CLEANSAT BB04 - FLUIDIC PASSIVATION VALVE

2017-10-24

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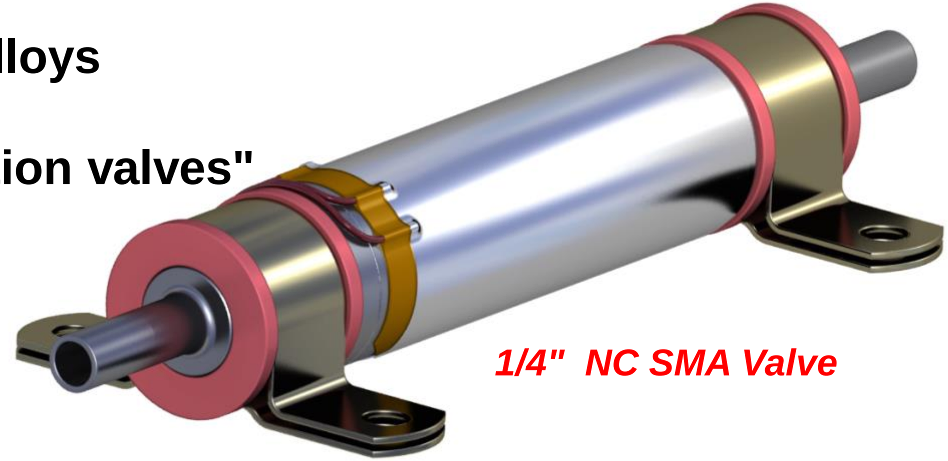
Supporting LSIs: OHB, TAS, Airbus DS

Ariane Group Lampoldshausen

AGENDA

- **Ariane Group Lampoldshausen**
- **SMA Valves - Motivation within "Clean Space"**
- **Introduction into Shape Memory Alloys**
- **Outcome of "BB04-Fludic Passivation valves"**
  - Requirements Analysis
  - Design Trade-Off and Results
  - System Accomodation
- **Current state of the project / On-going activities**
- **Summary and Conclusion**



1/4" NC SMA Valve

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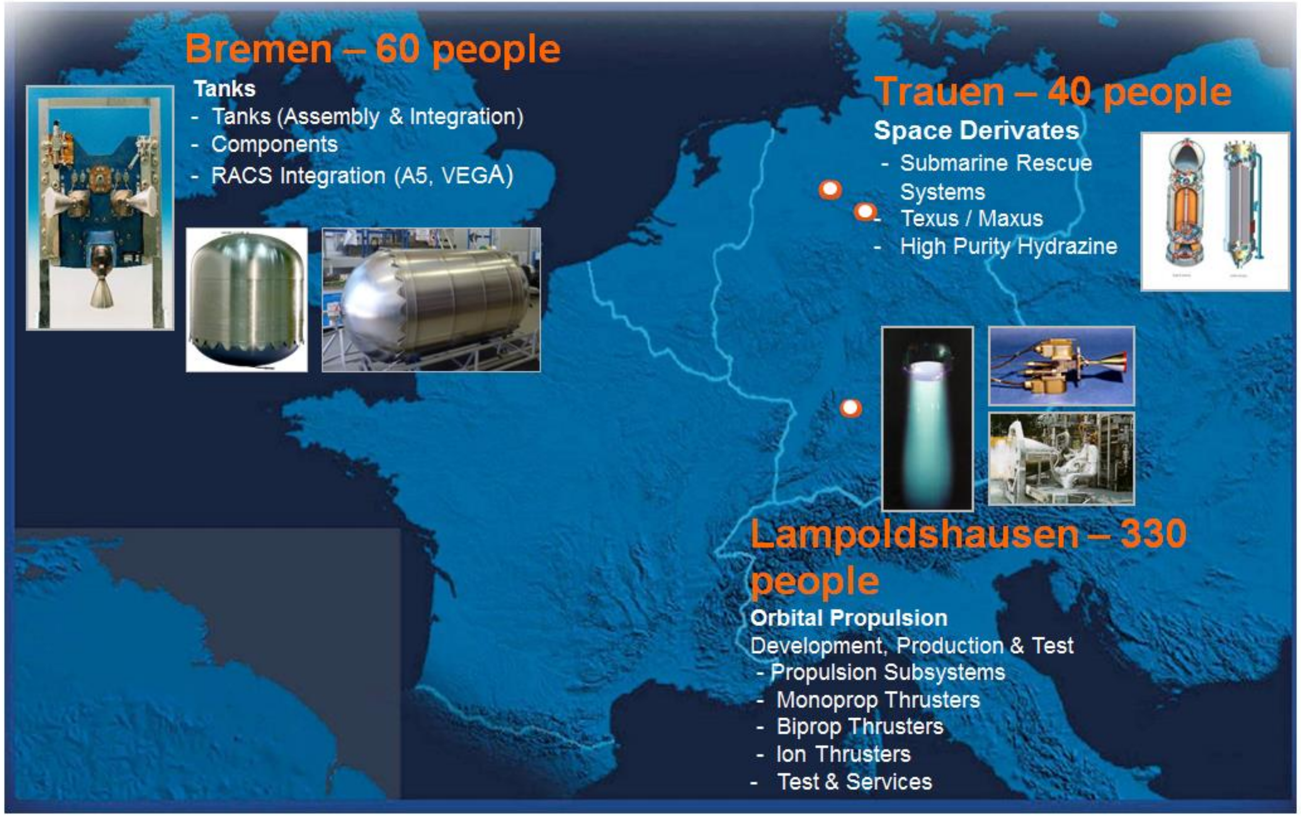


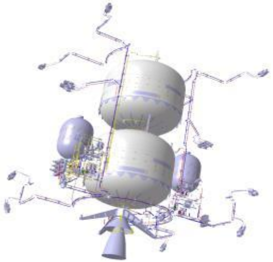
ARIANE GROUP IN LAMPOLDSHAUSEN

Lampoldshausen is since more than 50 years the leading site in Germany and Europe for the development, production and test of propulsion systems for satellites and orbital platforms such as ATV or MPCV Orion with more than 330 employees




This comprises a portfolio of:

- High precision propulsion components dedicated for orbital control on Satellites, Spacecraft and Launchers (Roll Attitude Control Systems)
- Chemical Monoprop- and Biprop Propulsion Systems
- Electrical Propulsion Systems based on the RIT Thruster Family
- Complete Propulsion Subsystems UPS (Unified Propulsion Systems)
- Components for Launchers (e.g. for Aestus Engine and PCA)
- Solution Provider for Service Activities such as Satellite Launch Support



SMA VALVES - MOTIVATION WITHIN CLEANSPACE (1)

- 30% of historical on-orbit spacecraft fragmentations accounted for propulsion related events [1].

- Popular example is 1996 breakup of Pegasus rocket hydrazine auxiliary propulsion stage (HAPS) [2] caused by missing of passivation measures.

- HAPS mass 97kg, 10kg Hydrazine residuals $\rightarrow$ $7x10^6$ particles > 1mm.

