Rolls-Royce Engine Investigation Report

Wreckage Exam Date: 4AUG2020
Wreckage Exam Location: MP Aviation Hangar, Standpoint, ID
Aircraft Type: MD600N
Aircraft Reg: N208MP
Engine Model: M250-C47M
Engine S/N: 847850
Engine Rating: 650 shp (takeoff)

The wreckage exam was conducted on 4 August 2020 under the supervision of the NTSB (via video feed) and the FAA in person. Also in attendance were the operator's Director of Maintenance, Chief Pilot, and an ASI from MDHI. The aircraft was recovered to the operator's hangar in Standpoint, ID and was situated on skids. The main rotor blades were removed for transport.

The engine was secure and in place with no external damage to the engine or mounts noted. There was some residual oil observed within the engine compartment. The engine N1 system turned smoothly and was continuous from the compressor to the starter/generator and first stage turbine wheel. The N2 system turned smoothly and was connected to the aircraft power train. Foreign Object Damage (FOD) was not observed on the compressor impeller blades or compressor inlet and the inlet barrier filter system was intact and free of debris. The fourth stage turbine wheel was normal in appearance when viewed from the exhaust collector. The first stage turbine nozzle and blades were viewed via borescope with no abnormalities observed.

The Power Lever Angle (PLA) linkage from the twist grip to the HydroMechanical Unit (HMU) was rigged appropriately and secure. All external air, fuel, and oil line connections were at least finger tight. The engine mounted fuel filter bowl retained ~1/3 bowl of fuel, which was normal in smell and appearance. The fuel filter element presented no obvious contamination and the pending bypass button was not extended. A fuel sample was retained from the bowl. All of the fuel lines from the airframe to the engine were flow-checked with no obstructions noted to include the pressure sensing lines attached to the Combined Engine Filter Assembly (CEFA) and those attached to the fuel flow meter (these lines are airframe supplied but attached to the engine). The fuel line from the fuel flow meter to the fuel nozzle retained fuel. All of the fuel line connections were verified as secure during removal.

The engine mounted scavenge oil filter was clean and full of oil which was normal in appearance and smell. The pending bypass button was not extended. Both the upper and lower magnetic chip detectors were free of ferrous debris and an oil sample was retained from the engine gearbox.

The engine Electronic Control Unit (ECU) retains data in non-volatile memory, which was downloaded during the wreckage exam. The ECU includes an incident recorder function, which begins capturing engine and input parameters upon trigger actuation and records a line of data ("record") every 1.2 seconds (Appendix A). The recorder captures twelve seconds of data prior to the triggering event (ten records) and forty eight seconds of data (forty records) post trigger. The initial incident recorder triggering event was low rotor RPM (Nr Droop), which fell below the 92% threshold. Then, within 3 seconds, the incident recorder captured the Flameout and Ng Low triggers. The FADEC system attempted to re-light the engine for the next 53 seconds until the PLA was rolled to cut-off; however, the engine did not re-start.

The FADEC system also retains routine maintenance information in the maintenance terminal section (Appendix B). The maintenance terminal data indicate that roughly 13.5 minutes prior to the event during the ECU power up Built in Test (BiT), the FADEC system recorded three overspeed system faults - Overspeed Test 4 Failed, Overspeed Test 7 Failed, and Overspeed Fault. These faults are normal during electrical system power up in this configuration due to the installation of a False Overspeed Trip (FOST) adapter. Rolls-Royce Commercial Engine Bulletin CEB-A-73-6059 describes the FOST adapter program which was implemented in 2013 on the M250-C47 series engines to reduce the likelihood of a false activation of the FADEC overspeed system (Appendix C). Based on the FADEC incident recorder and maintenance terminal data analysed, the implementation of this modification did not affect engine operation during the event nor did the engine experience false overspeed system activation.

Upon completion of the wreckage examination, the engine and the airframe to engine input fuel line was removed and installed in a shipping container for future testing.

Engine Exam Date: 06OCT2020
Engine Exam Location: Keystone Turbine Services, Coatesville, PA

The engine was removed from the shipping container on 6 October 2020 under the supervision of the NTSB IIC, FAA Rotorcraft Directorate, and MDHI ASI (all via internet live stream) with Rolls-Royce air safety and service engineering in attendance. The engine was inspected with no anomalies noted and then installed on a calibrated test stand.

