ATEX- and IECEx certified cells and batteries for use in potentially explosive atmospheres

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Certified "EX" cells from Saft´s M series of lithium manganese dioxide (Li-MnO_2) primary cells offer safe solutions for powering intrinsically safe equipment used in explosive atmospheres, especially for applications that require pulse currents.

Contents

1 Introduction

The continued trend to automatization and data collection in many areas of industry and daily life has led to an increased number of primary batteries used in potentially explosive atmospheres in recent years. Prominent examples include smart gas meters, gas detectors, oil tank level monitoring and tracking of dangerous goods. In consideration of the increasing demand for security among the population and in order to best fulfil the requirements of related standards and regulations, Saft offers certified “EX” cells in its M-series of lithium manganese dioxide ($Li-MnO_2$) cells, which were especially designed for use in potentially explosive atmospheres. This paper discusses the basics of explosion protection and related certification as well as the properties and advantages of Saft´s certified “EX” cells.

2 Regulations for explosive atmospheres

2.1 ATEX directives

In the European Union and associated countries, potentially explosive atmospheres are regulated by the two ATEX directives, the equipment directive 2014/34/EU and the workplace directive 1999/92/EG. ATEX is the short form of the French expression „ATmospheres EXplosibles“, referring to (potentially) explosive atmospheres. The aim of the ATEX equipment directive is the so-called secondary explosion protection, which is the prevention of an explosion in the presence of a potentially explosive atmosphere (as opposed to primary explosion protection, which is the prevention of an explosive atmosphere in the first place). This is done by avoiding sources of ignition such as sparks, arcs, flames, electromagnetic and ultrasonic waves, hot surfaces, and optical radiation. According to its full title, the ATEX equipment directive applies to “equipment and protective systems intended for use in potentially explosive atmospheres“ and is relevant for manufacturers of equipment and components used in such environments.

The ATEX equipment directive is a directive following the “new concept”, meaning that it defines basic health and safety requirements, while leaving the details of the technical requirements to harmonized European standards, which are regularly adjusted to the state-of-the-art. In this case, the EN 60079 series of standards is used, which is itself based on the international IEC 60079 series of standards of the International Electrotechnical Commission. The basis of the series is the EN/IEC 60079-0 „Explosive atmospheres – Part 0: Equipment – General requirements”, while other parts of the EN/IEC 60079 series define specific requirements for different types of protection and systems. In addition, there are requirements for the quality system of the manufacturer, which are defined in EN/IEC 80079-34, “Explosive atmospheres - Part 34: Application of quality systems for equipment manufacture”.

2.2 IECEx scheme

Inspired by the European harmonization, the IEC introduced the IECEx scheme, which is intended as a worldwide certification scheme for potentially explosive atmospheres. To date, only Australia has fully implemented the IECEx scheme, while other countries outside the ATEX area still maintain their own national certification schemes. Implementation of the IECEx scheme is partly made difficult by the fact that the basics of explosion protection in some countries differ very much from the IECEx scheme and ATEX. For example, in the USA the potentially explosive atmospheres are divided into two “divisions” instead of the three “zones” that are defined by the IECEx scheme and by ATEX.

However, in order to obtain a national certification in IECEx member states such as Brazil, Canada, India, Israel, Japan, China, South Africa and also in the USA, an existing IECEx certificate is usually considered to be more helpful than an ATEX certificate, because IECEx member states must recognize all conformity assessment data that were generated in an IECEx certification process. Thereby, IECEx certification often opens a “fast-track process” for achieving national certification. IECEx certification is usually also accepted in developing economies that do not have their own Ex standards. In the European Union, an IECEx certificate of conformity can often be obtained at relatively low additional costs together with an ATEX certificate, if the notified body is accredited for both certification schemes, because both are essentially based on the same IEC standards.

2.3 Basics of explosion protection

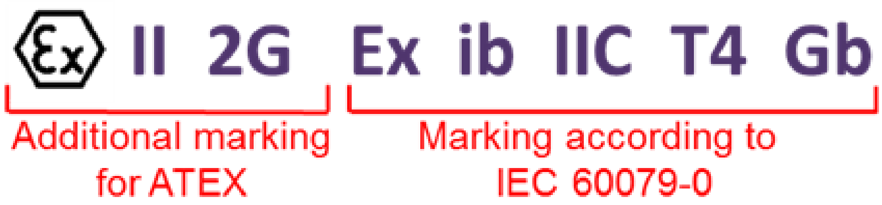

Figure 1. Typical Ex marking for ATEX and IECEx

Figure 1 displays a typical Ex marking for equipment used in potentially explosive atmospheres. It contains all the information in which kinds of explosive areas the equipment can be used. The second part is the marking according to IECEx and is based on the IEC 60079-0 standard. The first part is added for a full marking according to ATEX. In the following, the elements of the Ex marking and thereby the basics of explosion protection are explained.

