Operating Safety Lights in Potentially Explosive Atmospheres
Are "Ex Certifications" to be trusted?

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Early April 2012, a third party commissioned DEKRA Certification B.V, The Netherlands, to test six (6) brands of 'intrinsically safe' alkaline (4 x AA) powered hand lamps and to validate not only various performance claims published by the different vendors but also to verify if the lights were compliant with the issued ATEX certifications. The results of the study –"*Photometric and mechanical testing of six different type of professional torches*"*- are a cause of concern leading to the publication of this paper, the scope of which is to explain the basic technical prerequisites, which luminaries should fulfil to qualify as '*Intrinsically Safe'.* At the same time, the article shall provide operational warnings as, at closer inspection, some luminaries might prove to be safer than others!

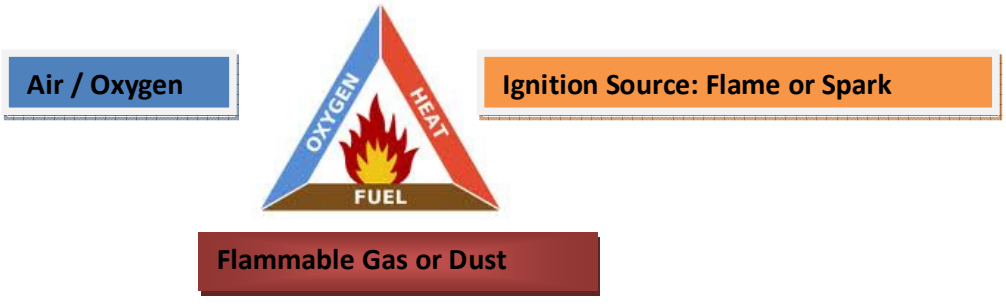
In brief, the DEKRA test report documented that five (5) out of six (6) flashlight samples did not live up to some of the vendors' claims, e.g. **grossly overstating lumen ratings**, and **three (3) samples failed the immersion tests,** e.g. water leaked into the battery chamber, in non-compliance with the issued ATEX certifications and IP ratings!

What is Intrinsic Safety?

As pictured below, to cause an explosion three elements must be present: Oxygen, flammable compounds and a spark or a flame.

As general definition, equipment termed as *'Intrinsically Safe'* is incapable to cause electrical sparks or sufficient thermal energy to ignite flammable compounds present in an explosive atmosphere, may they be gases, vapours or dust.

Elements needed to cause an explosion ("Triangle of Fire")



***Note:** DEKRA Certification B.V. is an independent internationally accredited Test Institute. The above mentioned study (DEKRA, Arnheim, 3 April 2012) measured the light performance (luminous flux and intensity, isolux, etc.) and investigated the physical endurance (dust and water ingress, 3 m drop test) of six (6) alkaline (4 x AA) handheld torches marketed by different US (3), German (2) and United Kingdom (1) vendors. It must be mentioned that light performance of a torch is not part of intrinsically safe certifications; lumen advertised by vendors are mostly unverified. The circulation of the report remains restricted.

In battery powered luminaries, three main components might cause a spark or a flame:

a) *Batteries* – they might leak, gas out or short-circuit.
b) *Light source* – incandescent bulb might break or explode; LED circuits can short-circuit and components may overheat or become faulty.
c) *Enclosure and material* - electrostatic discharge can cause sparks.

Batteries

Handheld flashlights and headlamps require a power source to operate; these can be rechargeable or non-rechargeable battery cells, e.g. Li-ion, NiMH, NiCd, alkaline, lithium, and so on. Batteries store energy to be released as 'electrical power', and depending on chemistry, some batteries are more energetic than others. Yet, batteries may leak over time, gas out or short-circuit damaging the electronics and the enclosure of the luminary. Gassing batteries are of special concern as there are risks that they might explode inside the compartment leading to injuries or, in the worst case, initiating a major explosion. Picture 1 shows an exploded flashlight (with pressure valve) after the inserted alkaline batteries gassed out. Noteworthy is and as the picture shows, 'safety gas valves' seem not to offer much protection when batteries start gassing.

