIES, with supporting photo evidence.

The voltages of each battery should also be measured using a multimeter set to "direct current". A normal voltage is between ~ 1.2 and 1.3VDC per cell.

NB: the electrolyte level in each cell may vary according to storage time, temperature or other environmental factors. Variable electrolyte levels are not necessarily an indication of leaks or spills.

An electrolyte leak or spill will appear as a yellowish liquid or dried electrolyte with crystallized deposits:

⚠ Do not use cells showing signs of electrolyte leakage.
Do not use a cell with a missing cap.

⚠ Only NIFE batteries 200Ah and below are supplied with blue plugs**. Larger models (> 250Ah) are supplied with white screw caps only**.

Sealing plugs on delivery, to be changed on models < 200Ah.

1.2 Location :

Install batteries in a dry, clean and safe room. Avoid direct sunlight and heat. The battery will give optimum performance and maximum life if the ambient temperature is between 10°C and 30°C. In addition, the battery room should be sufficiently insulated to limit temperature fluctuations as far as possible.

The site floor must be level and designed to support the weight of the battery system. With larger systems, adequate spacing between rows must be provided to allow access for routine maintenance.

1.3 Cell connection :

Each Nickel-Iron cell in a park has a nominal voltage of 1.2V. As a result,

- For a 12V park, you need **10x** 1.2V elements **connected in series** (i.e. 1.2x10 = 12V).
- For a 24V park, you need **20x** 1.2V elements **connected in series** (i.e. 1.2x20 = 24V).
- For a 48V park, you need **40x** 1.2V elements **connected in series** (i.e. 1.2x40=48V).

⚠ **Please follow the connection diagrams below. Incorrect connection can lead to short-circuiting and the generation of dangerous currents.**

Fig. 6: Example of series connection (24V park)

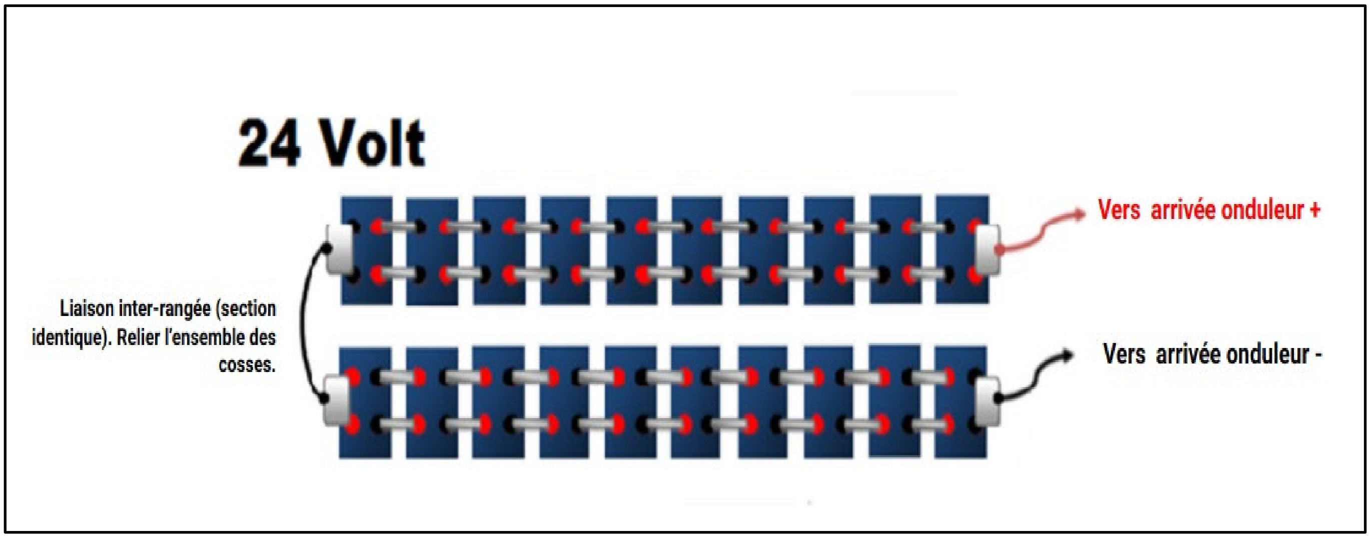


Fig. 7: Example of series connection (48V park)