Ex symbol

The full Ex marking for ATEX starts with the Ex symbol in a prescribed design, containing a specific “Ex” writing in a hexagon.

Equipment group

There are two equipment groups according to ATEX: group I contains equipment for mining and group II contains equipment for other potentially explosive areas.

Equipment class

For equipment group II, the equipment class corresponds to the level of protection and the zone in which the equipment can be used. Details are shown in Table 1. The letters G or D indicate the use in potentially explosive gas or dust atmospheres. The zones have to be classified according to the ATEX workplace directive and/or related EN/IEC standards.

Equipment class	Level of protection	Zone	Presence of explosive atmophere
1G	very high (a)	0	Long time or permanent Ex atmopshere
1D	very high (a)	20	Long time or permanent Ex atmopshere
2G	high (b)	1	Occasional Ex atmosphere
2D	high (b)	21	Occasional Ex atmosphere
3G	normal (c)	2	Probably no Ex atmosphere
3D	normal (c)	22	Probably no Ex atmosphere

Table 1. Equipment classes, levels of protection and zones.

The concept behind this scheme is to have an equally low probability of an explosion in all kinds of explosive atmospheres. In areas where an explosive atmosphere is often or always present, this has to be achieved by a very high protection level of the equipment, while a lower level of protection is sufficient in areas where the presence of explosive atmosphere is less likely.

Note that a different scheme is valid for mining (equipment group I), where the two equipment classes M1 and M2 exist. The difference is that M1 equipment can be continued to be used in the presence of an explosive atmosphere, while M2 equipment has to be switched off in this case.

“Ex” writing

The marking according to IEC 60079-0 starts with an “Ex” writing in normal font.

Type and level of protection

The type of protection is indicated by a letter such as “i” for intrinsic safety in Figure 1. There are 11 types of protection defined in IEC 60079-0, but 4 of them are most relevant for batteries. These are discussed separately in section 2.4.

The type of protection is often given in combination with the level of protection (a, b or c), which corresponds with the equipment class and zone as given in Table 1. Note that requirements for equipment given in the IEC 60079 series of standards are often different depending of the level of protection.

Explosion group

The explosion group defines the kind of gas or dust atmosphere in which the equipment can be used (see Table 2 for details). There are three different explosion groups for gas atmospheres (IIA to IIC) and dust atmospheres (IIIA to IIIC), respectively, where the letters A to C after the roman numbers indicate increasing hazardousness.

Explosion group	Kind of atmosphere	Definition or typical gas (used for testing)	Other examples for gases
I	Mining	Methane + conductive dust	
IIA	Gas	Propane	Methane, ethane, ammonik
IIB	Gas	Ethylene	Ethylene, ethyl ether, ethanole
IIC	Gas	Hydrogen or acetylene	Carbondisulfide
IIIA	Dust	Combustile fibers/ flyings	
IIIB	Dust	Non-conductive dust	
IIIC	Dust	Conductive dust	

Table 2. Explosion groups

Temperature class

The temperature class corresponds to the maximum surface temperature that is expected to be reached by any part of the equipment. It is only applied to potentially explosive gas atmospheres. The temperature class of the equipment needed for a certain gas atmosphere depends on the ignition temperature of the gas. Table 3 gives an overview of the temperature classes and some examples of gases for each temperature class. Note that there is no "T5 gas", meaning that this temperature class does not make much sense, maybe except providing an additional safety buffer for "T4 gases".

Temperature class	Max. Temperature	Examples of gases
T1	450 °C	Acetone, ethane, methane, propane, hydrogen
T2	300 °C	Acetylene, n-butane
T3	200 °C	Fuels, gasoline, heating oil
T4	135 °C	Acetaldehyde, diethyl ether
T5	100 °C	---
T6	85 °C	Carbon disulfide

Table 3. Temperature classes for gas atmospheres

No temperature classes exist for potentially explosive dust atmospheres. In this case the maximum surface temperature of the equipment is individually indicated in the Ex marking (example: "T135°C"). For explosion group I (mining), fixed maximum values for the surface temperature of equipment exist: 150 °C for surfaces that may have contact to carbon dust and 450 °C for surfaces where no coal dust is expected (e.g. within dust protected housings).