Pic 1 – gassing alkaline batteries

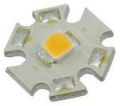
Pic 2 – exploded lithium batteries

For safety reasons, it is a requirement that all intrinsically safe lights list, at least in the manuals, the type, brand and manufacturer of batteries approved for safe operation with the specific luminary. Important, the listed batteries must have been tested and certified by a Notified Body/Test Institute.

Light Source

As light sources, most handheld flashlights and headlamps use either incandescent bulbs, e.g. Xenon or Krypton, or LEDs. Obviously, light bulbs can burnout or break when lit. Also, light bulbs will become very hot during operation –the brighter the hotter-, heating up the luminary enclosure (and batteries), sometimes to critical temperatures sufficient to ignite flammable gases or dust. Therefore, light bulbs have to pass electrical and the housings mechanical and environmental stress tests before the light will be certified as *'Intrinsically Safe'.*

In case luminaries include an LED light source, it is mostly ignored that LED chips not only generate considerable heat but that they require an electrical circuit and a heat-sink to operate. Unlike bulbs, LED emitters will not shatter if defect and are thus considered safer to use. The Achilles tendon of all LEDs is the electrical circuit which must be designed and manufactured in accordance to approved safety Norms and Standards in order that neither the circuit nor any of its components will short-circuit and cause electrical sparks!



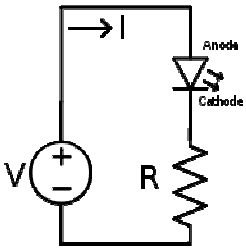
Circuits

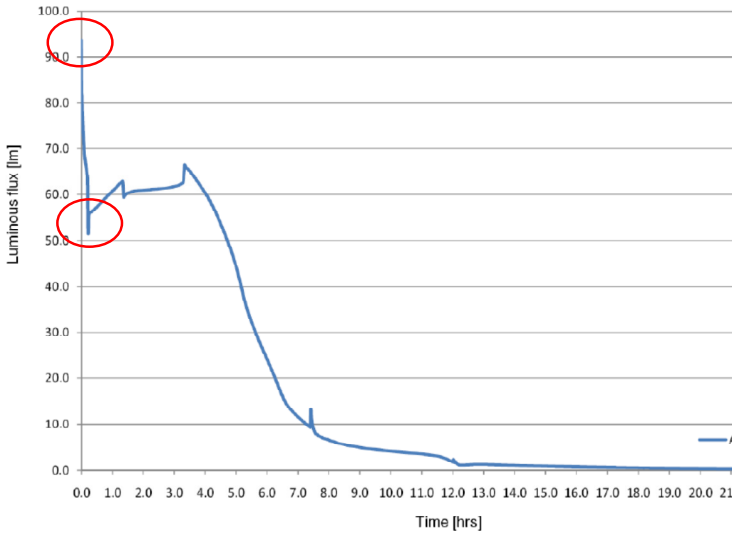
Incandescent *light bulbs* can be directly connected to batteries without having to take polarity into consideration. Therefore, the electrical circuit is rudimentary consisting of a bulb, batteries, contacts and likely a switch.

LED emitters are diodes allowing the current to flow in one direction only. In a very simple circuit, LEDs are direct driven, similar to a light bulb. Alternatively and more expensive is to drive the LED with a regulated circuitry. But which of the two is more efficient and safer? Performance wise, the LED with the regulated circuit will fare better than if direct driven; however, electrical safety can only be guaranteed if the regulated circuit includes current limiting resistors, a fuse and is reverse polarity protected. In addition, all components which might heat up must be insulated, creepage between conductive tracks must be avoided and clean and solid soldering is a prerogative.
ATEX and IECEx Norms and Standards, e.g. EN 60079-11:2007, applicable for intrinsically safe luminaries list out all safety requirements in great detail. Yet, caveat emptor (buyer beware), users should not automatically assume that the circuit and so the lamp is "truly safe" despite being certified and marketed as '*Intrinsically Safe*! The safety dilemma with the DEKRA test results in mind will be explained in -"*Norms, Certifications and Inconsistencies".*