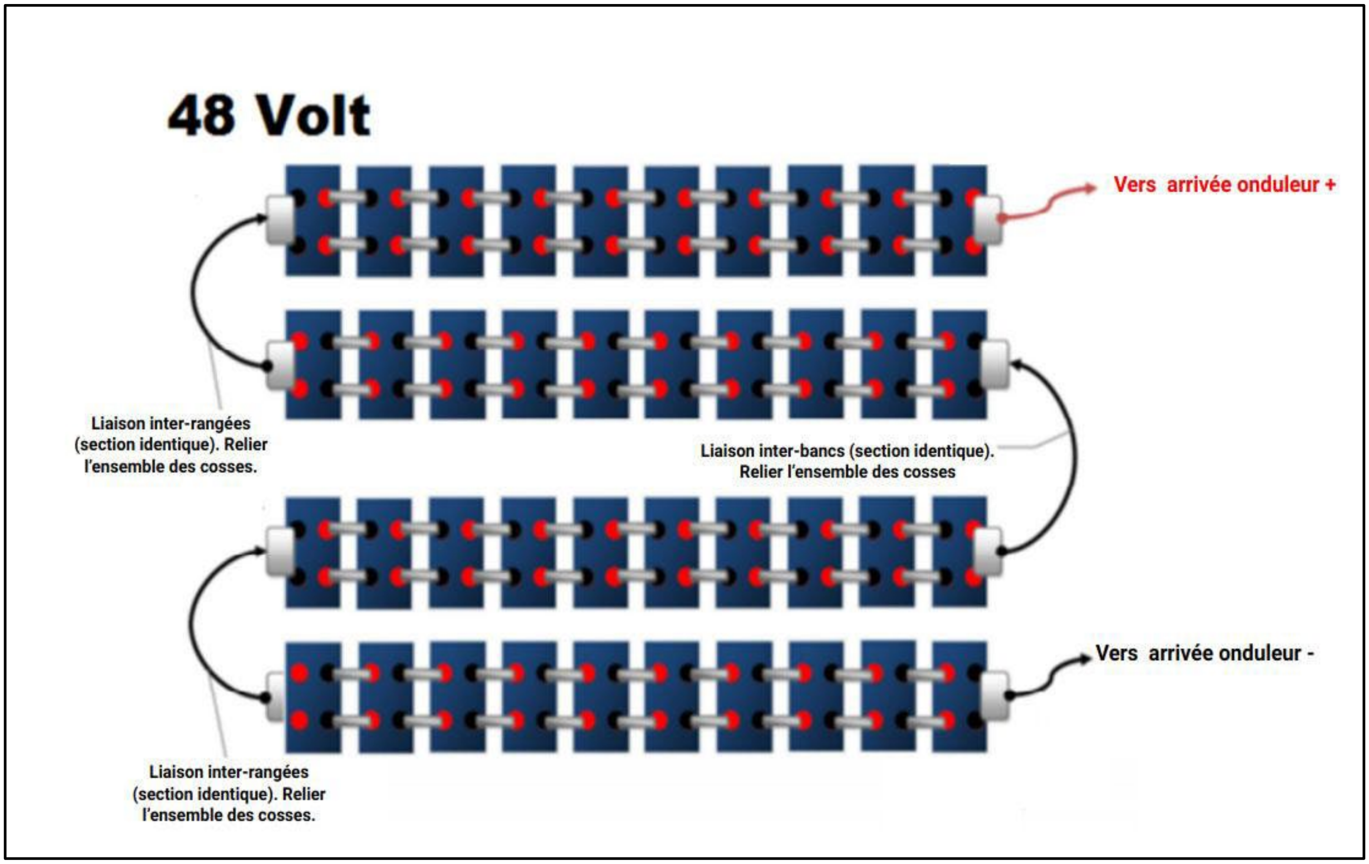
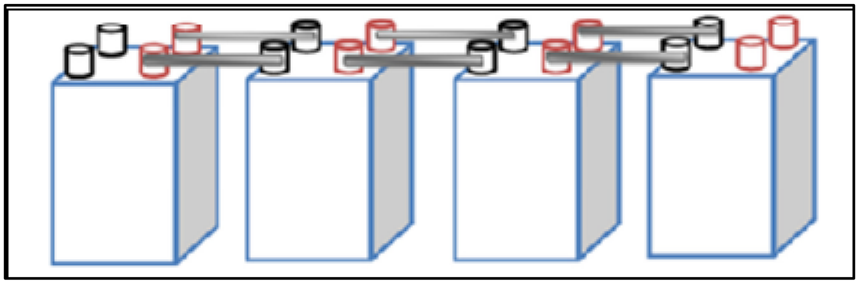