Equipment protection level (EPL)

The EPL was introduced by IEC for the IECEx scheme as a counterpart to the equipment categories defined in ATEX. It combines a capital letter for the kind of explosive atmosphere (Gas, Dust or Mining) with the level of protection (a, b or c).

Temperature range

The temperature range defines the range of ambient temperature (T_{amb}) in which the equipment has been tested and can be used. The standard temperature range according to IEC 60079-0 is from -20 °C to +40 °C. Other temperature ranges must be defined as an addition to the Ex marking (example: -40 °C ≤ T_{amb} ≤ 70 °C).

Other marking requirements

In addition to the Ex marking as described above, there are other marking requirements defined by the IEC 60079 series of standards and the ATEX equipment directive. These include, for example, the name or brand and address of the manufacturer, the type designation, the number of the ATEX and/or IECEx certificates and important safety information, some of which is specifically defined for certain types of protection in the IEC 60079 series.

2.4 Types of protection

Table 4 gives an overview of the types of protection that are most relevant for the use of batteries in equipment for Ex atmospheres. It follows a short description and discussion of the advantages and disadvantages of each approach.

Type of protection	Letter symbol	Relevant part of IEC 60079 series
Flameproof enclosures	d	IEC 60079-1
Increased safety	e	IEC 60079-7
Intrinsic safety	i	IEC 60079-11
Encapsulation	m	IEC 60079-18

Table 4. Types of protection most relevant for batteries.

Flameproof enclosures

Flameproof enclosures are housings that can withstand an inside explosion and does not transmit flames to the environment. Their main advantage is that relatively few limitations exist for the electrical installations inside the housing. On the other hand, the housings are expensive and too large and heavy for many applications. Furthermore, the approach cannot be used for equipment classes 1G, 1D and M1 (with the exception of certain gas sensors of equipment class 1G).

Increased safety

Increased safety aims at avoiding sparks and hot surfaces by construction. It is often used for rechargeable batteries (including large lead-acid batteries that have been traditionally used in industrial trucks such as forklifts), because it allows the charging of batteries inside the Ex atmosphere under certain conditions.

However, it can only be applied for equipment classes 2G and 3G. Strict requirements regarding the construction, e.g. the protection level of the housing, make this approach relatively expensive.

Encapsulation

All parts that can produce sparks and hot surfaces are encapsulated in a suitable potting compound in this approach. While it can be applied in all zones, it adds costs to the manufacturing process.

Intrinsic safety

In this type of protection, the releasable electric and thermal energy must be limited. Due to its relatively low cost, intrinsic safety has become the preferred type of protection for primary batteries and small electrical equipment with relatively low current and voltage levels. The following chapters therefore focus on this kind of protection.

3 Cells and batteries for intrinsically safe equipment

Intrinsic safety is, in first view, a rather special type of explosion protection, because it actually assumes that faults such as short circuits can happen, as opposed to the increased safety approach, where short circuits have to be prevented by construction. Therefore, for example, the requirements for housings are less strict in case of intrinsic safety.

However, it has to be made sure that even the most onerous fault condition, which is usually considered to be a massive short-circuit (external resistance ≤ 3 mΩ) of a cell in case of batteries, does not lead to the ignition of explosive atmospheres. This is achieved by the following measures:

1. Limitation of the releasable electrical power to a level where sparks caused by short-circuits or breakup of wires do not lead to the ignition of explosive atmospheres.

Compliance to this requirement can be tested experimentally by using the so-called spark test apparatus, where sparks are generated inside an explosive test atmosphere with the cell or battery under short-circuit conditions. Alternatively, compliance can be assessed by explosion limit curves and related voltage-current tables given in the Annex of IEC 60079-11.

While small cells with a low current capability and high inner resistance may fulfil this requirement without further measures, a current limiting device is usually necessary for cells with a higher current capability. For example, according to the explosion limit curves, the maximum allowable short-circuit current for a single cell is 5 A for level of protection c and 3.33 A for levels of protection a and b. Note that this current level should not be exceeded even at the highest applicable temperature level. Current limitation is usually achieved by a resistor in series to the cell or battery, while fuses are not suitable means to avoid ignition due to their time delay in interrupting the current. The current limiting element is usually added separately by the device manufacturer, however, in cases where the battery is intended to be replaced inside explosive atmospheres, it has to form an encapsulated or otherwise enclosed unit with the current limiting device.

