LM2500 User Group

Minutes of the meeting

*29 Sept. – 1 Oct. 2020, Teleconference**s*

Table of Contents

[1 Discussed topics 1](#_Toc59530693)

[1.1 SAC dual fuel gas circuit backflow and clogging (#118) 1](#_Toc59530694)

[1.2 AGB Sump sudden temperature elevation (#110 & #111) 2](#_Toc59530695)

[1.3 HPC St0 blisk pitting corrosion with limited repair options (#106) 2](#_Toc59530696)

[1.4 Combustion chamber – trumpet and dome plate failure (#107) 3](#_Toc59530697)

[1.5 Gas fuel hose rupture (#108) 3](#_Toc59530698)

[1.6 Objects flying out of turbine exhaust (#105) 4](#_Toc59530699)

[1.7 Bearing Failures – IGB Duplex, Nos 3R, 4B, 5R & 7B (#50, 72, 73, 101, 103) 4](#_Toc59530700)

[1.8 Error in Thrust Balance Pressure Alarm Calculation 5](#_Toc59530701)

[2 TCT Session (Day 1) 5](#_Toc59530702)

[3 MTU Session (Day 2) 5](#_Toc59530703)

[4 OEM Sessions 5](#_Toc59530704)

[5 Conclusion Users Session 7](#_Toc59530705)

[5.1 Regular LM2500 User Group calls 7](#_Toc59530706)

[5.2 Depot experience 7](#_Toc59530707)

[5.3 Sessions with Independent Service Providers and Suppliers 7](#_Toc59530708)

[5.4 Suggestions for next meetings’ sessions 7](#_Toc59530709)

[5.5 User Meeting’s Sessions Review 7](#_Toc59530710)

[6 Actions list 8](#_Toc59530711)

# Discussed topics

## SAC dual fuel gas circuit backflow and clogging (#118)

*User Session (Day1)*

* N. Ewart (BP) described this long-lasting issue observed on dual fuel +G4 SAC engines installed in the North Sea, where carbon residues accumulate in front of the gas fuel nozzles during liquid fuel operation and cause clogging. BP has installed and tried the new check valve design from BH, but trials were unsuccessful.
* Similar issues were highlighted by R. Sørlid (Equinor) on base SAC and + SAC engines, and by J. Verschelde (TOTAL) on +G4 SAC engines.
* Users reported that BH had presented the topic at their 2020 annual meeting in Florence: new check valves were installed offshore on +G4 but had to be removed.
* Users commented that given the time since the issue was first raised, the announced schedules were considered too long.

*OEM session*

* GE presented the status of the active program: a new check valve design prevented backflow and mitigated the issue but did not completely eliminate it
* Next development will see the implementation of a forward purge system
* N. Ewart commented that BP operators keep a backup set of manifold & check valve & feeder tubes in case clogging occurs and requested a long-term solution to be developed.

**Action** : ETN to follow-up on topic #118 (SAC dual fuel gas circuit backflow and clogging issue) and solution’s status of development at ETN’s LM2500 User Group meeting 2021.

## AGB Sump sudden temperature elevation (#110 & #111)

*User Session (Day1)*

* C. McFarlane (Shell Global Solutions) described observation of a +G4 DLE unit which when loaded above 29 MW, saw the SLO temperature outlet from AGB sump temp. increase by 55°C to 145°C and the SLO tank level drop by 3%. Similarly, the C sump temperature was 105°C, 8°C higher than normal at the same load. There was evidence of SLO foaming during sampling, and traces of silicon. The temperature increase seemed stable and operators kept the engine running, but there are concerns when ambient temperature increases.
* J. Rydland (ConocoPhillips) reported a similar issue on a base DLE unit with instantaneous temperature increase, no findings in filters or debris reported by MetalSCAN.
* This issue is new to all Users
* Impact on the engine and its operation is unknown

