Thales Cryogenics

Recent and future developments in cryogenic cooling technologies with high MTTF
Roel Arts, Tonny Benschop

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Introduction Thales Cryogenics

- Product range and capabilities
- Present day use of Thales coolers

System integration aspects

- Impact of cooler type
- Expected requirements HTc Supra markets
- Reliability aspects

Future foreseen developments

Conclusions
Thales Cryogenics organization

Thales Cryogénie SAS
4, rue Marcel Doret
BP 70022
31701 Blagnac Cedex
France
Tel : 33 (0) 5 62 74 58 00
Fax : 33 (0) 5 62 74 58 58

- Rotary coolers
- Joule Thomson coolers
- High Pressure Vessels

Thales Cryogenics BV
Hooge Zijde 14
PO Box 6034
5600 HA Eindhoven
The Netherlands
Tel : (31 40) 250 36 03
Fax : (31 40) 250 37 77

- Linear coolers
- Pulse tube coolers
- System integration

One global vision for your cryocooling solutions
TCsas BLAGNAC (Fr) leading CC wrt:
- Rotary Stirling coolers
- Joule-Thomson coolers
- High pressure vessels & filling equipment

TCbv EINDHOVEN (NL) leading CC wrt:
- Linear Stirling Coolers
- Pulse tube Coolers
- Space cooler
- Thermodynamic simulations tools
- Complex drive electronics

Joint future efforts:
- Technology building blocks
- Acoustic and vibrations
- MTTF calculations & predictions
Present day available cooler range

Rotary mono bloc coolers (0.1 .. 0.75 W) @ 77K
- Very high efficiency, compact solutions
- > 25,000 delivered
- Typical use: Strategic, compact IR camera’s

Close Contact (UP Series) (0.5 W .. 2.0 W) @ 77K
- High Efficiency
- > 11,000 delivered
- Typical use: Strategic, vehicle mounted systems

Flexure Bearing (LSF Series) (0.5 W .. 8.0 W) @ 77K
- Compressor almost wear-free
- > 1,200,000 test hours
- > 24,000,000 fielded hours
- Typical use: Strategic, Non-Strategic, Space

Pulse Tube Cold Head (0.5 W .. 15 W) @ 77K
- Baseline MTTF > 10 years continuous
- Low vibration
- Typical use: Non-Strategic, Space
Thales Cryogenics, everything under one roof

- 700 m² clean room (linears)
- Automatic test bench
- Electron beam welding
- Laser welding
- High vacuum oven
- Endurance test room
- Screen filling machine
- Automatic cleaning bench
- Noise measurement room
- Vibration bench
- High pressure room
- Conditioning & filling bench
Present day use of Thales Coolers

**IR Detection**
- Increase detection range & accuracy of IR camera,
- radiometer,
- missile seeker

**Gamma ray Detection**
- Detection of illicit product,
- Nuclear measurements,
- spectrometer

**Other civil applications**
- Gas spectrometer,
- Superconductive filters & LNA,
- space coolers,
- zero blow off systems

**Space applications**
- European programs
- US programs
Thales Cryogenics has extensive experience in providing full integrated solutions, including:

- Housing with heat sinking (convective or liquid loops)
- Highly efficient Cooler Drive Electronics
- Option for Active Vibration Reduction
- Cooler Diagnostics in Electronics
- Cooler Control (by PC)

For critical vibration requirements, dedicated electronics with Active Vibration Reduction (AVR) available:

- Individual control of each compressor coil
- Feedback mechanism minimizing residual vibration signal
- Adaptive algorithm implemented in DSP hardware for compact solution
## Stirling vs Pulse Tube (LSF-LPT)

### Technical comparison Stirling / Pulse tube

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Rotary cooler (RM)</th>
<th>Stirling (LSF)</th>
<th>Pulse tube (LPT)</th>
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</thead>
<tbody>
<tr>
<td>Efficiency</td>
<td>++</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Lifetime</td>
<td>0</td>
<td>+</td>
<td>++</td>
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<tr>
<td>Cooler induced vibration</td>
<td>-</td>
<td>0 (with balancer)</td>
<td>+ (with AVR control)</td>
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<td></td>
<td>0 + (active control)</td>
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<tr>
<td>MTTF</td>
<td>0</td>
<td>+</td>
<td>++</td>
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<tr>
<td>System integration</td>
<td>++ (compact)</td>
<td>+</td>
<td>++</td>
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</tbody>
</table>
Example of Pulse Tube performance operating window
Expected cooler requirements HTc applications

Temperature range:
• $50K < T_c < 77K$

Cooling power:
• Large range of cooling power depending on device and application
  Operating temperature device / Number of contact leads / size of device

High reliability required 24/7 use:
• Maintenance-free continuous operation for 10 years
• Compact solutions required

Integrated solutions required (device, dewar, cooler, drive electronics):
• Line-replaceable unit, “plug & play”
• Modular setup containing HTC device in vacuum dewar, cooler, heat sink
• Control electronics to be integrated in the module

Predictable uptime:
• Intrinsic reliability
• Diagnostic function in control electronics
Cooler failure behavior and mechanisms have been investigated and solved in detail by cooler manufacturers worldwide.

Different failure mechanisms have been identified and improved:
- Mechanical or electrical failure: Failure of bearings, springs, coatings etc. Almost always immediate loss of function.
- Very slow degradation in heat lift: Due to wear of contact seals or loss of dewar integrity, gradual increase in cool down time and eventually loss of set point.
- Linear coolers: Rapid wear of coating in case gaps are too large ("avalanche effect").

In 24/7 application health monitoring system advised to avoid unnecessary maintenance or adequate response for preventive maintenance.

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Cooler Diagnostic Software implemented in CDE devices

Implementation in existing hardware

Calculated operational parameters

- Elapsed time (C)
- Ratio between actual output voltage and maximum output voltage (C)
- Ratio between actual sensor voltage and sensor voltage set point (C)

Continuous measured performance

- AC Power supply voltage and (M)
- Ambient temperature (M)

Settings

- Low pass filter coefficients (S)
- Data storage intervals (S)
- Alarm trigger levels for: (S)
  - Remaining lifetime
  - Maximum output voltage ratio
  - Maximum sensor voltage ratio
Present day available options

Available cooler solution for HTc applications

Thermodynamic efficiency
Size & reliability

Development route:
- Improve reliability
- Reduce size (compactness)
- Increase efficiency (lower temperatures, lower consumption)
Available cooler solution for HTc applications

Cooling power @ 77K

Reliability (MTTF)

Development route:
- Improve reliability
- Increase cooling power
Available cryogenic coolers:

- High MTTF and compact solutions are readily available
- Broad cooling power and low temperature range
- Correct choice of cooling technology (RM?, LSF?, LPT?) and drive electronics (AVR?, diagnostics?) required

System aspects:

- System integration should be discussed with cooler manufacturer
  - Heat sinking // vibrations sensitivity // Temperature control // Diagnostics
- Mounting of device of cold plate and dewar concept very important for overall system performance

Today’s HTc devices and available cryogenic coolers can be matched to support future markets using HTc devices.

Joint efforts are required especially at integration aspects and required electrical connections.
Questions?