2. No heating of the surface above certain limits

In order to evaluate a cell with respect to this requirement, the short circuit test with an external resistance ≤ 3 mΩ is performed at different ambient temperatures within the intended temperature range. The actual aim of the test is to evaluate what happens in case of an inner short-circuit. A considerable current has to flow throughout the test until the cell is discharged, meaning that cells with internal current interruption devices such as with internal fuses or or fusible links will not pass the test and have to be tested with these elements having been deactivated. The reasoning behind this requirement is that this kind of safety devices does not prevent internal short-circuits. An exception was introduced in the latest edition of the IEC 60079-11 (Ed. 7 published in 2023) regarding the qualification of rechargeable lithium-ion cells for "ib", which can be tested with internal current interruption devices in place at an external resistance of 80 ± 20 mΩ under certain conditions.

In any case, the short-circuit test has to be done without the external current limiting device mentioned in point 1. The highest surface temperature reached at the surface of a cell during the series of tests is decisive for its temperature class.

3. No release of electrolyte

No release of electrolyte from cells or batteries is allowed even under fault conditions, for example because it may be flammable or cause more short circuits due to its conductivity. Investigation regarding this requirement is often done in parallel with point 2 by checking for any electrolyte leakage after the short circuit test. Note that the short-circuit test always has to be done at an external resistance ≤ 3 mΩ in this case, while the alternative method using an external resistance of 80 ± 20 mΩ as mentioned in point 2 cannot be applied to show compliance with this requirement. In case of failing in this test, measures to prevent the impact of escaping electrolyte on intrinsic safety are necessary (for example encapsulation or installation of the battery in a separate compartment).

4. Minimum insulation distances between + and – polarity outside the cell

According to IEC 60079-11, minimum separation distances have to be obeyed between circuits. For example, for voltages up to 10 V and levels of protection a and b, the minimum separation distance is 1.5 mm through air and 0.5 mm through solid insulation. Regarding cells, these minimum separation distances apply to the separation between + and – polarities, e.g. around the glass-to-metal seal (GTMS) which is often used at the plus pole.

When assembling a battery from several cells, the minimum separation distances have to be applied to the whole assembly and circuitry outside the cells. For example, wires with sufficient insulation thickness have to be used and additional spacers may have to be placed between cells depending on the thickness of the shrink sleeves of the cells.

4 Certification process

4.1 Basic requirements

With the exception of equipment class 3, where the certification can be done by the manufacturer, certification by a notified body is necessary. The certification process usually includes the inspection of the documentation of the equipment such as drawings and the testing of samples according to the procedures prescribed by the IEC 60079 series (see section 3, points 1 to 3 for intrinsic safety). If all requirements are met, the notified body issues the following documents:

- EU Type Examination Report, supplemented by a detailed Test and Assessment Report, in case of ATEX
- IECEx Certificate of Conformity, supplemented by an IECEx Test Report, in case of IECEx

In addition, the manufacturer needs a certificate about the acknowledgement of production quality assurance according to IEC 80079-34, which is obtained after auditing by a notified body. A re-certification is necessary every three years, with one or two surveillance audits in between according to the judgement of the notified body.

4.2 Component or equipment?

In principle, batteries can be certified either as components or as equipment, depending on their design and function. Equipment is defined as a product with an autonomous function. Batteries certified as equipment must be fully compliant with all requirements of a certain type of protection and must have a full Ex marking. They can be brought into explosive atmospheres according to their Ex marking and be exchanged inside the explosive atmosphere according to the instructions of the device they are used with.

A cell or battery may also be certified as a component. In this case, the cell or battery has been checked for compliance with all requirements of a certain type of protection that are applicable on the component level, but full compliance may only be achieved by combination with further safety elements in combination with combination with the device the cell or battery is used in. For example, Saft´s cell types M20 EX SV and M52 EX SV are of this kind, and more details can be found in chapter 5.

4.3 Non-certified cells and batteries

In principle, cells and batteries used in certified equipment do not need to have their own certificate. In this case, the notified body that works on the certification of the equipment will carry out all the tests (see chapter 3) at the cells or batteries and certify them as an integral part of the equipment. However, in this case the manufacturer of the equipment takes responsibility for the continued compliance of the used cells or batteries with all regulations, e.g. by carrying out frequent auditing of the cell or battery manufacturer. Chapter 6 gives a more detailed discussion of the advantages of using certified cells and batteries.

5 Certified cells from Saft

Cells and batteries certified according to intrinsic safety standards (EN/IEC 60079-0/-11) have been manufactured by Saft´s subsidiary Friemann & Wolf Batterietechnik GmbH under the FRIWO brand name since 2012. They have been brought into the core brand of Saft as “EX” cells and batteries of Saft´s “M range” in November 2014. So far, Saft offers two types of lithium manganese dioxide (Li-MnO_2) primary “EX” cells certified as components, which are designated as Saft M20 EX SV and Saft M52 EX SV (Figure 2).