*TCT Session*

* C. Kamble (Shell Global Solutions) described the issue to TCT, but they had never observed this phenomenon

*OEM Session*

* G. Mazzulli (BH) reviewed typical investigation steps, and noted that such event had not previously been observed by BH on base engine

## HPC St0 blisk pitting corrosion with limited repair options (#106)

*User Session (Day1)*

* J. Verschelde (TOTAL) highlighted the limited repair options for pitting corrosion on St0 blisk.
* Their engines are operated in an offshore environment without Sermatel coating on St0 blisk. Pitting corrosion leads to systematic rejection of parts without repair options being offered by MRO. As different levels of pitting are observed, the operator expects a certain level of remaining life for this expensive part.
* R. Sørlid (Equinor) commented that Equinor’s fleet had experienced similar effects and is now systematically using Sermatel coating on St0 blisk. He noted that blisk repair and coating have been pushed since the years 2000.
* R. Sørlid (Equinor) noted that E10-E12 air filtration gives good results to prevent corrosion.
* N. Ewart (BP) noted that BP’s fleet is using E12 air filtration but is also concerned by the question with many L3 overhaul coming in the next 2-3 years.
* The User Community agreed to request Aero Alliance to implement systematic risk assessment and repair options from the OEM. MTU is stuck with criteria defined by GE Aviation. Users suggested that measurements could be done on observed corrosion pitting levels in order to push for further analysis from the OEM.

*TCT session*

* TCT highlighted the new SB 312 for blisk recoating with Sermetel coating

*MTU session*

* MTU had investigated in 2015 the risk of corrosion on LM2500+ engines. Their report also reviewed repairs that were not approved by GE at the time. N. Brademann noted that most of these repairs can now be applied without restriction, or with an agreement with the customer.
* MTU recommended to re-apply coating at the 25khrs OH for units at higher risk of corrosion.
* MTU explained that in cases where a blisk needs repairs, it is sent to an approved vendor located in Europe.

*OEM session*

* M. Epstein (GE Aviation) referred to SB312 for active Sermetel coating option. He described the scope of repair developments which were announced for release and availability by end 2020. In 2021, an extension of the repair scope will be evaluated.
* M. Epstein noted that blend-repair may impact the expected life of the component, which must be taken into account.
* Users asked the OEM to provide information on the recommended maximum hours of operation allowed for SB312 implementation, based on a benchmark review.

**Action:** GE Aviation to provide recommendations on maximum operating hours allowed for SB312 implementation (cf. topic #106). A benchmark supporting the recommendations was requested by Users.

## Combustion chamber – trumpet and dome plate failure (#107)

*User Session (Day1)*

* J. Verschelde (TOTAL) described trumpet and dome plate failures, occurring at ~25khrs on LM2500+ engines used for power generation at 60-70% load. The issue was not observed on +G4 engines in similar configuration.
* The failures occurred on dual fuel engines which operate on 99% gas / 1% liquid. The operator suggested the issue may be linked to liquid because units running on 100% gas do not experience the issue.
* N. Ewart (BP) commented that similar issues had been observed and would report back.
* Users required the OEM to provide further details on potential sources

**Action**: N. Ewart to confirm similar observations to topic #107, combustion chamber’s trumpet and dome plate failure, on LM2500+ dual fuel engines.

*MTU session*

* U. Wassel presented MTU’s observations of trumpet and dome plate damage propagation. These were observed on only on +G4 engines and never on + engines, most likely because +G4 engines have different fuel nozzle than + engines.
* Besides, U. Wassel confirmed that damage was only observed on engine operating on Dual Fuel. No problem had been observed on units running on diesel only, until gas operation was commissioned. The cause of the problem could therefore be linked to transient operations.
* Damages were only observed with burners on the inner diameter. It was suggested that the component’s shape and/or the air flow could push the flame on the inner side.
* When starting the engine on diesel, then changing to gas, it was recommended to observe the temperature profile for a certain amount of time (minutes, hours). A large temperature spread could be a sign of contamination in the gas flow path