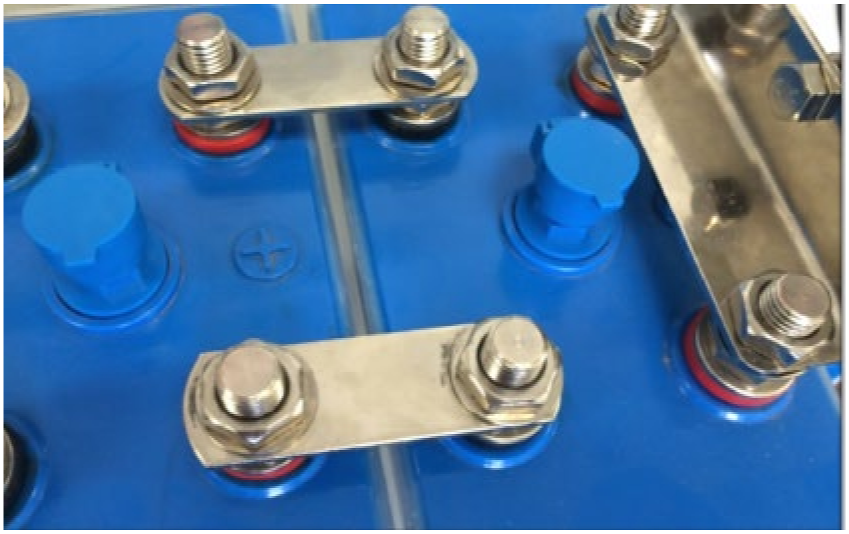
Fig. 8. side view (inter-cell connections).



Depending on the cell's capacity, it will have 2, 4 or 6 connection lugs of different diameters (M8, M10, M16, M20).

Each plate is installed in the following order: **fit washer - fit connecting plate - fit washer - fit nut - tighten to required torque.**

Fig.9. Fitting the interconnecting plates.



To ensure good electrical conduction and avoid overheating, correct tightening should be carried out using an insulated torque wrench with the appropriate torque:

Bolt diameter	Required tightening torque (N.m)
M6	10
M8	13
M10 x1	18
M16 & M16x1.5	30
M20	50

Once the batteries have been connected, grease the parts in contact with air with mineral oil to prevent corrosion of the metal parts. Before connecting to the inverter, inter-cell junctions should be protected using the insulators provided:

Fig.9. Installing insulating plates for inter-junction busbars.

1.4 Cell conditioning ("lapping").

Nickel-iron cells require a running-in period, during which their capacity gradually increases until they reach their normal capacity (approximately after 50-100 normal cycles). To speed up this process, we recommend an initial conditioning phase, as follows:

Charge at **constant current** (DC) with a suitable charger at **0.2C** for 12 hours. Then discharge the batteries for 5 hours with a C/5 charge (DC or AC).

Repeat **at least** 5 **times.**

During the running-in procedure, it is quite normal to hear the electrolyte "bubbling" (small bubbles bursting at the surface).

For example, a 24V/300Ah battery should be charged for **12 hours** at constant current with a current of 300X0.2 = 60A, until a voltage per cell of ~ **1.65V** is reached **(i.e. 33V for a 24V battery)**, then discharged with a 60A charge (60A x 24V = 1440W power dissipation) to 0% (1.00V per cell, i.e. **20V for the entire battery**).

During the conditioning phase, variables such as cell temperature and cell voltage must be checked regularly. The internal temperature of a Nickel-Iron cell must never exceed 45°C.

A Nickel-Iron battery **should never be charged at constant voltage** (CV), as this will lead to thermal runaway and damage (*increase in outgassing → drop in internal voltage --> increase in temperature → increase in current drawn by the charger*). Be sure to use a constant current source. For a list of compatible chargers, contact Perma-Batteries.

Once the running-in procedure is complete, the Nickel-Iron batteries can be commissioned and connected to the power electronics (inverter-charger).