Figure 2. Cell types Saft M20 EX SV (D size) and Saft M52 EX SV (C size) certified as components according to ATEX and IECEx.

These cell types, which are shown in Figure 2, offer a high power and current capability for demanding applications in potentially explosive atmospheres. According to their Ex marking (Ex) II 2G, they are certified for use in equipment class II and equipment group 2G. Note that this Ex marking does not exclude their use in equipment group 1G or in equipment for potentially explosive dust atmosphere, but in this case additional tests have to be carry out and additional safety measures have to be taken. For example, when used in 1G equipment, a two-fault inspection (two faults at the same time) has to be carried out with the cell in the equipment, while the inspection of the single cell is in principle a one-fault inspection (with the short-circuit as the only fault) and therefore does not allow a 1G marking for the cell itself. Alternatively, the equipment with the integrated cell has to be protected by two independent types of protection, for example encapsulation (type of protection “m”) in addition to intrinsic safety.

As components for integration into Ex equipment, the cells do not have a full Ex marking due to the following reasons:

- As seen in Table 5 and Figure 3, the cells show a rather high short-circuit current, which is an expression of their high power and current capability. This means that they do not pass the spark test (see chapter 3, point 1) without an additional current limiting element, which has to be combined with the cell in the equipment. The level of protection as well as the explosion group will then depend on the current limiting element and the electronic characteristics of the device.

- The temperature class in an Ex marking can only be given in combination with a level of protection and an explosion group. However, it is noted in the certificates and the installation instructions of the cells that the cells are compliant with temperature class T4 at ambient temperatures between -40°C and +72°C, based on the test result that the temperature during the short circuit tests did not exceed 135 °C (see maximum temperatures in Table 5).

This means that the cells can be used in intrinsically safe devices without any further testing being carried out on the cell level, but note that they can only be exchanged outside Ex areas.

Cell type	Saft M20 EX SV			Saft M52 EX SV		
Size	D			C		
Nominal voltage	3.0 V			3.0 V		
Rated capacity	12.4 Ah (at 150 mA)			5.6 Ah (at 60 mA)		
Max. recommended continuous & discharge current	3.5 A [1,2]			2.0 A [1,2]		
Max. recommended pulse current	8 A [1]			4.0 A [1]		
Weight	115 g			58 g		
Operating temperature	-40 °C to +72 °C			-40 °C to +72 °C		
Storage temperature	-55 °C to +90 °C [3]			-55 °C to +90 °C [3]		
Certified according to	IEC 60079-0, IEC 60079-11, UL 1642, File MH 61234			IEC 60079-0, IEC 60079-11, UL 1642, File MH 61234		
Transport according to	UN 3090 and 3091			UN 3090 and 3091		
ATEX/IECEx-relevant properties						
Ex marking	(Ex) II 2G			(Ex) II 2G		
EC-Type Examination Certificate-No.	BVS 12 ATEX E 026 U			BVS 13 ATEX E 035 U		
IECEx Certificate No.	IECEx BVS 15.0121 U			IECEx BVS 13.0053 U		
Typical behavior during short circuit at 3 mΩ and an ambient temp. of	20°C	40°C	72°C	20°C	40°C	72°C
Max. short-circuit peak current	62 A	71 A	73 A	70 A	72 A	80 A
Min. inner cell resistance	50 mΩ	43 mΩ	41 mΩ	44 mΩ	42 mΩ	37 mΩ
Max. cell temperature	94°C	100°C	110°C	100°C	101°C	108°C
Temperature class	T4			T4		

[1] Limitation of the max. current to a lower level, e.g. by a series resistor, may be necessary depending on the electrical properties of the device and the desired level of protection (ia,ib,ic) and explosion group (IIA,IIB,IIC).
[2] To maintain cell heating to safe limits. Battery packs may imply lower level of max. current and may request specific thermal protection.
[3] Long time storage at high temperatures may affect the performance.