*OEM Session*

* M. Mueller (GE Aviation) described an upgraded combustor design G92 for NOx water applications, which has shown improvement in cooling and will be rolling out in the first quarter 2021

## Gas fuel hose rupture (#108)

*User Session (Day1)*

* J. Verschelde (TOTAL) highlighted an SB published one year earlier to address the risk of combustion air backflow leading to gas fuel hose rupture during liquid to gas change-over for LM2500 + G4 Dual Fuel engines. SB301 was categorised as optional correction, therefore passing the risk and cost to the operator, and charges the operator for the correction of a design issue.
* M. Forget (Engie) had similar experience on LM6000. Vibration modes are excited when running on partial burner modes at high firing temperature / high power. The weak point becomes the rubbing of hoses.
* R. Sørlid (Equinor) mentioned that gaskets are replaced preventively at Equinor; they do not wait for signs of gas leak to appear.

**Action**: ETN to follow-up with GE on SB301 and developments on fuel manifolds on all +G4 engines, not only on Dual Fuel (cf. topic #108).

*OEM Session*

* M. Epstein (GE Aviation) described the previous upgrade linked to DLE dual fuel B2-ring gas fuel hose rupture on +G4 engines.
* R. Sørlid (Equinor) and M. Forget (Engie) noted that the new setup makes it difficult to prevent rubbing and physical interference with flexible hose

**Action**: ETN to follow-up on operators’ experience with SB301, regarding prior issue with DLE dual fuel B2-ring gas fuel hose rupture

## Objects flying out of turbine exhaust (#105)

*User Session (Day1)*

* J. Rydland (ConocoPhillips) mentioned that the risk of objects flying out of the exhaust had been raised during a safety review. Small components found in the neighbourhood of the exhaust stacks had been identified as potential hazard.
* R. Sørlid (Equinor) and N. Ewart (BP) commented that their organisation had made similar observations, but further action had not been deemed required yet.
* J. Rydland added that the issue is not seen on a site where the exhaust was provided by a different engineering company (i.e. not OEM / GE / BH)
* E. Slettebø (AkerBP) noted that AkerBP would install the new +G4 exhaust collector and could share experience in 2021.

**Action:** AkerBP to share return of experience with new +G4 exhaust collector, in the context of topic #105 (Objects flying out of the exhaust) at ETN’s LM2500 User Group meeting 2021.

*TCT session*

* TCT mentioned no specific experience with exiting objects

*OEM Session*

* G. Mazzulli (BH) described package enhancements introduced in 2013, and noted that no issue had been reported since then

## Bearing Failures – IGB Duplex, Nos 3R, 4B, 5R & 7B (#50, 72, 73, 101, 103)

*TCT session*

* I. Andrew (TCT) highlighted that the main sources of recent failure events had been associated with corrosion, hard particle, and load (4B-specific). He raised awareness regarding the risk of failure associated with handling of the engine: at the hot section overhaul, or during on site assembly
* N. Ewart (BP) asked if a root cause had been identified on the findings presented by TCT or if a Root Cause Failure Analysis (RCFA) had been carried out, as many bearing failures were observed. I. Andrew (TCT) commented that some potential root causes were considered but had not been further investigated as the customer did not request a root cause analysis.
* Users noted that the 3R failure’s RCA had shown silicon carbide contamination in the lube oil. They suspected it could have originated in the grinding of the spools linked to SB implementation.
* Participants discussed bearings availability. I. Andrew commented that TCT tries to keep 5 of each bearing in stocks. IGB Duplex were unavailable, even from GE.
* I. Andrew detailed HP recoup considerations and recommendations