The engine started satisfactorily with a slight delay. The longer start time was consistent with removal of the fuel lines during the investigation resulting in some residual air in the system. After the engine was warmed up for ~5 minutes, power was increased to the take-off setting, where the observed power was 680 shaft horsepower (shp). No unusual vibration was noted during the initial acceleration, so testing continued. Next, several accelerations and decelerations were achieved followed by testing of the anti-ice system and bleed valve, all of which were within specification. A full power calibration protocol was

achieved resulting in a maximum predicted take-off rating of 664shp at standard day conditions[1]. In an attempt to replicate the non-boosted fuel system of the MD600N aircraft, the test stand inlet fuel pressure to the engine was reduced to less than 1 psi. The dynamometer load was increased until the engine produced >500shp and ~316 pounds per hour (pph) fuel flow. The engine continued to run with no perturbations or abnormal behaviour at this setting.[2]

The engine was shut down and restarted normally within time and temperature limits. During the second run, the FADEC system manual mode operation was tested with normal engine response noted. The engine was then shut down and the fuel nozzle was removed for further inspection at the request of the operator.

The fuel nozzle was disassembled to view the inlet screen, which was normal in appearance and not obstructed. The nozzle spray tip was clean and normal in appearance as well. The airframe supplied fuel hose, which connects the airframe firewall to the HMU, was installed in a test bench and 600+ pph of fuel was flowed through the hose to check for leaks. No leaks were observed.

The engine, ECU, fuel hose, and several airframe components were re-installed in the engine shipping container for return shipment to the operator.

Engine Test Data Summary:

	PREDICTED DATA			
	TAKEOFF	MAX. CONT	CRUISE A	CRUISE B
SPEC MGT (F)	1268	1230	1181	1113
SPEC OUTPUT SHAFT POWER (hp)	650	600	540	450
SPEC SFC (lbm/hp-hr)	0.584	0.594	0.609	0.643
PRED SHAFT PWR AT SPEC MGT (hp)	664	623	569	492
PRED SFC (lbm/hp-hr)	0.589	0.595	0.605	0.626
PERCENT DELTA FROM SPEC PWR (%)	2.2%	3.8%	5.4%	9.3%
PERCENT DELTA FROM SPEC SFC (%)	0.9%	0.2%	-0.7%	-2.6%

[1] Note – during testing a technician noted an air leak from the compressor scroll at the customer bleed pad. The leak did not affect engine operation and could not be quantified.

[2] For reference, the fuel flow during the event was ~200-250pph prior to the flame out.

Executive Summary: No abn[redacted]ed during the wreckage exam and engine testing which would a[redacted] during the event. The engine started, accelerated, decelerated and [redacted]ver an hour with no flameouts or anomalous behaviour noted.[redacted]

[redacted]