Table 5. Technical data of Saft M20 EX SV and Saft M52 EX SV cells

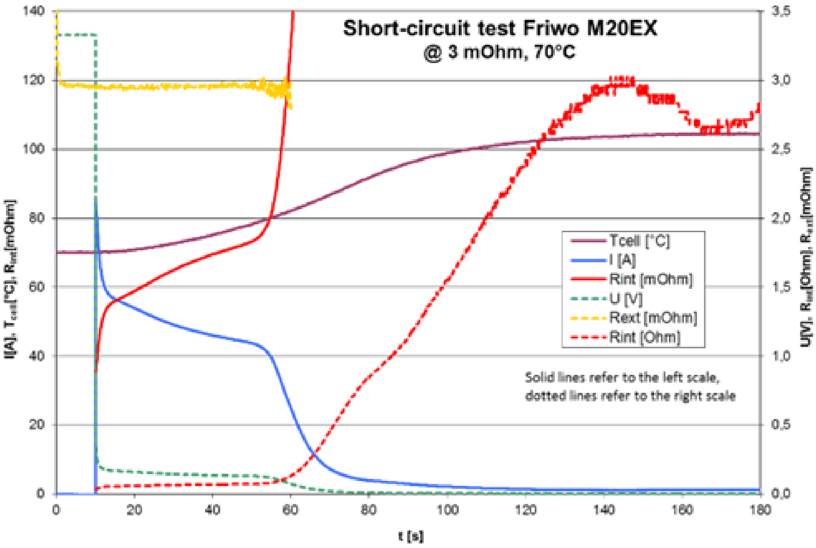

Figure 3. Short-circuit test according to IEC 60079-11 at a Saft M20 EX SV cell

6 Why certification ?

In principle, manufacturers of equipment for potentially explosive atmospheres can choose between using ATEX or IECEx certified cells and batteries or using conventional cells or batteries, which have to be tested by the notified body that certifies the Ex device. For this purpose, cells are often offered as “ATEX compliant” by their manufacturers if they pass the 3 mΩ short-circuit test. However, using certified cells has numerous advantages for device manufacturers, which are summarized in Figure 4.

Compliance is often solely declared on the basis of the 3 mΩ short circuit test carried out by the manufacturer, which has to be verified by a notified body when the cell is to be integrated into a device. In case of using certified cells, the full compliance of the cells (including other aspects such as insulation distance requirements) is verified by the issuance of the certificate, so that no further testing on the cell level is necessary during the certification process of the device. For the device manufacturer, this saves time and money.

Another important difference between the two approaches concerns the responsibility for continued compliance of the cell or battery. In case of certified cells and batteries, the cell or battery manufacturer and the certifying notified body take responsibility, based on the certification process, the certification of the quality assurance (QA) system of the manufacturer to IEC 80086-34 and frequent audits of the production and QA system by the notified body. Certification according to IEC 80086-34 includes requirements that go well beyond the ISO 9001 standard, regarding, for example, the inspection requirements for material used in the manufacture of the cells and batteries, inspection requirements during the production process, and the traceability of products and used materials. Without certification, there is no specific QA system for compliance with ATEX and IECEx, and the device manufacturer has to take a part of the responsibility by carrying out audits at the cell or battery manufacturer. Thus even more time and money are lost. The certification also assures that any relevant design changes to the cells or batteries are reported to the notified body, tested for ATEX compliance and communicated to customers before their implementation.

Certification	Compliance
Clearly defined system with 3 elements of certification by a notified body	No clearly defined system
1. Verification of full ATEX compliance	Usually only 3 mOhm short-circuit test by the cell manufacturer
2. Certification of the QA system to IEC 80079-34	No specific QA system
3. Audits of the production process to assurance (tracability of materials, approval of changes, etc.)	Audits to be done by the device manufacturer or repeated tests
→ Assurance of continued compliance by independent experts	→ The device manufacturer itself has the responsibility to assure continued compliance

Figure 4. Comparison between certification and the compliance approach without certification

7 General safety features

Throughout the long history of Saft´s subsidiary Friemann & Wolf, the safety of its products has always been first priority, having started as a manufacturer of safety lamps for mining in 1884. Regarding the design of our Li-MnO_2 cells, which is now known as Saft´s “M series”, no compromise has been made on their safety, leading to a cell design that is absolutely safe even under the most adverse conditions such as forced discharge and cell reversal.

In other respects, the cells fully comply with and even exceed the safety standards defined in IEC 60086-4 and UL 1642. This includes their ability to withstand high or low pressure, extreme temperature cycling, shock, impact, free fall, vibration, external short circuit, abnormal charging, and thermal abuse. In addition, cells and batteries of the «M series» meet the safety requirements of military standards and even the strictest reliability and safety requirements of the space agencies such as ESA and NASA.

