Engine ‘Core Lock-up’ Phenomenon

15 December 2004

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Core Lock-up Phenomenon (general)

- **Core lock up has been a result of differences in thermal time constant between static & rotating hardware. This may result in interference of hardware in either axial and /or radial direction**
- **Typically the most common region of interference has been in the hot section between rotating seals and static structure.**
- **Bombardier has experienced, during various engine development history, lock ups due to turbine or compressor blade tip rubs, and air seals.**
- **This phenomenon is a known potential condition that has been seen on many engines during their development and post certification, and is not limited to Bombardier aircrafts.**

Bombardier Processes & Procedures (general)

- During initial aircraft certification engines are forced to 0% core speed and subsequently the aircraft is accelerated to confirm that the engines will not lock-up and can be windmill re-started.
- Every engine potentially prone to ‘lock-up’, based on engine history, is verified during the aircraft FTP to not lock-up. Should a tight engine be discovered a ‘break-in’ procedure is executed.
- Engine models with no history of lock-up are not specifically tested for this phenomenon, but every engine is presently windmill restarted near the upper left corner of the envelope.
- Bombardier ensures that every ‘prone’ aircraft (e.g. CL300, CL604, CRJ200, DHC-8) is tested prior to delivery.

Bombardier Processes & Procedures

- **The current CRJ200 & CL604 FTP consists of the following process steps in order to eliminate locking engines from being shipped.**
  - Core lock-up is verified, if an engine fails to break free, a break-in procedure is performed.
    - Core lock verification
      - Engine shut down initiated at FL310
      - Drift down at 190 knots until N2=0%, (7.5 minutes max)
      - Reduce speed until N2=0%, if required.
      - Pushover and increase speed to 320 knots, record speed & altitude N2>0%
      - Level at FL210, ATS relight.
    - Break-in procedure
      - Engine shut down initiated at FL310
      - Descent at required speed to maintain N2 to 4%, 8-10 minutes
      - Core lock-up is re-tested afterwards
  - No CRJ200 or CL604 aircraft leaves BA production without both engines having passed the core locking determination procedure (robust process) and the windmill re-light procedure.

Bombardier Processes & Procedures

- **The CF34-3 engine series on Bombardier aircraft has had 2 areas suspected of causing core lock-up.**
  - Outer Balance Piston Seal: This area was suspect during initial CRJ certification, as noted within the Ops Test report. Design changes were implemented but no significant improvement was observed.
  - Inter-Stage Seal: This area was later determined to be a contributor. A design change was implemented (~1994) and the resultant lock-up phenomenon was substantially improved (~ 20% reduced to 1.5%)

Bombardier Processes & Procedures

- **Core lock up current rate, ~1.5% based on a sample of 669 engines tested between March 2001 and September 2004. 27 engines required the break-in in procedure.**