[1] R. Walker et.al. ESA Space Debris Mitigation Hand-book, QINETIQ/KI/SPACE/CR021539, 2002

[2] M. Matney, T. Settecerri. Characterisation of the breakup of the Pegasus rocket body 1994-029B, ESA-SP-393, May 1997

SMA VALVES - MOTIVATION WITHIN CLEANSPACE (2)

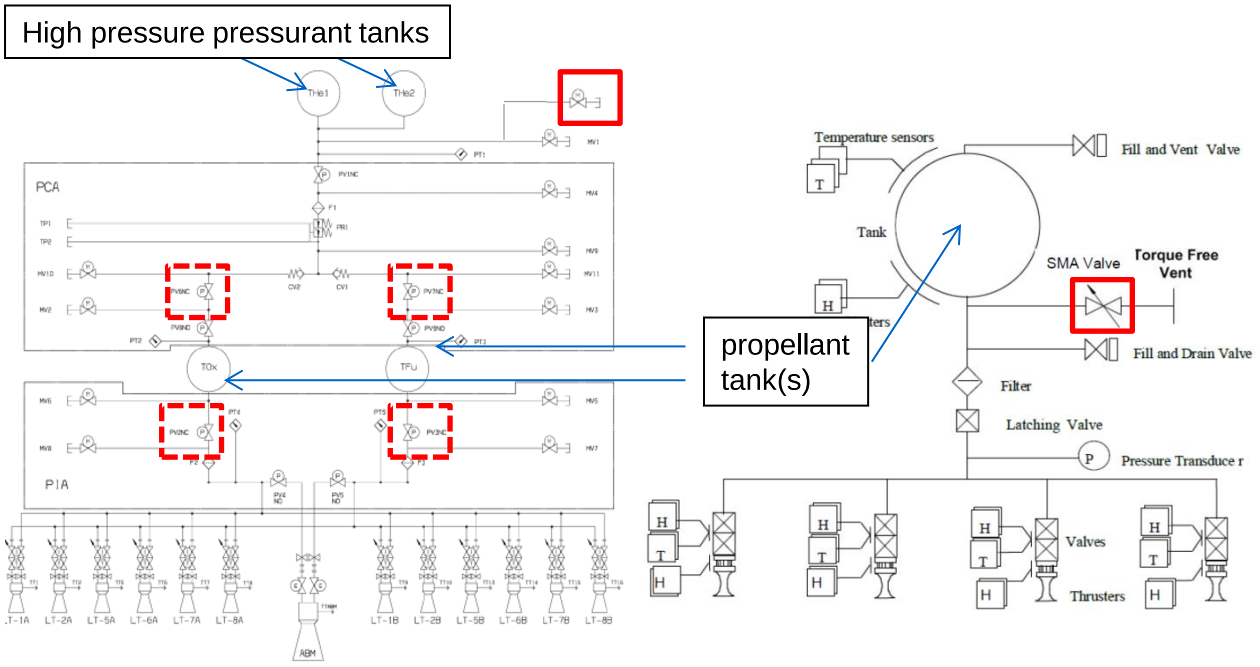
"In order to limit the risk to other spacecraft (...) from accidental break-ups, all on-board sources of stored energy should be depleted or made safe when they are no longer required for mission operations or post-mission disposal (....) Passivation requires the removal of all forms of stored energy, including residual propellants and compressed fluids (...)"

UN resolution 62/217, **Space Debris Mitigation Guidelines**, 2010

See as well:

- French "Space Operations Act", Art. 40.3 (2008)
- ISO 16127: Space systems
  Prevention of break-up of unmanned spacecraft (2014)

SMA VALVES - MOTIVATION WITHIN CLEANSPACE (2)



Bipropellant System (MMH/NTO) *Monopropellant System (N_2H_4)*

- Fluidic passivation enabled by normally-closed valves.
- Most "single activation" valves designed with pyrotechnical actuators.
- Most Pyro-Valves have life limitation non compliant with S/C life time.

→ Development of a new valve based on none life limiting actuator technologies.

→ Replacement of internal NC Pyro-Valves shall be investigated

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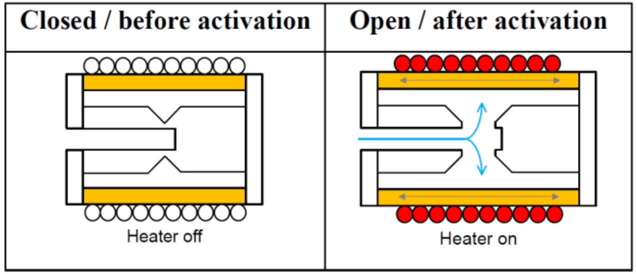
SMA VALVES - MOTIVATION WITHIN CLEANSPACE (4)

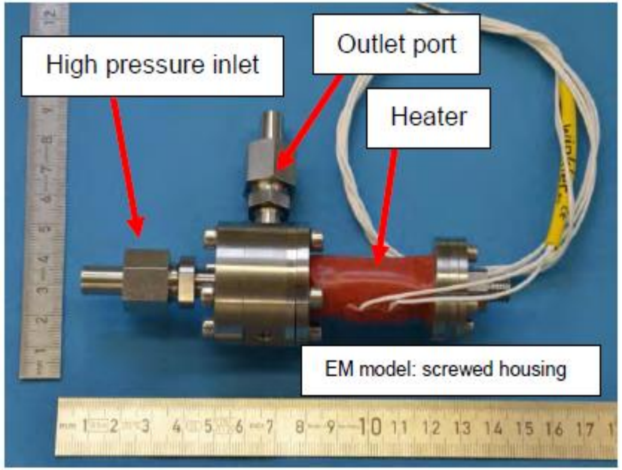
from idea...



NC SMA VALVE - Operational principle

- One-time expansion of a shape memory alloy actuator
- Activation triggered by temperature (electrical heating)
- Rupture of internal element (Zero leakage prior to activation)

...to Breadbaord Model



Motivation & : Advantages vs. pyrotechnical valves

- Lifetime extension (>25 years)
- Reduction of shock loads
- Elimination of pyrotechnics (no transport&handling constraints)
- Simplified electrical activation
- Insensitive towards ESD effects
- No hot combustion gases inside the valve that could leak into flow path

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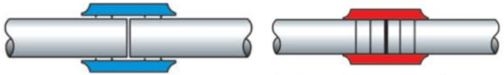
INTRODUCTION INTO SHAPE MEMORY ALLOY METALLURGY (1)

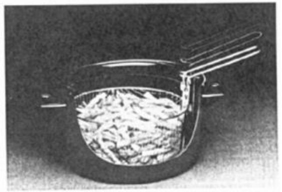
Discovery of effect
(1930‘s) Au-Cd

Cryofit couplings (1970‘s)
F-14, Trafalgar class nuclear submarines

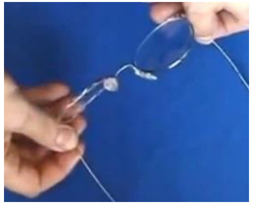


Expanded couplings have an inside diameter slightly larger than the tube outside diameter

As the coupling warms and recovers it swagers on the tubing generating a highly reliable metal to metal seal



Smart fryer. The intelligent deep fryer from Societe Ten uses an alloy to lower the basket into the oil once the desired temperature is reached.