8 Design features

The constantly growing market for remotely controlled devices such as smart meters as well as safety devices such as emergency beacons leads to an increasing demand for small, lightweight and high-performance batteries with a long lifetime. These requirements can only be met with primary lithium cells and batteries, which provide a higher energy density compared to conventional technologies such as alkaline batteries. Among the different primary lithium technologies, the lithium-manganese dioxide (Li-MnO_2) system with a spiral electrode design combines the advantages of low self-discharge and capability for high current and power in a single cell. This makes spiral-design Li-MnO_2 cells the system of choice for applications with a low average consumption, but temporary demands for high current pulses even after long stand-by periods.

Saft’s M20 EX SV and M 52 EX SV cells are ideally suited for applications of this kind in potentially explosive atmospheres in - 40°C / + 72°C environment. Figures 5 and 6 show some typical discharge curves of the cells for different temperatures. More detailed information can be found in the data sheets available on www.saft.com.

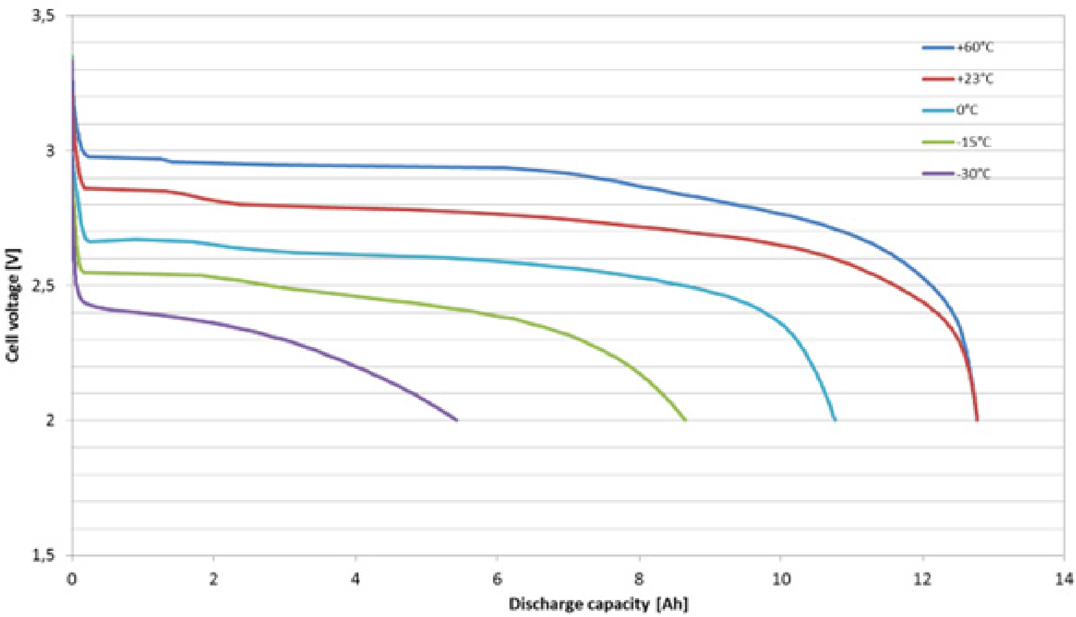

Figure 5. Discharge curves of the Saft M20 EX SV cell recorded at 500 mA continuous current and different temperatures

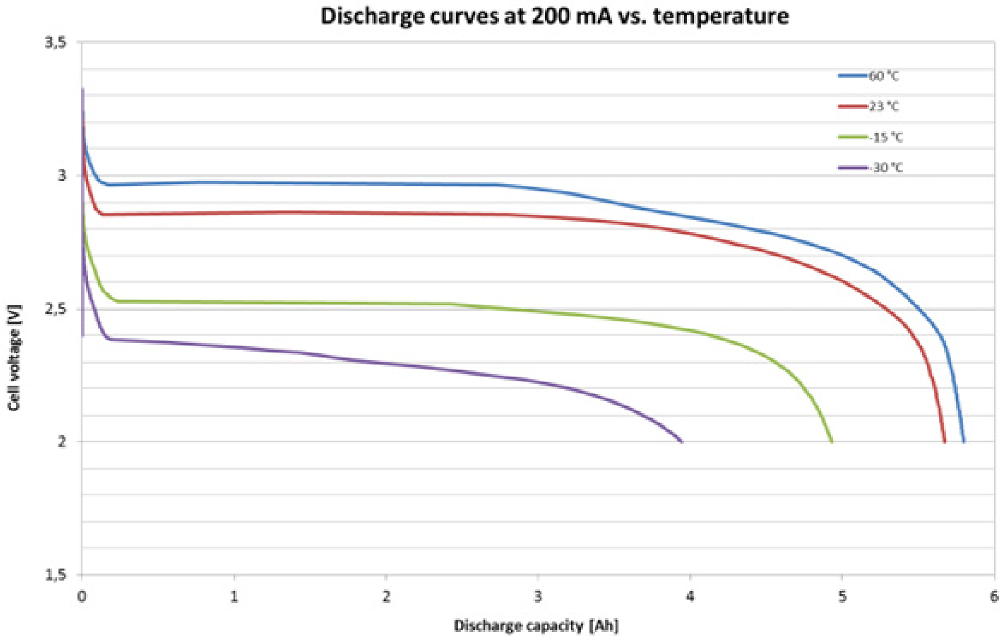

Figure 6. Discharge curves of the Saft M52 EX SV cell recorded at 200 mA continuous current and different temperatures