1.5 Long-term storage :

Nickel-iron batteries have a fairly long calendar life, which means they can be stored unused **for up to 6-8 months** at room temperature (20-30°C), without any special procedures, other than keeping them either in their original crate, or in a clean room, to limit dust penetration through their caps.

If batteries are to be stored over the long term (more than 8 months), we **recommend draining them of their electrolyte,** then sealing their filler caps (to prevent internal contamination).

⚠ Storing them in a vacuum for a long period will require a longer initial running-in period when they are put into service, in order to chemically recondition the electrodes.

On the other hand, you'll need to measure their individual voltages periodically to monitor their evolution. Normal voltages (~ 1.2VDC) are common after 6-8 months' storage, but their "real" charge will be zero. Consequently, when they are connected to the solar system's inverter, it's normal for the voltage to drop sharply at first, but this will be rectified by the initial running-in phase.

C. Maintenance operations :

1.1 Summary :

The following table summarizes the various routine maintenance operations to be carried out on Nickel-Iron batteries:

Object	Frequency	Methods

Checking electrolyte level	**Monthly**	Visual inspection **at end of charge**
Battery cleaning	**Monthly**	Remove dust from battery terminals and covers.
Check terminal tightening torque	**Annual**	Torque wrench control
Lubrication of metal parts	**Semi-annual**	Application of mineral grease to terminals and inter-cell junctions
Equalization load	**Semi-annual / Annual**	See Chap.2 Section 1.8
Checking electrolyte density	**Every 10-15 years**	Check with a battery densimeter (see Chap 3 Section 1.3).

1.2 Filling the electrolyte level :

Due to the electrolysis of water during recharging, the electrolyte level is consumed gradually, so Nickel-Iron batteries need to be topped up regularly with distilled or deionized water.

⚠ **Use only distilled / demineralized / deionized water!**

Distilled water should only be topped up at the end of charging, preferably in the evening. During the day, the electrolyte level may fluctuate and not indicate a reliable value. Fill using a funnel or watering gun.

Warning:

⚠

The electrolyte level in each cell should be **checked monthly** to monitor progress and ensure that the level is **above the "MIN" level at all times.**

If the electrolyte level is too low, this can cause internal overheating, followed by a thermal runaway that can cause the battery to explode (rupture of the casing) due to the ignition of H2 + 02 gases.

1.3 Why change the electrolyte?

Over the long term, potassium hydroxide (KOH) in the electrolyte of a nickel-iron cell absorbs carbon dioxide (CO^2) from the air, recombining in the electrolyte to form potassium carbonate, K^2CO3 (carbonation). These carbonate deposits do not damage the cells, but they can lead to a significant reduction in capacity by altering the ionic conductivity of the electrolyte solution. The higher the discharge current, the more pronounced the effect. Although there is no precise consensus on the subject in the technical literature (it is very difficult indeed, given the life span of a Ni-Fe battery, which extends over several decades, to monitor performance with or without electrolyte change), we recommend a total electrolyte change every 10-15 years to revive battery performance.

It is accepted that a carbonate level of up to **80-100g/L** for a nickel-iron cell is tolerable.

The KOH concentration of the electrolyte may also decrease significantly over long periods. During recharging, part of the electrolyte is evaporated when the cell is degassed, and a small amount of KOH is lost in this way. In addition, regular topping-up can accentuate this depletion and lower the KOH concentration. One way of measuring electrolyte density is to use a battery densimeter (or acid scale) to check the concentration. When it falls below 1.160, it's time to change the solution entirely.

1.4 Electrolyte change procedure

Warnings

Potassium hydroxide is highly corrosive to skin and organic materials.

Always wear PPE when changing electrolyte!

Always dilute potassium hydroxide IN water, never the other way round!