Ni-Ti Consumer products (1990‘s)

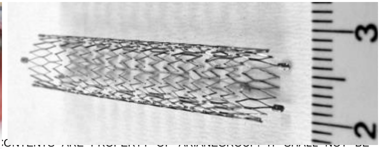
First NiTi actuator
in Deep Space (2014)

Ni-Ti („NITINOL“) Discovery (1960‘s)
Non-toxic SMA
Nickel Titanium Naval Ordnance Lab

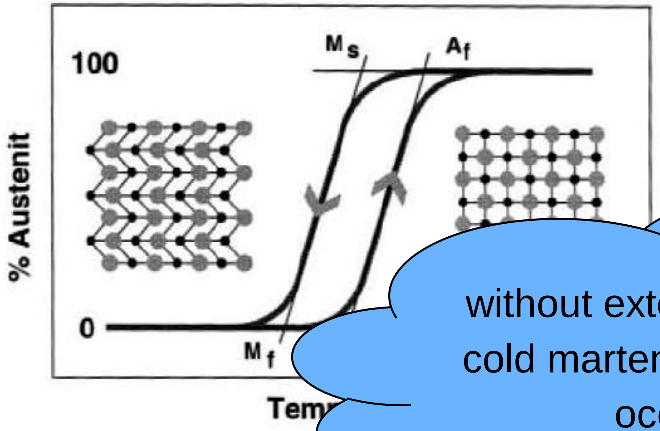
Ni-Ti Stents &
Medical Appl. (1980‘s)

Shape Memory
Polymers (2002)

Magnetic Shape
Memory (2005)



INTRODUCTION INTO SHAPE MEMORY ALLOY METALLURGY (2)



<u>Characteristical Temperatures</u>

As : Austenit Start

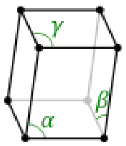
Af : Austenit Finish →body centered cubic

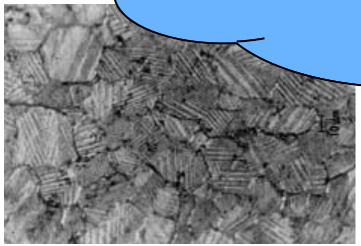
Start

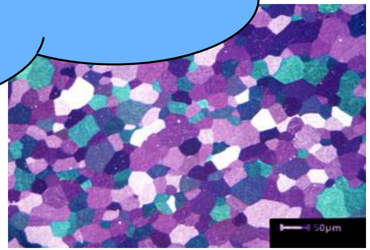
monoclinic

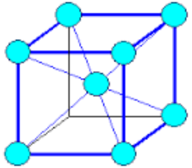
ependant)

without external load / Deformation in cold martensite, no shape change will occur during heating







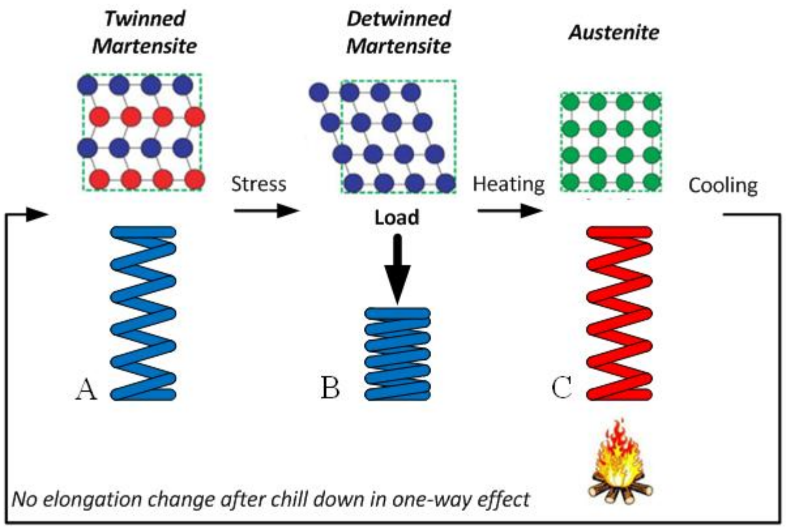


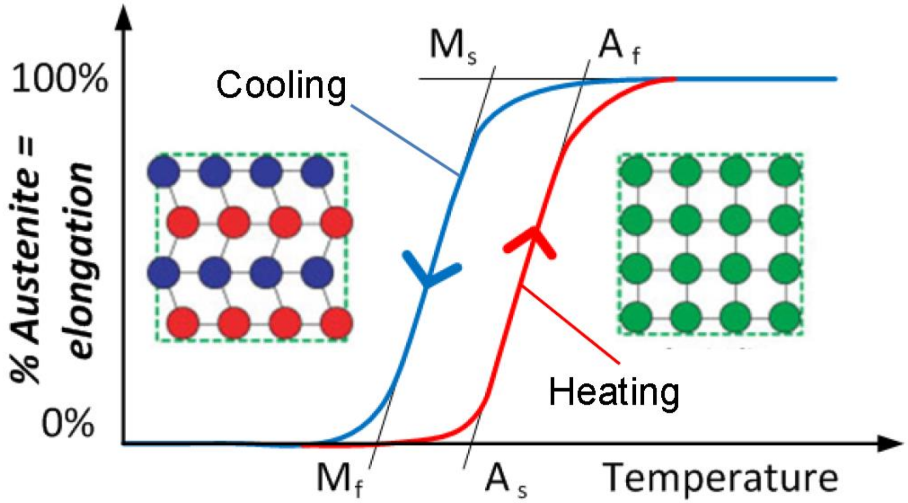
monoclinic

body centered cubic

See:
Platinum Metals Rev., 2003, 47, (4), 142: Platinum Alloys for Shape Memory Applications

INTRODUCTION INTO SHAPE MEMORY ALLOY METALLURGY (3)