*MTU session*

* N. Brademann (MTU) reported only one recent 4B bearing failure observation, and noted a new assembly procedure to come from GE
* N. Brademann mentioned that several 5R bearings events had been observed. These may have been caused by aluminium oxide contaminant from HPT aft shaft diameter G coating.
* HPT Aft shaft coating was discussed, as + and +G4 engines now have new procedures in which no coating is involved. Base engines should receive new procedures as well, but no OEM information was circulated to MRO yet. Participants assumed that the change in repair procedures where based on previous MTU findings, but Al2O3 contamination had not been acknowledged by the OEM.
* Participants discussed the observation that GE appears to be removing the description of repair procedures from the manual and requesting a license fee to access it. Users shared concerns that they may not be aware that repairs are available and wondered if repairs could start depending on the MRO partner involved. N. Brademann clarified that repairs need to involve an authorised vendor, which guarantees harmonised repair options.

OEM Session

* M. Epstein (GE Aviation) mentioned that since the removal of the coating on dia G, a lower number of 5R bearing events had been observed. Participants required a follow-up in 2021 to confirm the trend

**Action**: GE Aviation to present trends of 5R bearing failure events before and after removal of diameter G coating procedure.

## Error in Thrust Balance Pressure Alarm Calculation

*MTU Session*

* Findings were presented by MTU as they found issues in Mark VI & VIe system for the Power Turbine thrust Balance (PTB) calculation. A first issue corresponded to a wrong constant value used in the controller, and a second one was identified with incorrect calculations for upper & lower alarm threshold values.
* M. Forget highlighted the good practice to monitor alarm values levels over time.

# TCT Session (Day 1)

The topics addressed by the TCT team in their presentation are listed below.

* Highlights and improvements
	+ Contract with Aero Alliance and +G4 capabilities
	+ TCT’s Calgary test cell upgrade
* Category 1 topics
	+ HPC Stage 15 &16 Blade Failure (#19)
	+ Bearing Failures – IGB Duplex, Nos 3R, 4B, 5R & 7B (#50, 72, 73, 101, 103)
	+ Stage 0 Blisk Pitting Corrosion (#106)
	+ Objects Out of the Turbine Exhaust (#105)

Topics in blue: see additional comments under Section 1.

# MTU Session (Day 2)

The topics addressed by the MTU team in their presentation are listed below.

* #4B Bearing Failure - Preliminary Observation
* #5R Bearing failed
* HPT Aft Shaft Coatings
* Pitting and corrosion issues
* HPC Rotor Blade Events
* Combustor Burning
* Thrust Balance Pressure Alarm

Topics in blue: see additional comments under Section 1.

# OEM Sessions

The topics addressed by representatives from GE, BH and AA in their presentations are listed below.

Topics in blue: see additional comments under Section 1.

Reference material:

(1): *ETN-LM2500-2020-GE\_usersonly.pdf*

(2): *ETN-LM2500-2020-BH-CMU\_usersonly.pdf*

(3): *ETN-LM2500-2020-BH-PSE\_usersonly.pdf*

**Day 2 – Fleet overview and upgrades**

* Intro & safety moment – P. Bianchi
* Aero Alliance JV: scope & activities – L. Marcuzzi
* Service shop capacity – S. Rogers
	+ Services are moving to a new facility owned by AA in Massa
* Aero GT Products – T. Montgomery (replacing D. Kempf) (1)
	+ LM9000: highlight aeroderivative design, commercial operation in 2022-23
	+ LM6000 PF+
	+ LM2500 +G5
* Hydrogen fuels – R. James (1)
* Retrofitability & upgrades to existing packages – R. Migliorini (2)
	+ LM2500+ to +G4
	+ LM2500+G4 to +G5
	+ LM6000 to PF+

**Day 3 – Technical session**

GE Aviation Presentation (part 1) (1)

* Introduction – R. James
* Trends in Unplanned Engine Removals – M. Mueller
	+ Note: blue = bearings
* Reliability and availability – G. Saccardi
	+ Based on 176 units serviced by BH
* HPC Ruggedization – R. James
	+ Vane count change introduced in end 2019
	+ Everything has been implemented
* HPC St0 blisk – M. Epstein
* +G4 SAC Combustor dome distress – M. Mueller
* HPT Aft shaft repair – M. Epstein
* Improved chip detection system – M. Epstein
	+ Description of optional MetalScan sensor on the common scavenge line
	+ Users noted that one single MetalScan sensor may fire an alarm before any detectable debris could be found on chip detector. If such case were to happen, the affected scavenge line would not be identifiable.