Electrolyte composition varies according to the required operating temperature, and breaks down as follows:

Operating temperature (degrees Celsius)	**Density (g/cm3)**	**Formulation**
- 5 / + 30	1.20 + / - 0.01	KOH + 20g LiOH
+ 30 / + 45	1.20	NaOH + 20g LiOH
- 20 / - 5	1.25 + / - 0.01	KOH + 20g LiOH

Thus, for a standard density of 1.20g/cm3, one liter of electrolyte will contain :

- **~ 242g KOH (CAS 1310-58-3, min. purity > 90%)**
- **~ 950g H_2O (distilled / demineralized / ionized water)**
- **~ 20g LiOH (CAS 1310-66-3, min. purity > 50%).**

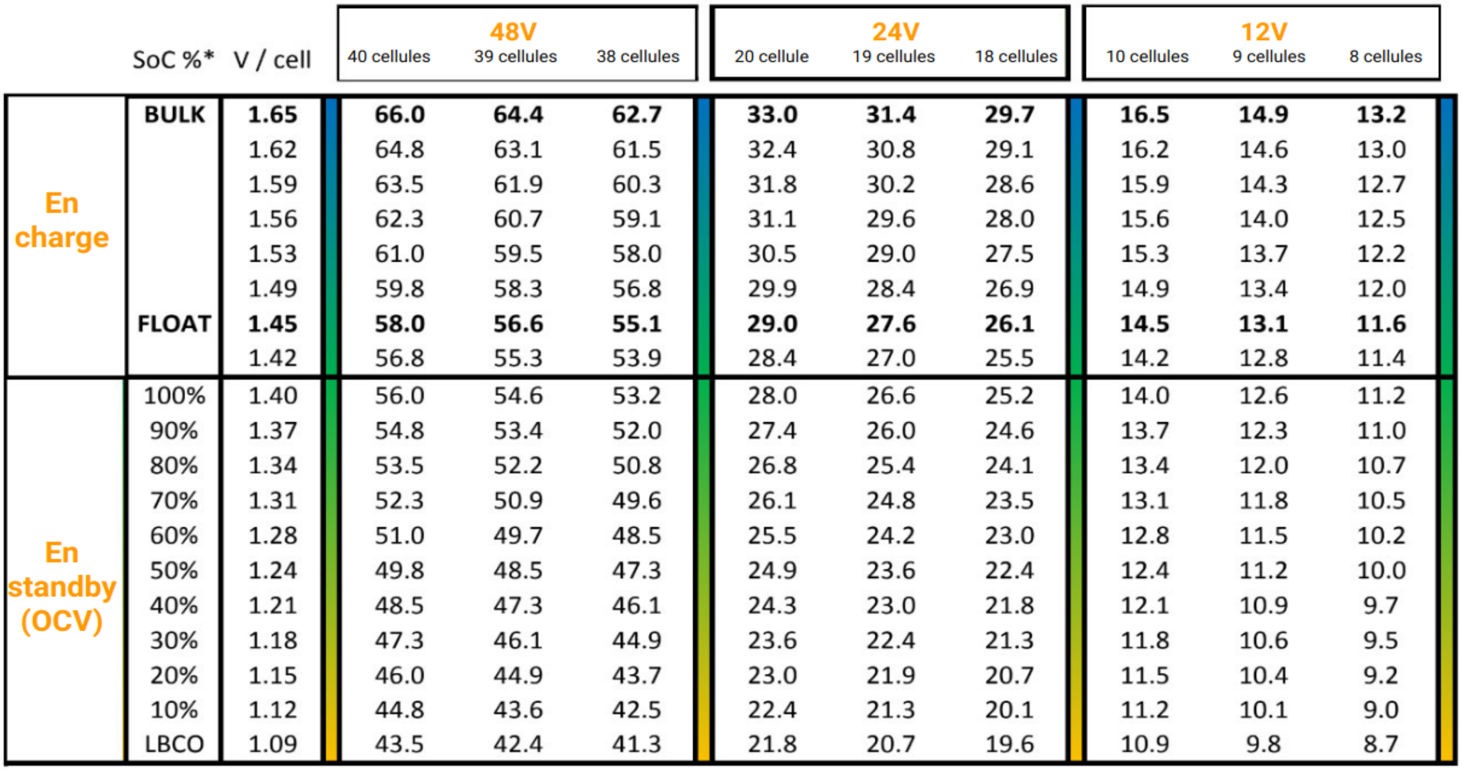
The solution prepared in this way cannot be stored (KOH absorbs carbon dioxide from the air). Make sure you use the solution quickly.

The procedure for changing the electrolyte is as follows:

- Fully discharge the cells (0.9V).
- Short-circuit each cell for 3 hours.
- Empty electrolyte into a suitable container
- Rinse the inside of each cell with distilled water. Repeat 2 or 3 times.
- Fill each cell to "MAX" level with the prepared solution.
- Reconnect each cell.
- Perform an equalization load at C/5 for 15 hours.

