

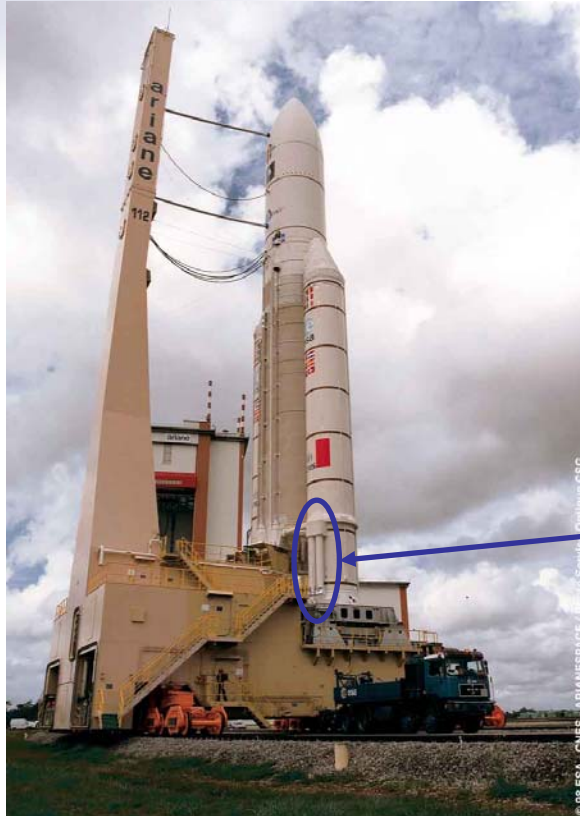
DEALING WITH SAFETY ISSUES OF HIGH POWER BATTERIES FOR A NEW EUROPEAN LAUNCHER

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- **Introduction**
- **Safety requirements**
- **The lower stage modules**
- **The lower stage safety issues**
 - Conception issues
 - Integration issues
- **The upper stage battery**
- **The upper stage safety issues**
 - Conception issues
 - The safety analysis
- **Conclusions**



Up to now, engine nozzle gimbaling performed by **hydraulic actuators**.

But hydraulic tanks GH are **bulky and heavy** units :

Main stage GH : 140 kg

Booster GH : 471 kg

→ **Electrical Thrust Vector Control TVC** more effective.

Chosen for future launcher VEGA.

Never had so much electrical power been requested !

Safety requirements

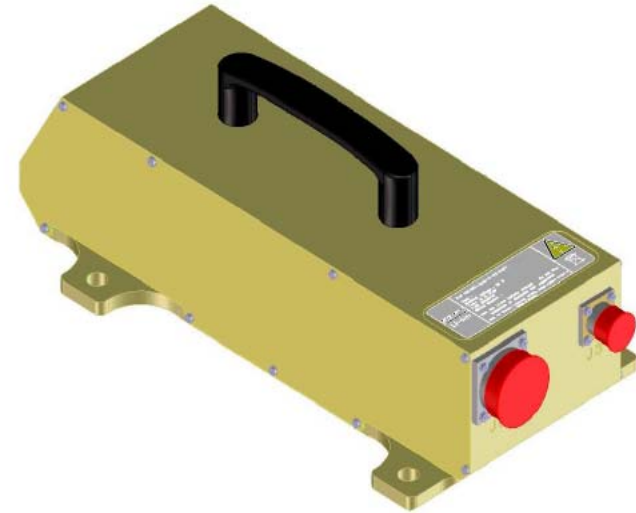


The VEGA TVC electrical sources shall meet the CSG safety rules :

- **Fail Safe / Fail Safe** criterion
 - = **Double failure resistant**
 - = **Three safety barriers**
- **Release of a risk analysis**

For the first three stages, sources are based on SAFT cylindrical high power "VL8P" lithium-ion cells.

Development of a **module** based on 15 cells in series.



Nominal voltage : 54 V
 Max power : 9 kW
 Nameplate capacity : 8 Ah
 Mass : 10,5 kg

stage	voltage	current	Nber of modules
3rd	45-75	111	1
2nd	135-210	111	3
1st	270-400	190	6

The conception issues

Following Risk analysis & FMECA :

- Drop test

 - 1-meter fall on a concrete slab

 - No impact** on the safety of the operator

- Fire test

 - 6 min @ 600 - 800°C

 - Impact of module **marginal**

- Short-circuit test

 - $I_{max} : 2\ 200\ A$, $\theta_{max} : 90^{\circ}C$

 - 1 cell bursts open 40 s into test

 - Fumes, but no flame nor projections
→ **safety OK**



The integration issues (1/2)

To reduce the occurrence of an electric shock :

- Sockets on battery output connectors :
1st barrier



- Protective gloves : **2nd barrier**



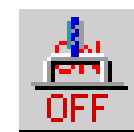
The lower stage safety issues

The integration issues (2/2)



- Harness continuity and isolation test before module integration

- Preliminary connection through fuses to spot any short-circuit
- Check of the OFF state of the TVC control unit before connection to harness : **3rd barrier**



For the **upper stage**, sources are based on SAFT high energy "Medium Prismatic" MP lithium-ion cells.

