Design of Compact Heat Exchangers for Aero-Gas Turbines

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**1. REPORT DATE (DD-MM-YYYY)**
30-05-2001

**2. REPORT TYPE**
Workshop Presentations

**3. DATES COVERED (FROM - TO)**
30-05-2001 to 01-06-2001

**4. TITLE AND SUBTITLE**
Design of Compact Heat Exchangers for Aero-Gas Turbines

**5. AUTHOR(S)**
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**6. PERFORMING ORGANIZATION NAME AND ADDRESS**
Serck Aviation
xxxxx
xxxxx, XXXXXXX

**9. SPONSORING/MONITORING AGENCY NAME AND ADDRESS**
Office of Naval Research International Field Office
Office of Naval Research
Washington, DCxxxxx

**12. DISTRIBUTION/AVAILABILITY STATEMENT**
APUBLIC RELEASE

**13. SUPPLEMENTARY NOTES**
See Also ADM001348, Thermal Materials Workshop 2001, held in Cambridge, UK on May 30-June 1, 2001. Additional papers can be downloaded from: http://www-mech.eng.cam.ac.uk/onr/

**14. ABSTRACT**
Compact heat exchangers

**15. SUBJECT TERMS**

**16. SECURITY CLASSIFICATION OF:**
a. REPORT Unclassified
b. ABSTRACT Unclassified
c. THIS PAGE Unclassified

**17. LIMITATION OF ABSTRACT**
Public Release

**18. NUMBER OF PAGES**
16

**19. NAME OF RESPONSIBLE PERSON**
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**19b. TELEPHONE NUMBER**
International Area Code
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The Company

Bob Hamaberg - CEO
Employees: 3,602
1999 Revenue: £326 million

David Johnson
Managing Director

Piet Walton-Knight
Managing Director

David Shaw
President
The Company

Aero Equipment Division
David Johnson
Managing Director
Employees: 660
2000 Revenue £60M

- Mark Johnson
  Managing Director
  Coventry

- Steve Salt
  Managing Director
  Birmingham

- Jerry Hoover
  President
  Indianapolis

- Peter Smith
  Managing Director
  Shepshed
The Company

Headline Figures
- 2000 Sales £15m
- Employees 130
- Sole Market in Aerospace (91% export)
  - 85% Civil
  - 15% Military
- OEM - 59% of sales
- Spares - 27% of sales
- R&O - 14% of sales

Product Applications include
- Pratt and Whitney
  JT8, JT9, PW2000, PW4000,
  PW6000, F100
- Rolls Royce
  Tay, Adour, RB211 524 & 535,
  Pegasus, Trent, RTM322
- General Electric
  F404, CF34
- SNECMA
  CFM56 All Marks
- Boeing 777
- BAe Harrier, Hawk
The Products

- Compact aluminium tubular construction offers the advantage of low weight.
- Modular design for repair and overhaul provides low cost of ownership.
- Well proven design and robust construction meets High Mean Time Between Failure requirements.

Shell & Tube

- Compact aluminium construction offers the advantage of low weight and cost.
- Brazing technology used provides high joint integrity.

Plate & Fin

- Operating at approximately 1200°F to provide positive cooling to bearing chambers.
- Compact inconel tubular construction offers exceptionally long service life.

High Temperature
# Existing Products

<table>
<thead>
<tr>
<th>Type</th>
<th>Applications</th>
<th>Heat transfer area/volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fuel/Oil</td>
<td>Air/Oil</td>
</tr>
<tr>
<td>Tubular</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Plate - Fin</td>
<td>✓*</td>
<td>✓</td>
</tr>
</tbody>
</table>

* Low Pressure & Temperature applications
Metal Foam Heat Exchanger

Construction

- Use of Metal foam, (nickel or aluminium) to increase heat transfer.
- Several designs under consideration.
- Rapid development of product expected.

Benefits

⇒ Cost Reduction

⇒ Weight Reduction

⇒ Performance Improvement
Metal Foam

The heat exchanger built up of alternate plates.

Note: the foam can be brazed to the plates.

Hot fluid flows through the metal foam.

Cooler fluid flows around the fins.

Fig. 1
Metal Foam

Design Option - 2

⇒ Contact between tubes and foam is fixed by brazing.

⇒ Extended secondary surface for heat transfer.

⇒ Increased turbulence of the shell-side fluid.

⇒ The materials of construction have the same thermal expansion.

Fig. 2
Metal Foam

Design Option - 3

Rotating Air/Oil Heat Exchanger & Separator:

- The Retimet® uses centrifugal action to force the denser oil to separate from the less dense air.

- Rotational energy required is available within the gearing system.

- Heat exchange possibilities present in such a configuration.

Fig. 3
Metal Foam

Key points for consideration

Using metal foam:

⇒ Is the pressure drop acceptable?
⇒ Fouling is likely to occur with a small-celled metal foam. Therefore, can we make larger cells without losing performance, or should it have a filter added?
⇒ Will Foam break/fragment under operation?
Metal Foam

Compactness of the Metal Foam HE

Estimated $@ \approx 2500 \text{ m}^2/\text{m}^3$

Compare with current tubular of 650 $\text{ m}^2/\text{m}^3$
Design considerations

- Heat Transfer Performance & pressure loss
- Economic manufacturing cost
- Size, installation and removal for overhaul
- Dynamic loading induced from engine including vibration, blade out, manoeuvre
- Static loading from internal fluid pressures
- Thermal structural loading
- Material properties
- Fluid Properties
- Contamination / Fouling
- Repair and overhaul
- Life
Structural loading

⇒ Design is evaluated by Finite Element Analysis (FEA) to determine resonant frequencies and displacement of the assembly and component parts over the engine frequency range (typically from 5 to 3000 Hz with 20G load applied above 100Hz).

⇒ Static FEA for pressure loads

⇒ Dynamic FEA for blade out (120G) and manoeuvre loads
Thermal loading: particularly in the case of high temperature heat exchangers, a transient thermal FEA is completed using a validated model. This evaluates the induced metal temperatures and strain range throughout an entire flight cycle. A fatigue life analysis can be completed using the strain range, material properties and the number of defined engine cycles.

Computation Fluid Dynamics (CFD) is used to identify flow patterns (hot spots, reduced flow zones) within the unit which enables us to refine our heat transfer models. It also provides a good indicator of whether flow induced vibration will be a problem, and if so, how effective different design solutions will be.
Testing

Component Certification for flight worthiness testing will include:

- Vibration
- Pressure - including Proof/Burst/cycling
- May include PTF - pressure/temperature/flow cycling
  (although this may be avoided with the use of validated FEA)
- Impact
- Fire
- Icing
- Bird Strike/FOD.

Pass by analysis for sand, dust & fungus.