**Action**: GE Aviation to follow-up on the concern of Users on the improved chip detection system: they highlighted that the MetalSCAN sensor could fire an alarm before any detectable debris could be found on chip detectors, therefore preventing identification of the affected scavenge line.

* DLE dual fuel B2-ring on +G4 – M. Epstein
* Hot rotor reburst / Software developments – R. James
* Part power efficiency – M. Mueller
	+ Upgrade on base and + engines only if they are already equipped with DLE 1.5 system. Refer to SB LM2500-IND-281 for base engine, available on demand for + engine (no SB)
	+ Upgrade on + engines only if they are already equipped with DLE 1.5 system (SB LM2500-IND-281)
	+ R. Migliorini (BH) commented that BH is working on improvements on 1.0 combustor for base engines
	+ Upgrades are not available on +G4 engines due to the limited demand from operators

BH presentation – G. Mazzulli (3)

* Exhaust: objects flying
* AGB high temperature
* TMF strut #7 – supply line bushing wear

GE Aviation presentation (part 2) (1)

* Completed engine programs
	+ HPC stage 2 Inconel disk
	+ DLE-auto-mapper
* Active engine programs
	+ VSV actuator bracket wear
	+ SAC dual fuel circuit backflow
	+ HPT stage 1 blade
		- +G5 engine developments lead to this upgrade. GE recommended it for SAC wet operation. Availability was scheduled for 3Q21
	+ TMF liner
* Best Practices – M. Epstein
* Leading Indicators – M. Epstein
* Service Bulletin overview – M. Mueller

# Conclusion Users Session

## Regular LM2500 User Group calls

Users suggested to schedule well in advance 3 or 4 calls per year for the Users of the ETN User Group, in addition to the User Group meeting. These calls would support a closer follow-up on topics reported by Users and would be excellent opportunities for Users to catch-up on things happening with the fleet.

**Action:** ETN to arrange a yearly schedule of calls of the ETN LM2500 User Group (Users only)

## Depot experience

Users suggested to draft a review of service depot experience. They recommended including users of other engines such as LM6000 (Uniper, E.ON), to increase the input pool.

**Action:** ETN to coordinate a review of Users’ experience with service depot

## Sessions with Independent Service Providers and Suppliers

Users’ general comment was that non-authorised service providers usually cannot provide support on expensive services and parts. If they would want to meet with the Users, they should first highlight what they can bring to the table compared to ASPs and OEM.

Users suggested that ETN should invite interested Service Providers and Suppliers to submit topics they would want to address with the User community. Based on Users’ response, ETN could then organise individual webinars for third parties to make a presentation and discuss with the User community.

**Action:** ETN to circulate invitation to Independent Service Providers and Suppliers companies to submit topics they would want to address with the User community via individual webinars.

## Suggestions for next meetings’ sessions

2021 User Group meeting:

* Users suggested to invite Sermetel to clarify the extent of repair & coating technology
* Users recommended to request TCT and MTU to share their own findings and not only focus on topics submitted by ETN Users

2021 Use Group meeting or follow-up session:

* Users proposed to invite TCT and MTU to organise a common session on depot findings – similar to what they do at WTUI.
* Users proposed that GE/AA/BH could hold a follow-up session addressing their actions from this meeting, before next ETN User Group meeting.