The most important cell features, leading to superior performance, include the following:

- Spiral design for high current and power capability
- High energy density (320 Wh/kg at room temperature)
- Low self-discharge (< 1.5 % in the first year, ca. 0.5 % / year from the second year at room temperature)
- Superior resistance to corrosion due to stainless steel can and end caps
- Hermetically sealed with glass-to-metal seal and laser welding
- No "voltage delay" even at high currents due to low passivation
- No influence of orientation on capacity and performance
- No internal cell pressure
- Safety vent at cell bottom
- Safety "shut-down" separator
- REACH compliant electrolyte (no use of substances of very high concern)

9 Applications

Since 2012, Saft´s ATEX and IECEx certified cells and batteries have already been used in numerous applications, such as

- Smart gas meters (with built-in GPRS communications)
- Tracking systems for dangerous goods
- Data loggers
- Position switches
- Gas detectors
- Antistatic devices

Other potential applications include tank level monitoring, pipeline inspection and other wireless automation applications in the chemical industry.

The Saft M20 EX SV and Saft M52 EX SV cells can either be directly supplied to equipment manufacturers for integration in their Ex equipment, or they can be assembled into battery packs according to ATEX / IECEx requirements and the specifications to be defined by the equipment manufacturer and the notified body that certifies the equipment. Note that such battery packs are usually certified as a part of the equipment.

10 Appendices

10.1 About Saft

Saft specializes in advanced technology battery solutions for industry, from the design and development to the production, customization, and service provision. For more than 100 years, Saft's longer-lasting batteries and systems have provided critical safety applications, back-up power and propulsion for our customers. Our innovative, safe, and reliable technology delivers high performance on land, at sea, in the air and in space.

Saft is powering industry and smarter cities, while providing critical back-up functionality in remote and harsh environments from the Arctic Circle to the Sahara Desert. Saft is a wholly owned subsidiary of TotalEnergies, a broad energy company that produces and markets energies on a global scale: oil and biofuels, natural gas and green gases, renewables and electricity.

#WeEnergizeTheWorld

10.2 About Friemann & Wolf

Saft´s subsidiary Friemann & Wolf has been one of the world-leading manufacturers of spiral-design Li-MnO_2 cells and batteries for more than 20 years. Being a company of the Saft Group since 2003, it combines the flexibility and dedication of a medium-sized company with the network and resources of a globally active corporate group. As a manufacturer of innovative Li-MnO_2 cells and custom-made batteries, Friemann & Wolf has set high standards regarding quality, optimum reliability and perfect safety being the main criteria, as well as its exemplary customer service, which goes well beyond usual standards. All Li-MnO_2 cells of Saft´s "M range" are manufactured in Friemann & Wolf´s production facility located in Büdingen (Germany) on state-of-the-art fully automatic production lines.

Saft and Friemann & Wolf are committed to the world class philosophy. The management systems are certified according to DIN EN ISO 9001 and DIN EN ISO 14001.

10.3 About the author

Dr. Torsten Oekermann is Product Engineering Manager and the responsible person for Ex applications at Saft´s subsidiary Friemann & Wolf Batterietechnik GmbH. He joined the Saft group in 2009 after various academic positions in the field of electrochemistry in Germany and Japan. Since 2013 he is a member and since 2021 the co-convenor of the IEC working group TC31/WG37 dedicated to the use of batteries in potentially explosive atmospheres.

10.4 Contact information

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We energize the world.

On land, at sea, in the air and in space.

Saft has launched a sustainability initiative, Program Net Zero, consisting of 5 pillars:

1. Reducing the environmental footprint of our activities and that of our battery solutions.
2. Assisting Saft's customers in lowering their environmental footprint.
3. Using natural resources sustainably and implementing circular economy principles throughout our operations.
4. Prioritizing suppliers with strong environmental, social, and human rights records.
5. Working to always ensure compliance with environmental regulations and best practices in all locations.

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