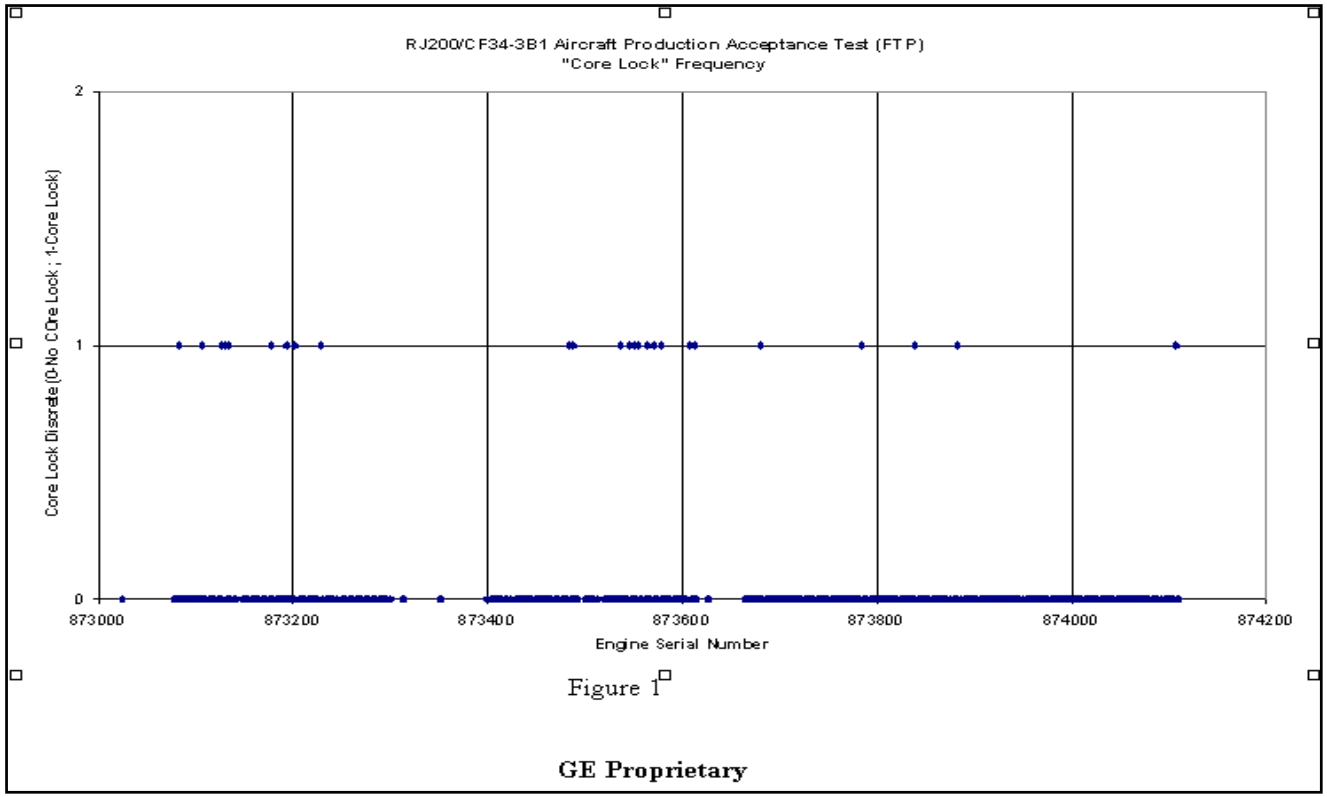

Figure 1

GE Proprietary

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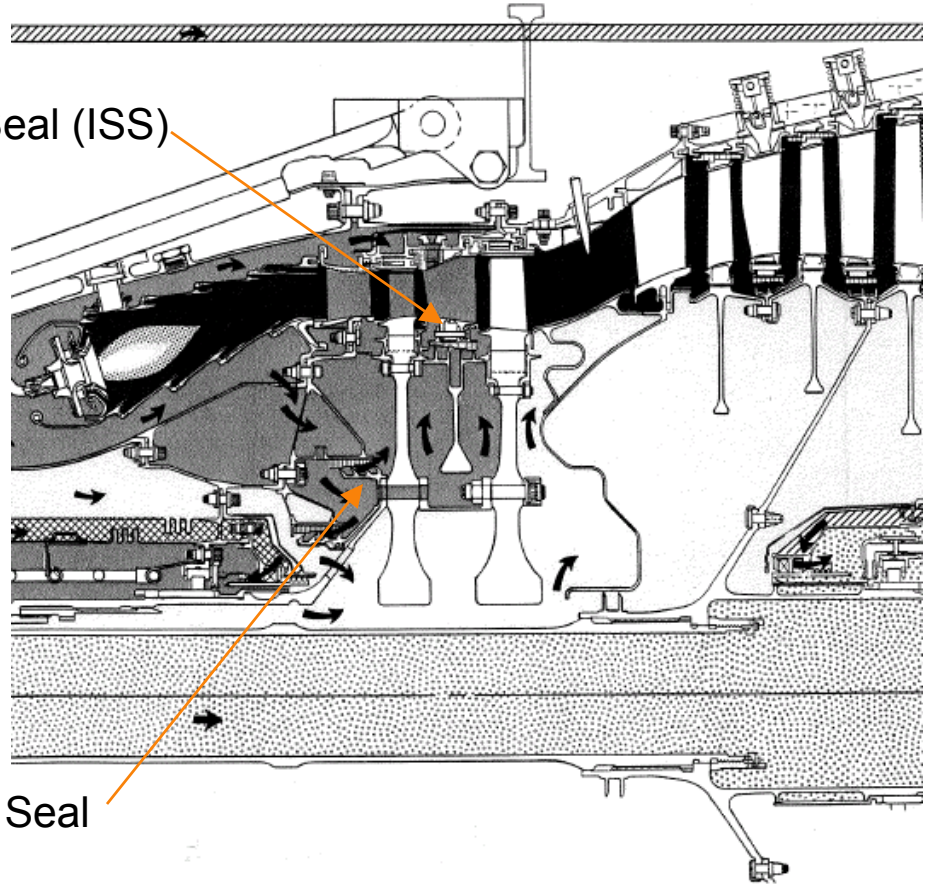
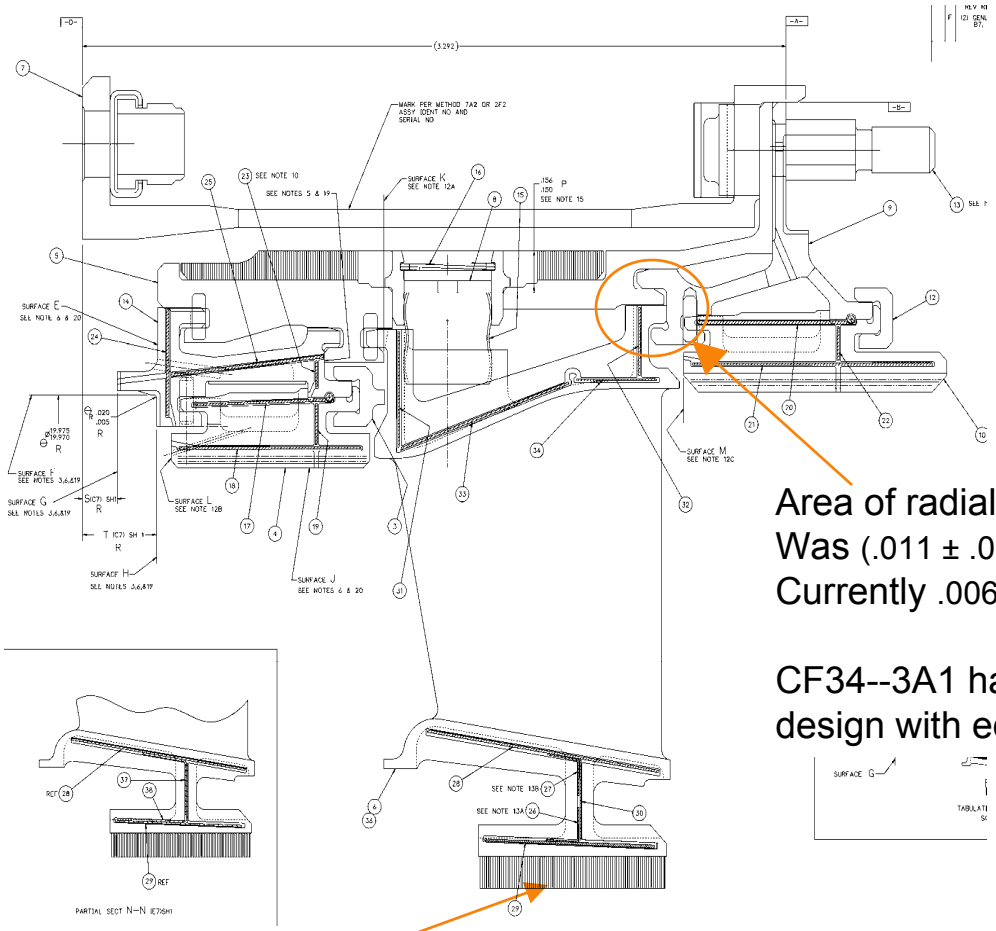
CF34 support illustrations

Interstage Static Seal (ISS)



Outer Balance Piston Seal

CF34 support illustrations (continued)



Area of radial stack gap
Was (.011 ± .009”)
Currently .006±.004” (50% less)

CF34--3A1 has different HPT Stator design with equiv. Gap of .006±.006”

Interstage Static Seal (ISS)

CRJ200 / CL604 Service History

- **There has never been a reported lock-up in-service.**
- **In-flight shutdowns are rare (.016 / 1000 flt hrs)**
- **Not normal for the flight crew to re-start an engine once it has been shutdown (< 10%).**

CRJ200 A/C 7396 Engine history

- **A/C 7396 originally shipped**
  - RHS, delivered with engine S/N 872712
  - LHS, delivered with engine S/N 872715
- **A/C 7396 engines replaced**
  - RHS
    - Installed S/N 873514 from GE services, Oct 2003
    - TSN at time of accident: 2303 hours
  - LHS
    - Removed S/N 872746 from A/C 7409, installed April 2004
    - A/C 7409 at delivery
      - RHS, S/N 872746
        - No core lock
    - TSN at time of accident: 8856 hours