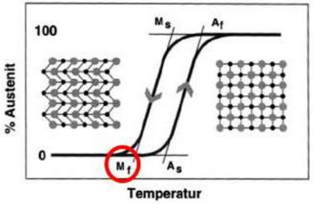


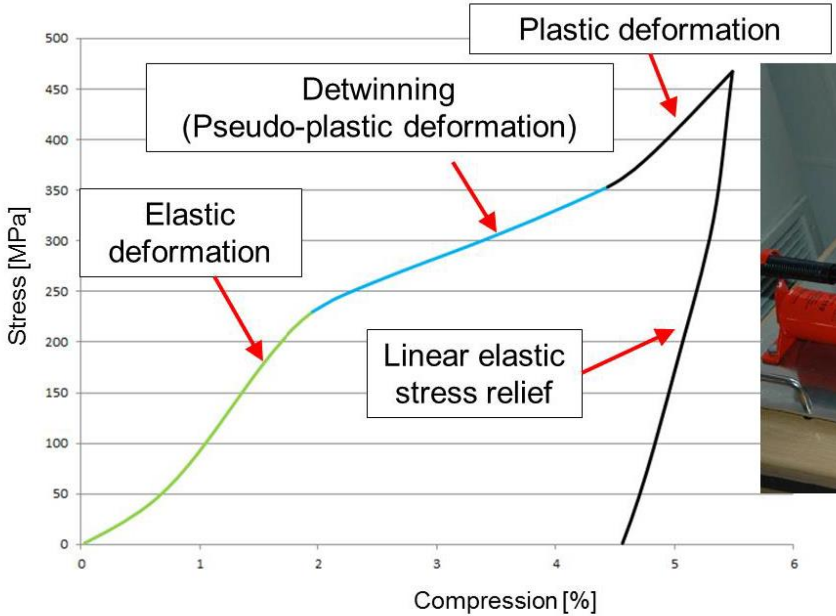


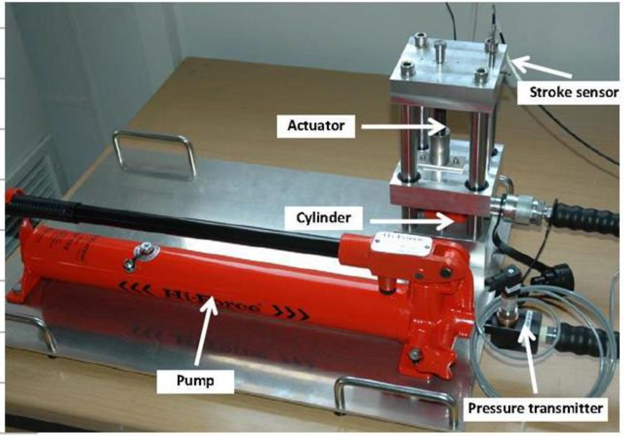
See:
Duerig: Engineering Aspects of Shape Memory Alloys, 1990

INTRODUCTION INTO SHAPE MEMORY ALLOY METALLURGY (4)