Considering the above two circuit types, for the user important to know is:

a) *Direct driven* LEDs are connected directly to the batteries and will be very bright in the first few minutes but then lose rapidly around 50% of the light power! The below graph shows the drastic drop in luminous flux from 96 lumens to 53 lumens within a few minutes (notable is that the DEKRA tested product is advertised by the vendor to emit "200 lumens"!). Reasons are, firstly, alkaline batteries show a significant voltage drop when under heavy load and secondly, the LED, if unregulated, will draw as much current as it can causing "thermal runaway" to the degree that the light starts flickering; at the end, the excessive heat will damage the LED! For cost considerations, simplicity of engineering and production, the majority of "intrinsically safe" lights rely on direct driven LED circuits!

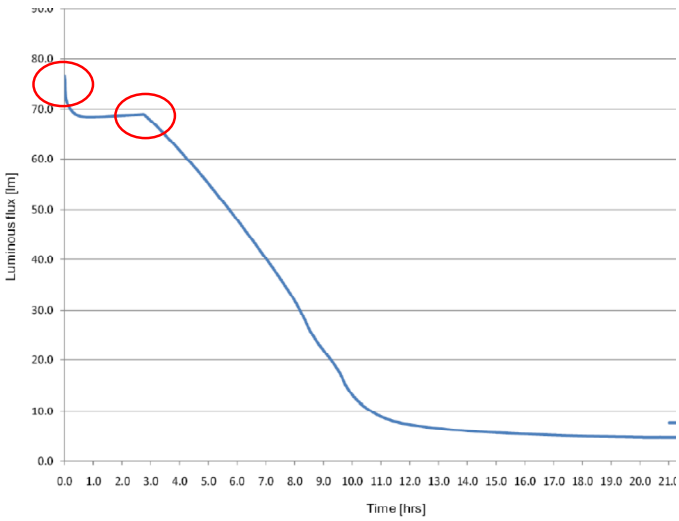




The graph shows the light performance using a direct driven LED circuit.

Source: DEKRA Certification, Test Sample 2

b) *IC controlled* LED circuits regulate the current supply either by pulse modulation (PWM), constant current (CC) or alternatively by applying constant voltage (CV); in other words, a Microcontroller constantly senses and optimises the forward current respectively forward voltage applied to the LED keeping the light output constant and so reducing negative thermal effects. Nevertheless, to make the circuit truly safe, it must be reverse polarity protected, include current limiting resistors and a fuse should be added. Current limiting resistors keep the forward current to the LED at a defined level. In case of a short-circuit, the fuse is the last safety resort interrupting the current flow in the LED circuit. Therefore, regulated circuits which include an IC, resistors, capacitors, safety fuse, etc. and are not only safer but show a far better performance than direct driven LEDs.



The graph shows the light performance with a safe IC controlled LED circuit.

Source: DEKRA Certification, Test Sample 1

Enclosures

Enclosures protect critical components, namely the light assembly and batteries, from the elements, exposure to explosive gas and dust and from impact. Therefore, much attention must be given to the construction and quality of materials used to guarantee that the flashlight and headlamp housings remain waterproof, do not crack when accidentally dropped and resist impacts.

Enclosures of intrinsically safe lights are predominantly made of plastics; these might have *conductive* or *non-conductive* properties. Non-conductive polycarbonate (PC), e.g. Lexan, is the most common and cost effective plastic. Conductive anti-static materials like carbon fibres and "XAG" are expensive and preferred if lights are to be certified for safe use in highly explosive atmospheres, e.g. Nitrogen gas. Before a flashlight can be certified as *'Intrinsically Safe',* the entire enclosure has to pass various laboratory tests which include impact and drop tests, water and dust immersion (IP rating) and, depending on certification, temperature stress and electrical resistivity tests.
In temperature stress and endurance tests, the flashlight (excluding batteries) will be exposed to temperatures of around 100 ºC and higher for four weeks, at low and high humidity. Once out of the oven, the light is frozen to -25 ºC for 24 hours and then impacted with a weight of 1 kg dropped from different heights. It is obvious that many enclosures will crack during the last test. Therefore, most vendors prefer not to subject their lights to temperature stress tests. Yet, customers might misinterpret or misunderstand temperature ratings. As example, one of the DEKRA tested lights is ATEX Dust certified: *"II 2 D Ex ibD 21 T 135 ºC".* The stated temperature of "135 ºC" does not mean that the light has been exposed to a temperature of 135 ºC but that the maximum operational (when lit) surface temperature of the housing reaches 135 ºC, which is high, considering that the heat deflection temperature (HDT) of the polycarbonate housing is 132 ºC and that the material starts softening at 154 ºC! Last but not least and as a warning, the Ignition Temperature of Dipentyl Ether is 171 ºC (T4), close to the certified housing temperature.