Development of a **battery** based on 3 strings of 15 cells in series (total of 45 cells).



Nominal voltage : 54 V
Max power : 615 W
Nameplate capacity : 18 Ah
Mass : 11 kg

The conception issues (1/3)

Battery technologies can be hazardous if not properly managed :

- very high current,
- excessive internal pressure,
- vent their contents,
- corrosive contents.



C - Corrosif

→ Introduction of risk reduction measures into the cell design.

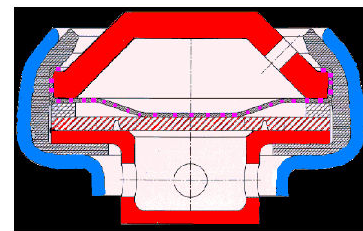
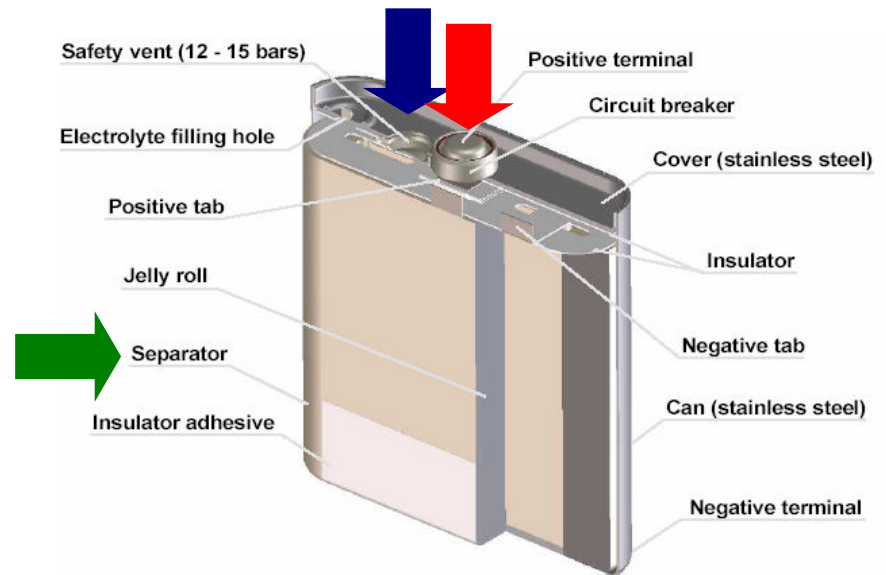
→ Verification of cell resistance to abuse tests.

The upper stage safety issues

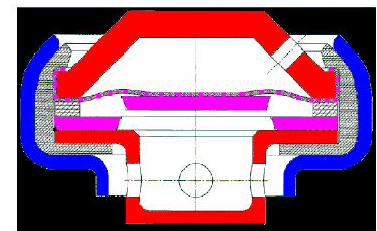
The conception issues (2/3)

Three risk reduction measures :

- a burst disk (venting),
- a circuit breaker,
- a shut down separator.



• Before



• After

The conception issues (3/3)

Three abuse tests (requirement : no explosion nor fire) :

- the **short-circuit test**

100 m Ω @ 55°C

30 to 40 A for 13 min, θ up to 120°C (< 170°C)

test successful.

- the **overcharge test**

3 C discharge rate @ 20°C

θ up to 55°C within 6 min

test successful.

- the **heating test**

20°C up to 150°C in 10 min,
separator shut-down @ 135°C,
circuit breaker opens @ 29 min,

test successful.

The safety analysis (1/2)

Hazard identification and risk reduction

- external short circuit

 - Protective caps on connectors

 - Test showed short-circuit to be harmless to operator

- internal short circuit

 - Battery voltage and temperature monitored as warning signals

 - Test showed circuit breaker to be effective

The safety analysis (2/2)

- excessive internal cell pressure
 - Leak-before-burst criterion
 - Test showed burst disc to be effective
- overtemperature
 - Shut down microporous separator
- leakage of battery container
 - Leak test performed on all laser welded cases

- Safety issues taken into account from the **beginning of the development.**,
- Risk reductions measures implemented first into the **cell design,**
- Otherwise, measures introduced into the **battery (or module) design,**
- Some measures implemented through proper **handling and integration procedures.**
- The compliance with all these safety requirements guaranty a **fully safe usage of the sources.**

Grazie per la vostra attenzione !