Preparation of actuators

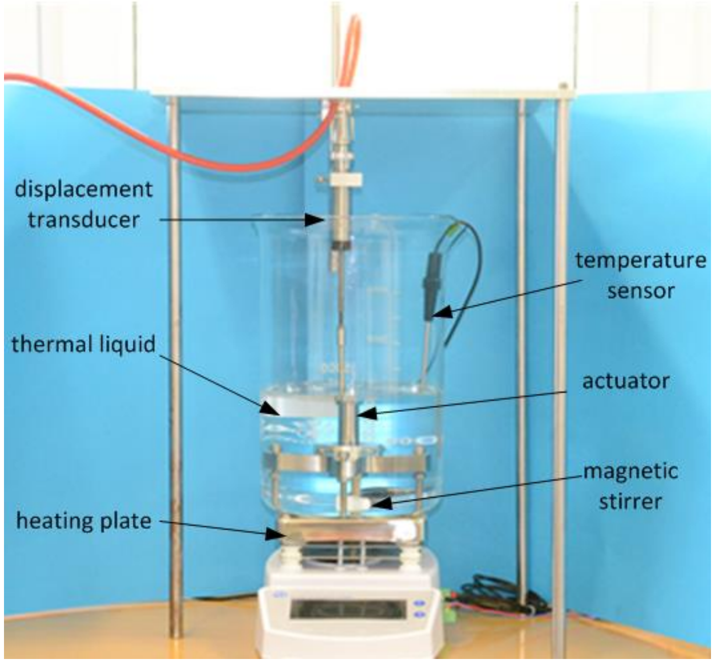


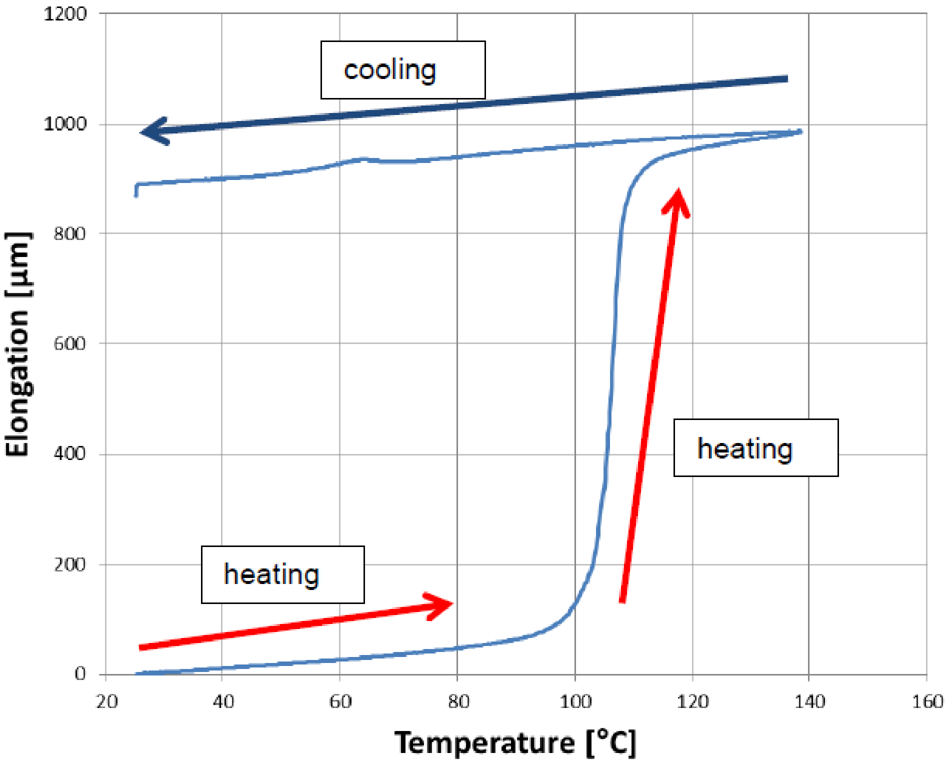




See:
CLEAN-ASLLAM-TN-0008

SMA ACTUATOR STROKE / ACTIVATION TEMP DETERMINATION





See:
CLEAN-ASLLAM-TN-0008

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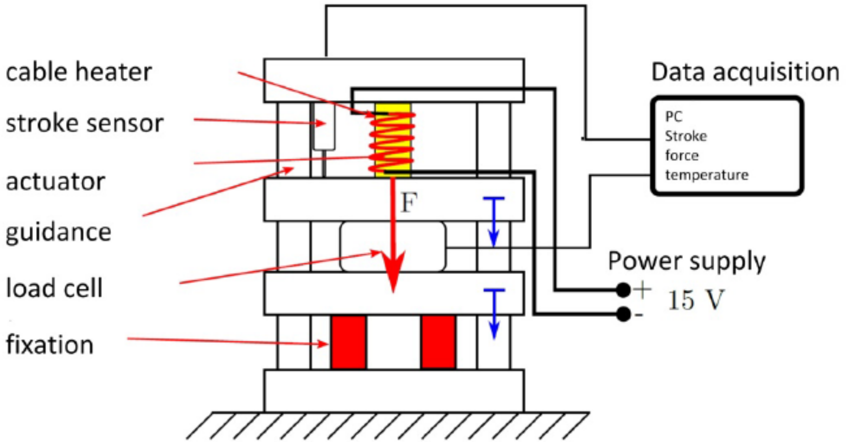
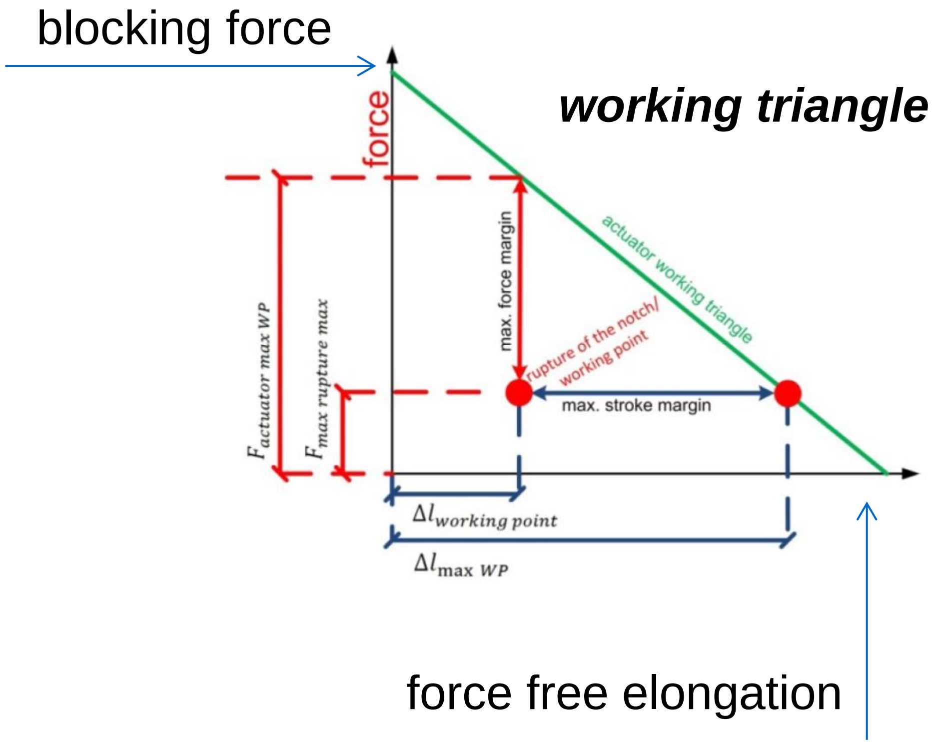
SMA ACTUATOR BLOCKING FORCE DETERMINATION



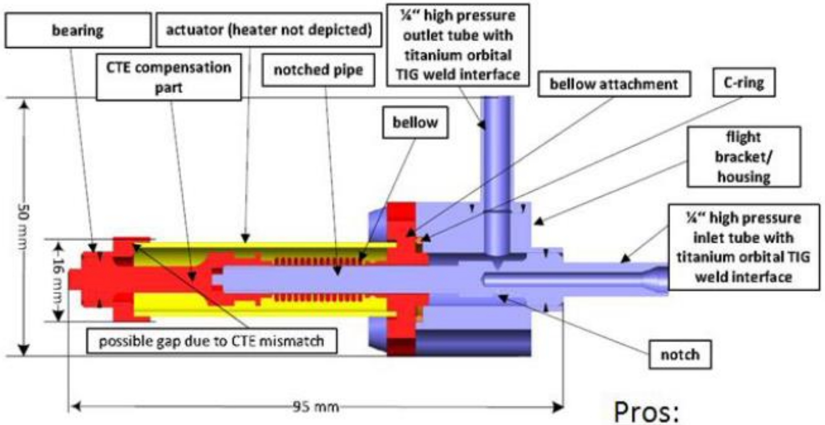


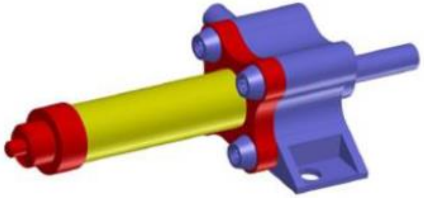
See:
CLEAN-ASLLAM-TN-0008

BB04 - HARMONIZED REQUIREMENTS

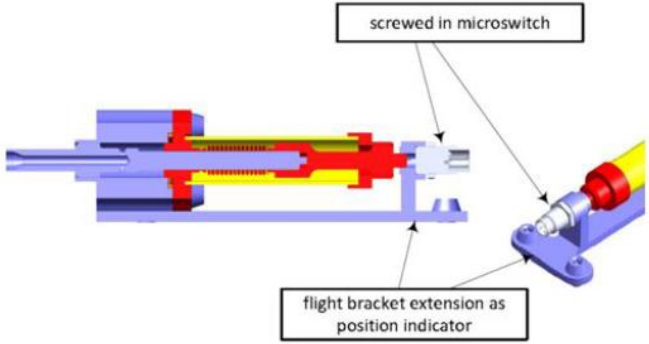
Main Requirements	Value
Inlet-Outlet port	1/4" TIG weld interface
Media	N2H4, MMH, NTO, inert gases, LMP-103S
MEOP	310 bar, Burst: 4x MEOP
Operation temperature	0°C ... 60°C
Internal / External leakage	<1E-6 scc/s
Power demand	< 20W at 24....53V inlet voltage
Activation time	t=15min at 20°C
Required Lifetime	25 years on ground + on orbit

BB04 - DESIGN TRADE OFF - OPTION A





≈150g, l=100mm



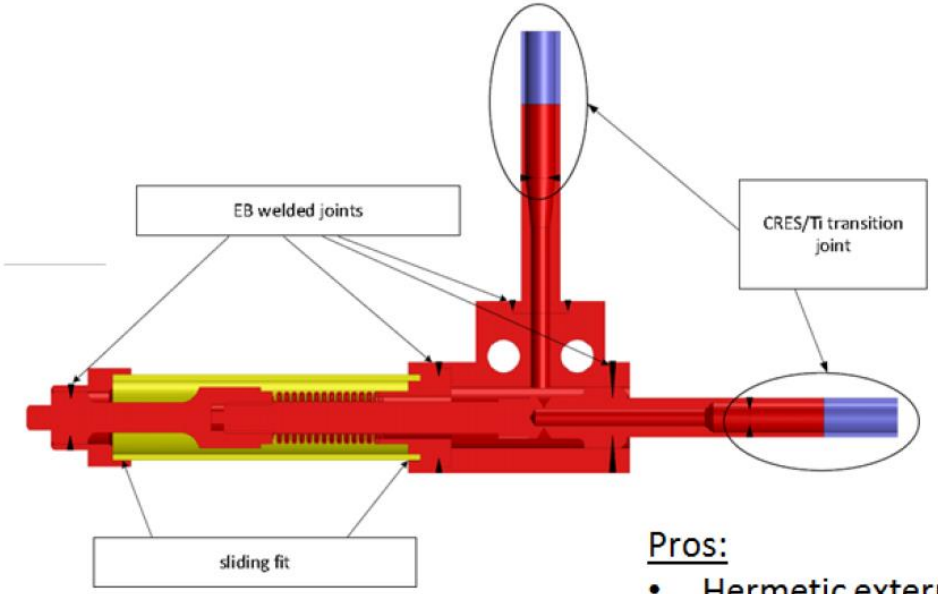
Pros:

- Fast heating
- No media contact with hot actuator
- Low pressure drop
- Position indicator possible
- Integrated flight bracket
- No induced shock

Cons:

- Costly (5 welds, 12 parts), > PV
- Transition Joint or screwed housing
- Heater to actuator motion compensation

BB04 - DESIGN TRADE OFF - OPTION B



≈200g, l=100mm

Blue: Titanium

Red: Stainless Steel

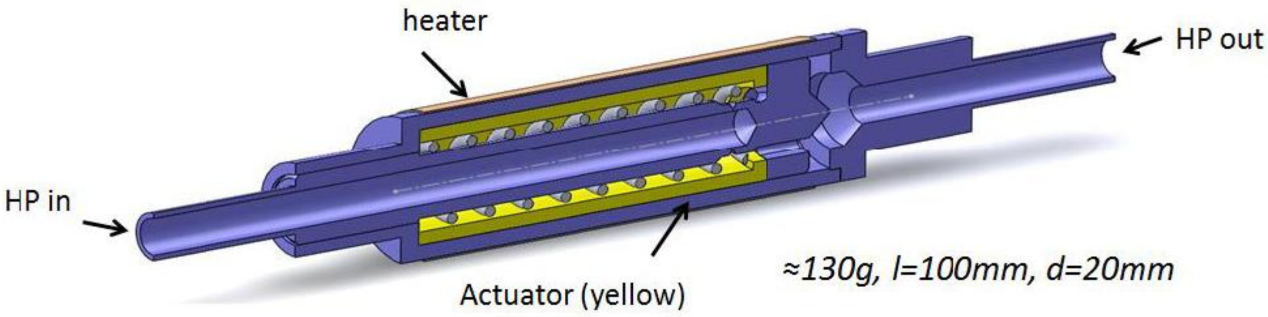
Pros:

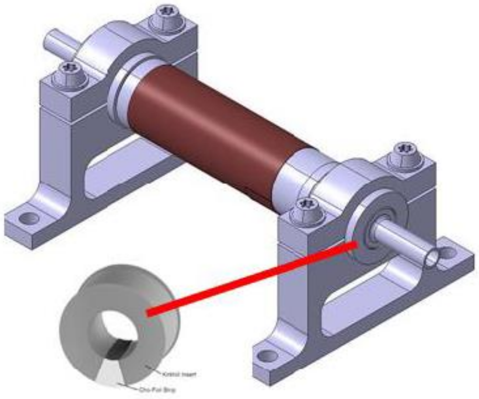
- Hermetic external seal

Cons:

- Very costly manufacturing (10 welds, 11 parts)
- Transition Joint or screwed housing
- Heater to actuator motion compensation

BB04 - DESIGN TRADE OFF - OPTION C





<u>Pros:</u>

- All welded housing
- Low cost design (2 EB weld seams, 6 parts)

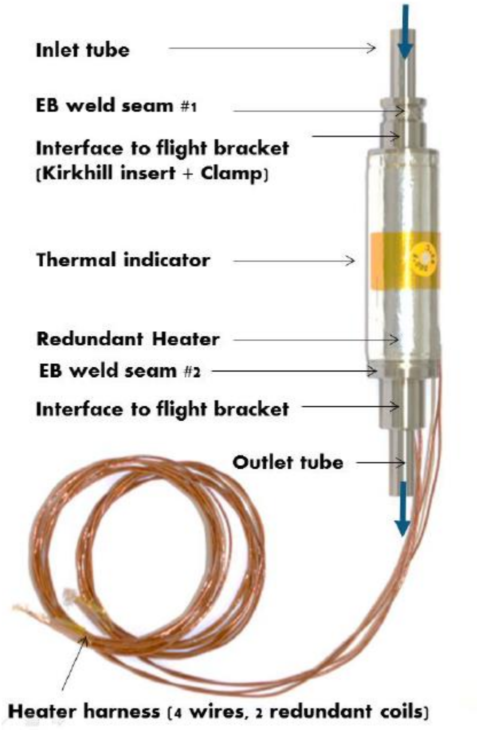
<u>Cons:</u>

- Spring causes induced shock
- Indirect actuator heating (long activation time)
- Fluid in direct hot actuator contact after activation
- Brackets need thermal decoupling
- Higher pressure drop
  (could be reduced by diameter increase, e.g. ¾", ½")

DESIGN TRADE OFF - RESULTS (1)

OPTION	A	B	C Baseline
Cost*	>PV	>>PV	<<PV
External Leakage	-	+	++
Weight (PV=160g)	≈160g	≈200g	≈120g
Bracket weight (PV=250g)	0g	0g	≈20-175g
Activation time ≈10W, amb. 20°C	≈7 min	≈7 min	≈15 min
Opening process	Slow - several minutes (direct coupling between slow moving actuator an notched tube)		Fast <1s (Spring pushes broken parts away from each other)
Pressure drop DP Reproducibility	2.5 x PV -	2.5 x PV -	4x PV ++
Induced shock	No shock	No shock	Depending on spring force
Actuator with media contact	no	no	yes
All-european design	yes	no	yes

OPTION "C" selected as baseline



DESIGN TRADE OFF - RESULTS (2)