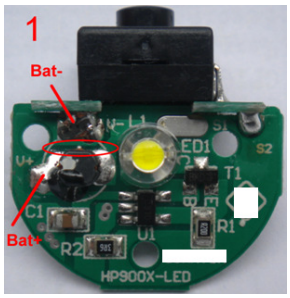
IP ratings indicate the level to which the flashlight is water and dust proof. Water immersion is part of the 'product certification tests'. After the tests, the product will be IP rated, e.g. IP 67 or IP 68. As example, IP 67 certifies that the product is *"Dust Tight"* and suitable for *"Immersion up to 1 m"*. In the mentioned DEKRA report, three (3) out of the six (6) flashlights (50%) failed the 1 m immersion test despite two vendors are claiming that the affected models are "suitable for diving"!

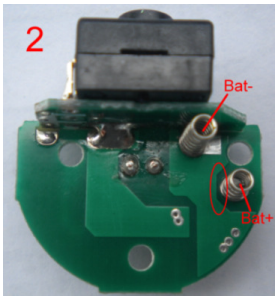
Tool secured – luminaries to be operated in explosive DUST atmospheres should be *'tool secured'* so that hot light assemblies and batteries especially will not become accidently exposed to explosive dust and particles. In the DEKRA report, only one (1) of the six (6) lights was tool secured!

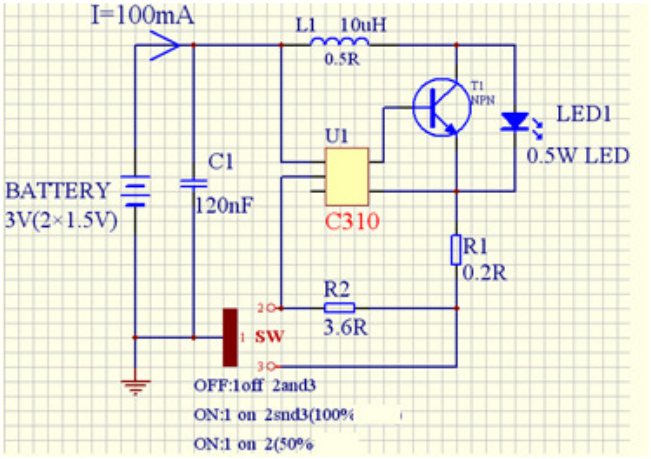
Norms, Certifications and Inconsistencies

The above comments refer predominantly to ATEX which stands for "*Appareils destinés à être utilisés en **AT**mosphères **EX**plosives*"; ATEX applies mainly to the European Community (EC). However, countries, such as the US, Canada, Australia, Russia, Japan, etc. all implement