Jon-Adam Michael
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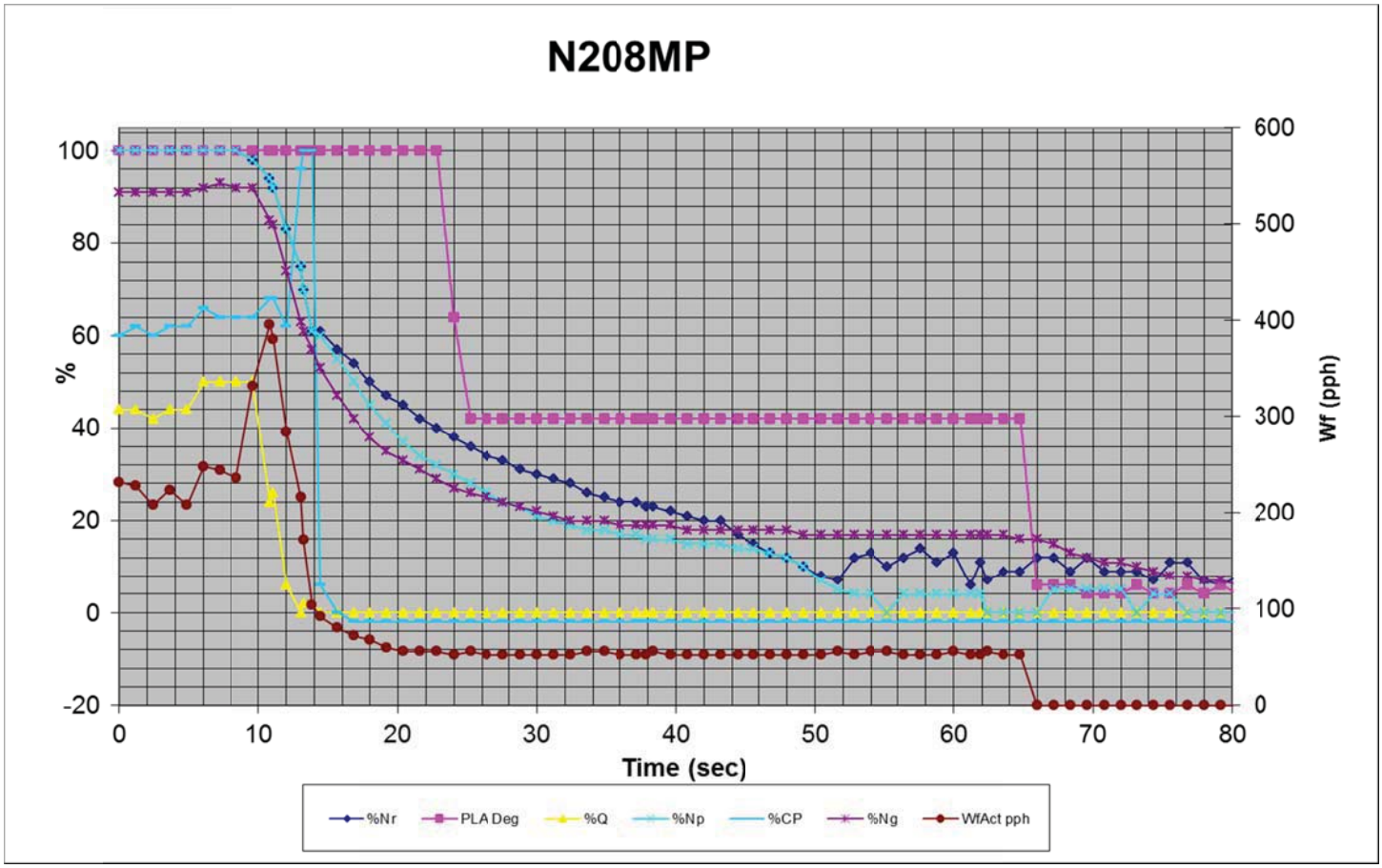
airsafetyinvestigationindy@[redacted]

[redacted]

Appendix A ECU Incident Recorder Data



Numeric Record	Time Seconds	Ng %Ng	Nr %Nr	MGT Deg	Q %Q	Np %Np	WfAct pph	CP %CP	PLA Deg
1	0.000	91	100	1060	44	100	232	60	100
2	1.200	91	100	1060	44	100	228	62	100
3	2.400	91	100	1040	42	100	208	60	100
4	3.600	91	100	1060	44	100	224	62	100
5	4.800	91	100	1060	44	100	208	62	100
6	6.000	92	100	1080	50	100	248	66	100
7	7.200	93	100	1080	50	100	244	64	100
8	8.400	92	100	1080	50	100	236	64	100
9	9.600	92	98	1100	50	98	332	64	100
10	10.800	85	94	940	24	94	396	68	100
NR Droop	11.064	84	92	940	26	92	380	68	100
11	12.000	74	83	780	6	83	284	62	100
Flameout	13.032	63	75	640	0	75	216	96	100
12	13.200	61	70	620	2	70	172	100	100
NG Low	13.800	57	61	580	2	61	104	100	100
13	14.400	53	61	560	0	60	92	6	100
14	15.600	47	57	540	0	55	80	0	100
15	16.800	42	54	520	0	50	72	-2	100
16	18.000	38	50	520	0	45	68	-2	100
17	19.200	35	47	500	0	41	60	-2	100