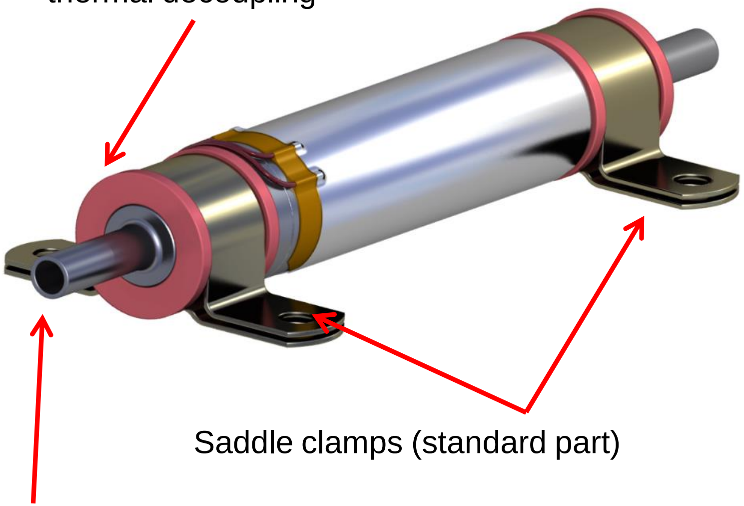
Suitability for different conceivable applica-tions	A	B	C Baseline
Application A EOL gas passivation (Helium, Xenon, Nitro-gen…)	++	++	++
Application B EOL liquid passivation (Hydrazine, MMH, NTO,…)	++	++	++
Application C Long lifetime NC Pyro Valve replacement – HP gas side	-	+	++
Application D NC Pyro valve replacement – liquid low flow Monopropellant System (e.g. Myriade) Bipropellant System (e.g. Rosetta)	++	++	++ **
Application E NC Pyro valve replacement – liquid high flow Biprop Liquid Apogee Engine 400N Thrust class Launcher roll control 400N (e.g. Ariane 5 SCA)	- DP too high*	- DP too high*	- DP too high*

*) Taking into account ¼ valve type.

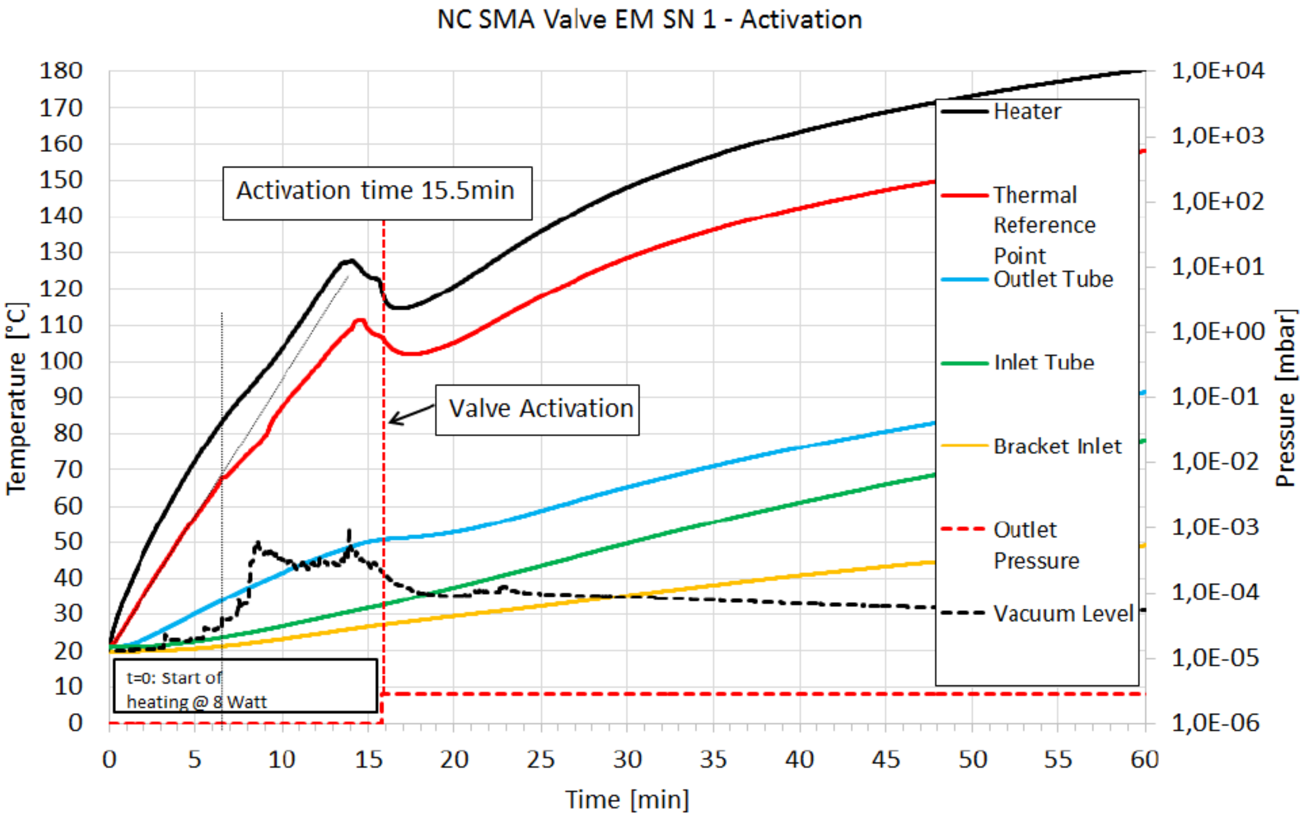
Increase of valve body diameter reduced DP

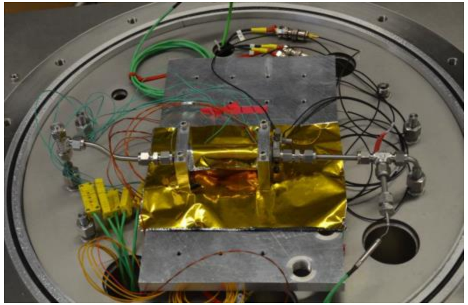
**) Qualification test „actuator with hot propellant contact" pending

OPTION "C" accomodation to system



OPTION "C" VALVE ACTIVATION (GAS AT INLET)





SUMMARY AND CONCLUSION

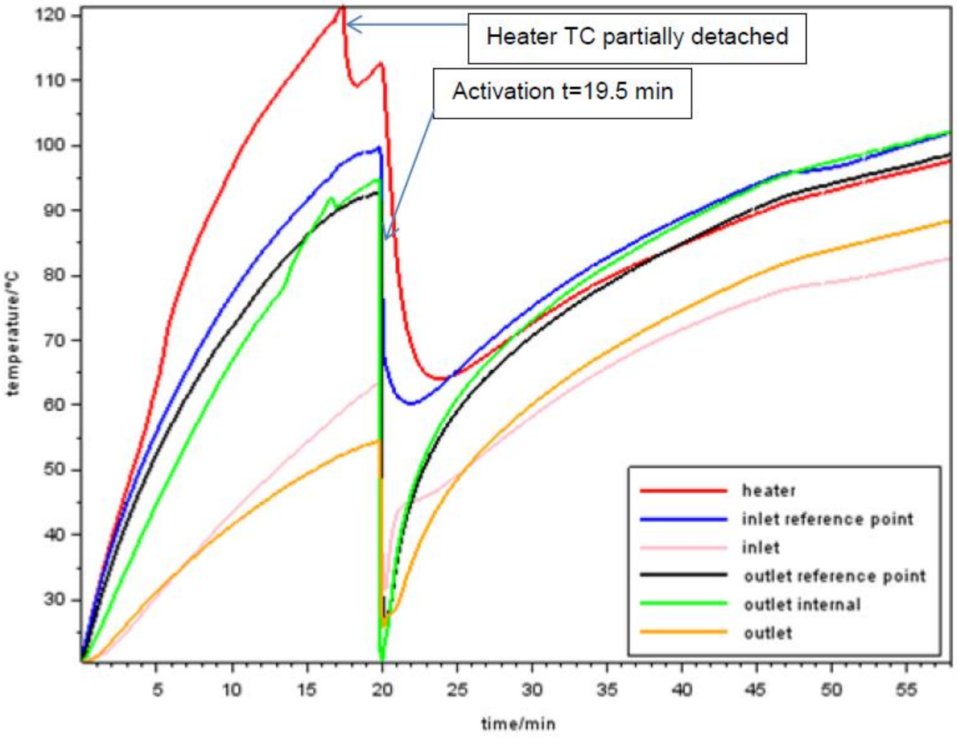
- **Definition of harmonzied requirements between OHB, Ariane Group, AirbusDS and TAS**
- **Elaboration of Design Studies and -Trade- off between different conceivable design varieties**
- **Performance of thermal mapping / valce activation tests**
- **Development road mapping up to qualification**