D. Appendices :

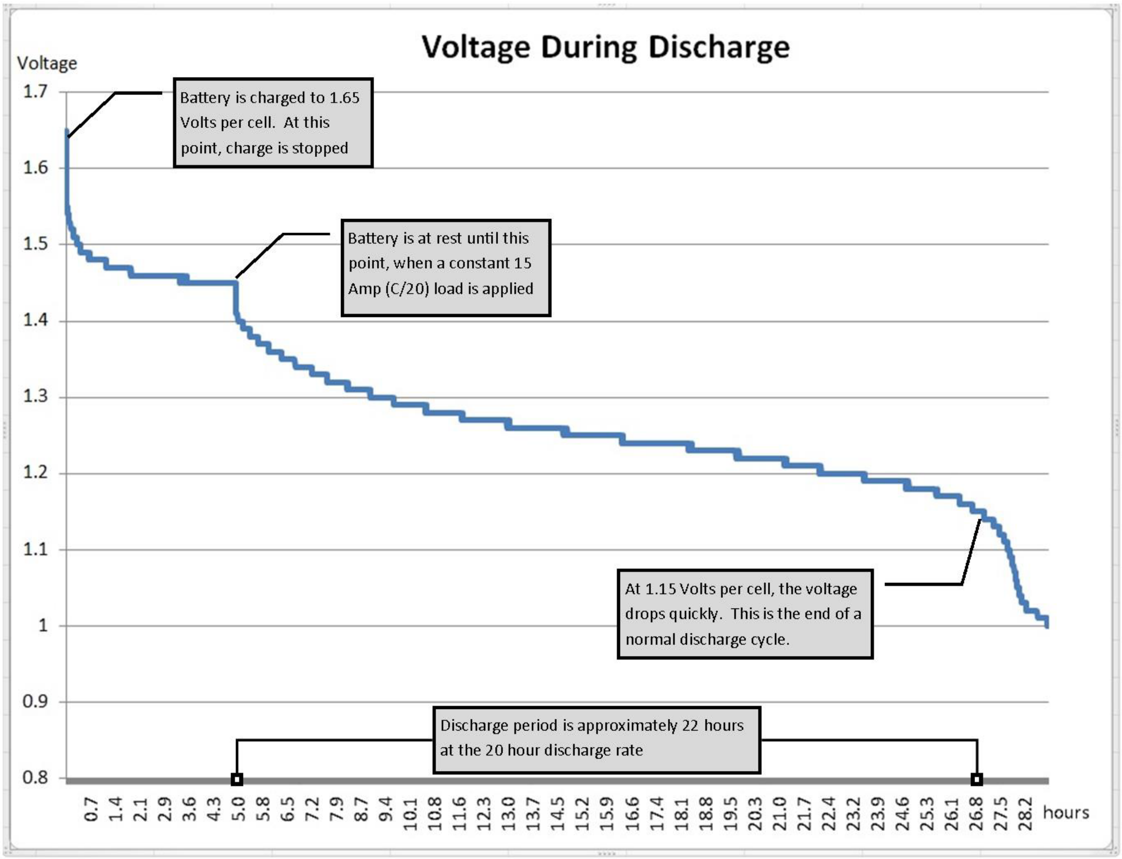
A. Voltage vs. SOC (state of charge) :