different Directives –UL, FM, ETL, IECEx, TIIS, to mention a few. It is outside the scope of this paper to explain the nuances and differences of these Directives other than to state that the general product test methods follow and apply schedules similar to ATEX. In accordance to the various Certification Schemes, *'Intrinsically Safe'* products can only be distributed if the *facilities of certified vendor* are audited by a Notified Body (Accredited Organisation). Still, vendors who market "Ex certified" lights under their own brand may not necessarily be the original manufacturer but employ uncertified subcontractors in third countries instead. Most subcontractors do not have any 'Ex' Quality Assurance Module in place and the production facilities are not inspected and audited by any Notified Body! In other words, US or European vendors may purchase flashlights either as "Complete Knocked Down" (CKD) kits or as finished products from 'anonymous' and uncertified subcontractors located in different jurisdictions. In case of CKD kits, the vendor assembles the parts at his facilities and sells the products as "intrinsically safe lights" under his own brand including certifications issued by a Notified Body in his name. On the other side of the coin, customers risk to purchase, in good faith, a 'branded and Ex certified' flashlight or headlamp which might turn out to be unsafe if used in hazardous areas! In the following example, an unnamed European "Ex safety" company markets an alkaline battery powered headlamp certified to ATEX "II 2 G Ex ia T4", -"ia" approves the lamp for Gas Zone 0, an area in which explosive gases are continuously present! However, the LED board (pictured below) is made in China by an "Ex" uncertified subcontractor. The circuit as shown does not include any current limiting resistors or a fuse, components are without insulation and conductive tracks are closer than permitted risking current creepage for sure. And yet, the head lamp was approved and certified by a Notified Body in Germany!







Comments:
The headlamp is powered by
2 x AAA batteries (3V).
The light source : 0.5W "two-pin" LED.

ATEX Certification: II 2 G Ex ia T4

The circuit:
a) Battery short-circuit current is 5.44A
b) Without fuse and current limiting resistor, the short-circuit across the batteries is calculated to be 27.2W, yet only 0.33W are permitted!
c) Inductance is 360µJ exceeding the permitted 160µJ!

Conclusion

The aforementioned DEKRA report and the cited examples should sound alarm bells to users who operate luminaries in hazardous areas. "Branded" flashlights and headlamps with "Ex Certifications" are no guarantee that the lights will perform as advertised by vendors and will be truly safe for deployment in potentially explosive atmospheres! The reasons are:

a) **Notified Body** - To be certified as *'Intrinsically Safe'*, products must comply with specific Norms and Standards (e.g. ATEX); nevertheless, it is left to the interpretation of the Notified Body how to implement these. As certifications are expensive and Notified Bodies are fighting for customers, vendors tend to select accredited organisations which interpret and apply Directives and requirements in a laxer way.
For safety reasons and in order to avoid ambiguity, it should be made mandatory that only products can be called and marketed as *'Intrinsically Safe'* if the entire production chain**,** vendor including the main subcontractor who supplies electronic boards and LED modules, is audited and certified by a Notified Body!

b) **Certifications Definitions** - The various definitions, nomenclature and letterings classifying intrinsically safe products are confusing to most users. As example, US and European Norms apply different criteria: "Classes" versus "Zones". ATEX and IECEx use different letterings for the same danger Zones despite both organisations apply identical EU safety Norms.

c) **Vendors** - For marketing purpose some vendors tend to overemphasise product performance. To be 'competitive' and/or lack of electronic engineering, many 'Ex certified' vendors purchase electronics modules, such as complete LED assemblies or even the entire product, from 'Ex' uncertified subcontractors without having direct control over production, product quality and safety.

d) **Users** - Price driven, many customers put a lower priority on "safety" as long as long as the product is 'branded' and carries some kind of 'Ex' certification. However, users are well advised to select only 'Ex' luminaries that are certified by two different organisations, e.g. ATEX and IECEx! Two separate product 'Ex' certifications provide a certain guarantee that the products comply with all requirements set in the applicable safety Norms.

e) **Legal Implications -** In the event that an 'Ex' certified luminary would cause an accident, fire or an explosion, the above comments lead to the conclusion that **the user will, at the end, bear all responsibilities and liabilities**! In a worst case scenario, the vendor of an "intrinsically safe light" will claim that the product has been tested and is certified by a Notified Body. In support, the Notified Body will confirm that all tests have been conducted in accordance to the applicable Norms "passing the buck" back to the user. One of the many legal but not hypothetical questions is what will happen if a Notified Body has its accreditation suspended or revoked? Will the product/s certified by this very organisation have the 'Ex certifications' invalidated so that the products cannot be distributed any longer as "intrinsically safe" luminaries? The answer remains open! As explained above, for safety and legal reason, it is good practice to use and rely on intrinsically safe lights which carry two *separate* certificates!