CURRENT STATE OF THE PROJECT

- **ARTES C&G program with ESA (Qualification for MMH/MON/inert gases) - finalisation Q1/2018**
- **Delta qualification for hydrazine pending**

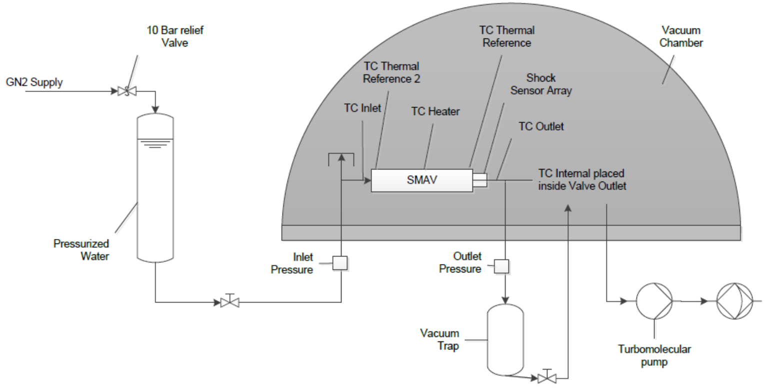
END

OPTION "C" VALVE ACTIVATION (WATER AT INLET)



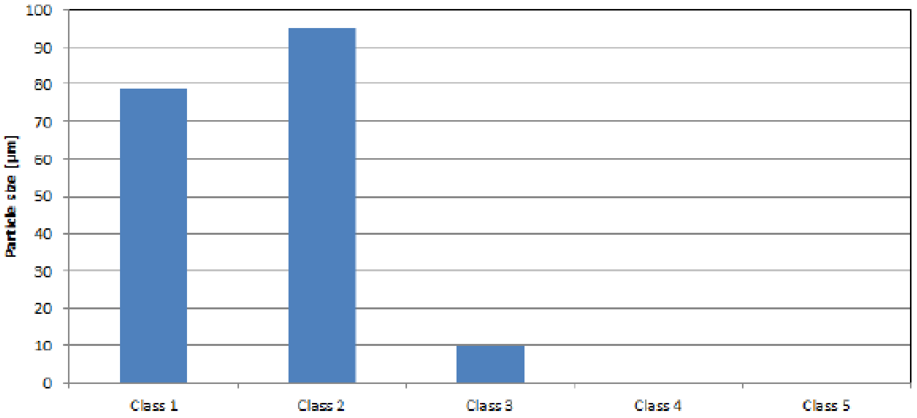
Following test setup / test boundary conditions have been used:

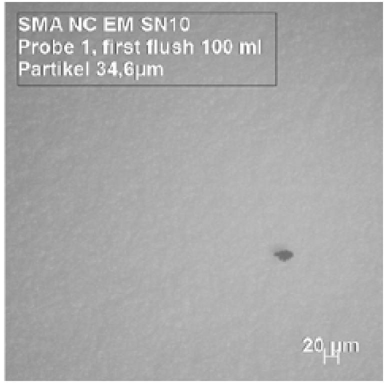
- Valve in vacuum chamber, p ≈ 1E-5 mbar
- Inlet pressurized with de-ionised water, p=10bar
- Valve and notched tube filled completely with water
- Valve outlet connected to reservoir (1 liter, vacuum conditions)



PARTICLES GENERATION DURING ACTIVATION

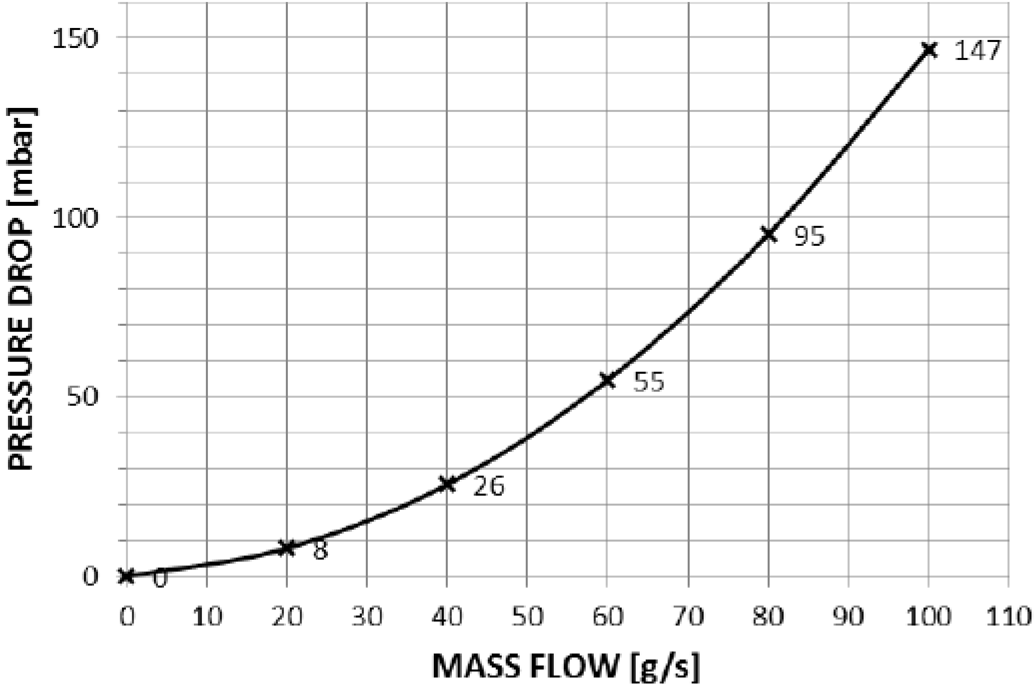
Particle Number generation by SMA Valve activation





	Particle size min	Particle size max	Number of Particles per class
	[µm]	[µm]	[/]
Class 1	6	10	79
Class 2	10	25	95
Class 3	25	50	10
Class 4	50	100	0
Class 5	100	>100	0

SMAV PRESSURE DROP (ACTIVATED VALVE), WATER 20°C



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