Identification of a fluid for two phase fluid capillary pumped system cooling dedicated to aircraft applications

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HISPANO-SUIZA at a glance
SAFRAN AT A GLANCE

- An international **high technology** group.
- Revenues of **10.8 billion euros**.
- More than **54,000 employees** in over **50 countries**.
- 2010 revenues by branch:

  - **Aircraft Equipment**: 26%
  - **Aerospace Propulsion**: 52%
  - **Defence**: 12%
  - **Security**: 10%
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A major player in the airborne applications of electrical power

Specialist in the transmission and management of onboard power

- **Power transmissions** for engines on commercial airplanes, business and regional aircraft, military aircraft and helicopters

- **Electronic power controllers** and electrical systems
A380 / NACELLE: ETRAS® (Electrical Thrust Reverser Actuation System)

The first electrical thrust reverser actuation system in the world:

- Fitted to nacelles made by Aircelle (Safran group) for the GP7200 and Trent 900 engines offered on the A380;
- In production, ETRAS® has logged over 700,000 hours of operation (as of September 2011).
PROPULESION SYSTEM

cka C919 / NACELLE: TRCU (Thrust Reverser Control Unit)

cka TRCU: an innovative electronic power converter

cka Controls the thrust reverser actuation system of the COMAC C919 Nacelle developed by Nexelle (an Aircelle/GE Joint Venture)

cka Based on experience with the ETRAS® system for the A380.

cka A work in synergy with fellow Safran companies for Aircelle:

cka Aircelle: Architecture and equipment integration in the nacelle;

cka Sagem (Safran Electronics): Reverser actuation system;

cka Hispano-Suiza (Safran Power): TRCU (Thrust Reverser Control Unit).
LANDING AND BRAKING SYSTEMS

BOEING 787 / BRAKING: EBAC (Electrical Braking Actuation Controller)

The first electrical braking system in the world developed for civil application. Safran Power provides the EBAC electronic control unit:

- EBAC is used with Messier-Bugatti-Dowty electric brakes for the Boeing 787;
- 4 EBAC units control braking on the main gear’s 8 wheels.
LANDING AND BRAKING SYSTEMS

A400M / LANDING: EBMA (Electrical Back-up Mechanical Actuator)

An electro-hydraulic assembly developed by Messier-Bugatti-Dowty:

- The EBMA handles the opening and closing, in backup mode, of the landing gear doors on the A400M;
- Hispano-Suiza supplies the electrical drive for the EBMA, comprising an EMCU (electric motor control unit) and GBA (gearbox assembly) reduction gearbox.
ELECTRICAL SYSTEM

KC390 / EEPGS (Emergency Electric Power Generation System)

- Emergency electric power generation system (ATA 24),
- The system will convert air stream in electric power for the loads that are essential for continued safe flight and landing in case of emergency.
Thermal management of power electronics
Thermal management in More Electrical Aircraft at equipment level

- High heat power density => efficient heat transfer systems
  - Capillary pumped two-phase fluid loop

- More efficient than Heat pipes
- As efficient as One-phase fluid loops:
  - Up to 100 W/cm²
- Passive system: no mechanical pumping
Key Design Drivers

\[ P_{\text{cap, max}} \geq \Delta P_{\text{liq}} \left( f(Q, l) \right) + \Delta P_{\text{vap}} \left( f(Q, l) \right) + \Delta P_{\text{grav}} \]

- **Capillary pressure pumping capability**
- **Liquid flow pressure drop**
- **Vapor flow pressure drop**
- **Hydrostatic pressure drop**

- Capillary pumping capability: surface tension
- Liquid / vapor pressure drop: dynamic viscosity and density
- Hydrostatic pressure drop: density
- Mass flow rate: Latent heat of vaporization
Fluid specification
Generality

- **Commonly used fluid in capillary pumped two-phase systems:**
  - List:
    - Water
    - Ammonia
    - Methanol
    - Ethanol
    - Acetone
    - ...
  - Only partially compliant with all aerospace application requirements

- **New fluid is required:**
  - Performances similar to classical fluids ones
  - Compatible with aerospace environmental requirements
  - Water that freeze below –55 °C !!!
Environmental requirements

- REACH compliant

- Fireproof fluid:
  - Not flammable
  - Auto-ignition temperature > 400°C
  - Auto-extinguishing under this temperature

- Temperature range: [-55°C;150°C]

- Fungus proof

- Compatible with fluid commonly used in aircrafts (see DO160-G)

- Compatible with common metals

- Dielectric fluid preferred
Thermal physical properties requirements

→ Main typical properties:
  - Latent heat of vaporization as high as possible: at least higher than \(500 \text{ kJ/kg}\)
  - Dynamic viscosity of vapor as low as possible: at least lower than \(140 \times 10^{-7} \text{ kg/m/s}\)
  - Surface tension as high as possible: at least higher than \(11 \times 10^{-3} \text{ N/m}\)
  - Vapor density at least higher than \(1 \text{ kg/m}^3\) at 80°C

→ Other properties required:
  - Dynamic viscosity of liquid as low as possible: at least lower than \(0.12 \times 10^{-3} \text{ kg/m/s}\).
  - Specific heat of liquid as high as possible: at least higher than \(2000 \text{ W/kg/K}\).
  - Specific heat of vapour as high as possible: at least higher than \(1300 \text{ W/m/K}\).
  - Thermal conductivity of liquid as high as possible: at least higher than \(0.150 \text{ W/m/K}\).
  - Thermal conductivity of vapour as high as possible: at least higher than \(0.015 \text{ W/m/K}\).
  - Density of liquid as high as possible: at least higher than \(700 \text{ kg/m}^3\).
  - Saturation vapor pressure must be lower than \(7 \text{ Bars}\) over the temperature range.

→ Requirements over the whole temperature range
Schedule of work
Schedule and major deliverables

- **Review of existing fluids**
  - To identify fluid kinds which are the most adequate
  - Deliverable is expected within 2 months

- **Synthesis of new fluid**
  - First, in silico
  - Then, Experimental synthesis
  - Deliverable is expected within 6 months (TBC)

- **Experimental characterization of the synthesized fluid:**
  - Evaluation of thermal physical properties to check compliance with requirements
  - Deliverable expected at the project end