## User Meeting’s Sessions Review

* MTU: good RCA and in-depth discussions
* TCT: they could dedicate more time to present ongoing developments in their service offer (e.g. free floating pre-mixers)
* GE:
	+ Sue Rogers’ presentation was too high-level. User requested that GE provide a more detailed overview on services and quality aspects:
		- Detailed overview of shop capabilities worldwide
		- Clarifications on the transition phase to the Massa shop
		- Communication on identified supply chain / services bottleneck (e.g. Sermetel coating), and plans under consideration (e.g. increase the number of licensed suppliers)
		- Parallel comparison of capacity increase and observed quality levels, including parameters such as: rework rates, review of non-conformance, share of successful engine tests in the first try
	+ UERs review lacked transparency (no numbers)

**Action**: ETN to ask GE/AA/BH to provide an in-depth presentation on services and quality aspects:

* Detailed overview of shop capabilities worldwide
* Clarifications on the transition phase to the Massa shop
* Communication on identified supply chain / services bottlenecks (e.g. Sermetel coating), and plans under consideration (e.g. increase the number of licensed suppliers)
* Parallel comparison of capacity increase and observed quality levels, including parameters such as: rework rates, review of non-conformance, share of successful engine tests in the first try

# Actions list

| # | Actions | Resp. | Deadline |
| --- | --- | --- | --- |
| 1 | ETN to follow-up with operators and GE Aviation on topic #118 (SAC dual fuel gas circuit backflow and clogging issue) and solution’s status of development at ETN’s LM2500 User Group meeting 2021. | ETN & BP & GE/BH | Follow-up session or UGM 2021 |
| 2 | GE Aviation to provide recommendations on maximum operating hours allowed for SB312 implementation (cf. topic #106). A benchmark supporting the recommendations was requested by Users. | GE Aviation | Follow-up session or UGM 2021 |
| 3 | N. Ewart to confirm similar observations to topic #107, combustion chamber’s trumpet and dome plate failure, on LM2500+ dual fuel engines. | N. Ewart (BP) | Q1 2021 |
| 4 | ETN to follow-up with GE / BH on SB301 and developments on fuel manifolds on all +G4 engines, not only on Dual Fuel (cf. topic #108). | ETN & GE/BH | Follow-up session or UGM 2021 |
| 5 | ETN to follow-up on operators’ experience with SB301, regarding prior issue with DLE dual fuel B2-ring gas fuel hose rupture | ETN | Q1 2021 |
| 6 | AkerBP to share return of experience with new +G4 exhaust collector, in the context of topic #105 (Objects flying out of the exhaust) at ETN’s LM2500 User Group meeting 2021. | AkerBP | UGM 2021 |
| 7 | GE Aviation to present trends of 5R bearing failure events before and after removal of diameter G coating procedure. | GE Aviation | Follow-up session or UGM 2021 |
| 8 | GE Aviation to follow-up on the concern of Users on the improved chip detection system: they highlighted that the MetalSCAN sensor could fire an alarm before any detectable debris could be found on chip detectors, therefore preventing identification of the affected scavenge line. | GE Aviation | Follow-up session or UGM 2021 |
| 9 | ETN to coordinate a review of Users’ experience with service depot | ETN | Q1 2021 |
| 10 | ETN to circulate invitation to Independent Service Providers and Suppliers companies to submit topics they would want to address with the User community via individual webinars. | ETN | Q1 2021 |
| 11 | ETN to ask GE/AA/BH to provide an in-depth presentation on services and quality aspects:* Detailed overview of shop capabilities worldwide
* Clarifications on the transition phase to the Massa shop
* Communication on identified supply chain / services bottlenecks (e.g. Sermetel coating), and plans under consideration (e.g. increase the number of licensed suppliers)
* Parallel comparison of capacity increase and observed quality levels, including parameters such as: rework rates, review of non-conformance, share of successful engine tests in the first try
 | ETN & GE/AA/BH | Follow-up session or UGM 2021 |