	SoC %*	V / cell	48V			24V			12V		
			40 cellules	39 cellules	38 cellules	20 cellule	19 cellules	18 cellules	10 cellules	9 cellules	8 cellules
En charge	**BULK**	**1.65**	**66.0**	**64.4**	**62.7**	**33.0**	**31.4**	**29.7**	**16.5**	**14.9**	**13.2**
		1.62	64.8	63.1	61.5	32.4	30.8	29.1	16.2	14.6	13.0
		1.59	63.5	61.9	60.3	31.8	30.2	28.6	15.9	14.3	12.7
		1.56	62.3	60.7	59.1	31.1	29.6	28.0	15.6	14.0	12.5
		1.53	61.0	59.5	58.0	30.5	29.0	27.5	15.3	13.7	12.2
		1.49	59.8	58.3	56.8	29.9	28.4	26.9	14.9	13.4	12.0
	FLOAT	**1.45**	**58.0**	**56.6**	**55.1**	**29.0**	**27.6**	**26.1**	**14.5**	**13.1**	**11.6**
		1.42	56.8	55.3	53.9	28.4	27.0	25.5	14.2	12.8	11.4
En standby (OCV)	100%	1.40	56.0	54.6	53.2	28.0	26.6	25.2	14.0	12.6	11.2
	90%	1.37	54.8	53.4	52.0	27.4	26.0	24.6	13.7	12.3	11.0
	80%	1.34	53.5	52.2	50.8	26.8	25.4	24.1	13.4	12.0	10.7
	70%	1.31	52.3	50.9	49.6	26.1	24.8	23.5	13.1	11.8	10.5
	60%	1.28	51.0	49.7	48.5	25.5	24.2	23.0	12.8	11.5	10.2
	50%	1.24	49.8	48.5	47.3	24.9	23.6	22.4	12.4	11.2	10.0
	40%	1.21	48.5	47.3	46.1	24.3	23.0	21.8	12.1	10.9	9.7
	30%	1.18	47.3	46.1	44.9	23.6	22.4	21.3	11.8	10.6	9.5
	20%	1.15	46.0	44.9	43.7	23.0	21.9	20.7	11.5	10.4	9.2
	10%	1.12	44.8	43.6	42.5	22.4	21.3	20.1	11.2	10.1	9.0
	LBCO	1.09	43.5	42.4	41.3	21.8	20.7	19.6	10.9	9.8	8.7

**LBCO = "Low battery cut off" Voltage at which the inverter goes into "low battery voltage" alarm.*

B. IU curves for unloading/loading @ C/20



Battery is charged to 1.65 Volts per cell. At this point, charge is stopped

Battery is at rest until this point, when a constant 15 Amp (C/20) load is applied

At 1.15 Volts per cell, the voltage drops quickly. This is the end of a normal discharge cycle.

Discharge period is approximately 22 hours at the 20 hour discharge rate

C. Settings for a Victron BMV-7xx series battery monitor

These values can be accessed in a Victron BMV-700 from the **"SETUP"** menu (refer to the Victron user manual). Press the "SETUP" button for 2 seconds to access the paramẽtres menu, then scroll through the values using the "+" and "-" buttons. Press the "SELECT" button to save the paramẽtre (an audible BIP alert follows).

Manual available at: https:[//www.victronenergy.fr/battery-monitors/bmv-700#manual/](https://www.victronenergy.fr/battery-monitors/bmv-700#manual/)

- ***01. "Battery capacity***

*Enter the **C/5 capacity in Ah of the Nickel-Iron battery, increased by 10%** (the Victron BMV-700 requires the C/20 value, whereas a Ni-Fe is given in C/5. A Ni-Fe battery discharged more slowly will have its capacity increased by around 10-15%).*

Example for a 350Ah battery: enter 385 Ah.

- ***02. "Charged voltage***

Value for an array of 20x cells (24V): 33V.

Value for an array of 40x cells (48V): 66V.

Value for an array of 10x cells (48V): 16.5V.

- ***04. "Charged detection time***

Enter value 20 minutes.

- ***05. "Peukert exponent.***

Enter value 1.12.

- ***06. "Charge efficiency factor (in %)***

Enter value 75

- ***08. Time-to-go averaging period***

Enter the value 8 minutes.

- ***68. Temperature coefficient (only for BMV-702 with temperature sensor)***

Enter value 1.3 (in %).

D. Settings for a Blue Solar series Victron MPPT charge controller (via the Victron Connect app on Android / IOS / PC) :

Guide available at https://www.victronenergy.com/live/victronconnect:start

"Max Charge Current": enter the C/5 value for the battery pack (e.g. 60A for 300Ah Nickel-Iron batteries).

"Battery preset": enter custom mode, then enter the following values:

- **"Absorption voltage**: 1.63V x N cells (1.63V X 20 cells = 32.6V for a 24V park).
- **"Maximum absorption time**: 12 hours.
- **"Float voltage**: 1.45V x N cells (1.45 x 20 cells = 29V for a 24V park)
- **"Equalization voltage:** 1.70V x N cells (1.70 x 20 = 34V for a 24V park).
- **"Automatic equalization"**: YES or NO (if automation is required)
- **"Temperature compensation"**: Activate function, then enter value **-3mV/C°.**

⚠ For other types of equipment (Studer Innotec), please consult us for instructions and settings.

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