Numeric Record	Time Seconds	Ng %Ng	Nr %Nr	MGT Deg	Q %Q	Np %Np	WfAct pph	CP %CP	PLA Deg
18	20.400	33	45	500	0	37	56	-2	100
19	21.600	31	42	480	0	34	56	-2	100
20	22.800	29	40	480	0	32	56	-2	100
21	24.000	27	38	480	0	30	52	-2	64
22	25.200	26	36	440	0	28	56	-2	42
23	26.400	25	34	420	0	26	52	-2	42
24	27.600	24	33	400	0	24	52	-2	42
25	28.800	23	31	380	0	23	52	-2	42
26	30.000	22	30	380	0	21	52	-2	42
27	31.200	21	29	360	0	20	52	-2	42
28	32.400	20	28	360	0	19	52	-2	42
29	33.600	20	26	360	0	18	56	-2	42
30	34.800	20	25	340	0	18	56	-2	42
31	36.000	19	24	340	0	17	52	-2	42
32	37.200	19	24	340	0	17	52	-2	42
NG Low	37.848	19	23	320	0	16	52	-2	42
33	38.400	19	23	320	0	16	56	-2	42
34	39.600	19	22	320	0	16	52	-2	42
35	40.800	18	21	320	0	15	52	-2	42
36	42.000	18	20	300	0	15	52	-2	42
37	43.200	18	20	300	0	15	52	-2	42
38	44.400	18	17	300	0	14	52	-2	42
39	45.600	18	15	300	0	14	52	-2	42
40	46.800	18	13	300	0	13	52	-2	42
41	48.000	18	12	280	0	12	52	-2	42
42	49.200	17	10	280	0	10	52	-2	42
43	50.400	17	8	280	0	7	52	-2	42
44	51.600	17	7	280	0	5	56	-2	42
45	52.800	17	12	260	0	4	52	-2	42
46	54.000	17	13	260	0	4	56	-2	42
47	55.200	17	10	260	0	0	56	-2	42
48	56.400	17	12	260	0	4	52	-2	42
49	57.600	17	14	260	0	4	52	-2	42
50	58.800	17	11	260	0	4	52	-2	42
51	60.000	17	13	260	0	4	56	-2	42
52	61.200	17	6	260	0	4	52	-2	42
NG Low	61.896	17	11	240	0	4	52	-2	42
53	62.400	17	7	240	0	0	56	-2	42
54	63.600	17	9	240	0	0	52	-2	42
55	64.800	16	9	240	0	0	52	-2	42
56	66.000	16	12	240	0	0	0	-2	6
57	67.200	15	12	240	0	5	0	-2	6
58	68.400	13	9	240	0	5	0	-2	6
59	69.600	12	12	240	0	5	0	-2	4
60	70.800	11	9	240	0	5	0	-2	4
61	72.000	11	9	240	0	5	0	-2	4
62	73.200	10	9	240	0	0	0	-2	6
63	74.400	9	7	240	0	4	0	-2	4
64	75.600	8	11	240	0	4	0	-2	4
65	76.800	8	11	240	0	0	0	-2	6
66	78.000	7	7	240	0	0	0	-2	4
67	79.200	7	6	240	0	0	0	-2	6

Numeric Record	Time Seconds	Ng %Ng	Nr %Nr	MGT Deg	Q %Q	Np %Np	WfAct pph	CP %CP	PLA Deg
68	80.400	6	8	240	0	0	0	-2	4
69	81.600	6	8	240	0	0	0	-2	4
70	82.800	6	8	240	0	0	0	-2	4
71	84.000	5	7	240	0	0	0	-2	6
72	85.200	5	5	240	0	0	0	-2	4
73	86.400	5	7	240	0	0	0	-2	4
74	87.600	4	7	240	0	0	0	-2	4
75	88.800	4	8	240	0	0	0	-2	4
76	90.000	4	8	260	0	0	0	-2	6
77	91.200	4	9	260	0	0	0	-2	4
78	92.400	0	5	260	0	0	0	-2	6
79	93.600	0	0	260	0	0	0	-2	6
80	94.800	0	0	260	0	0	0	-2	4

Appendix B ECU Maintenance Terminal Data

Data Source:	ECU
Data Time:	8/4/2020 12:23:49 PM
Aircraft Model:	MD 600N
Engine Model:	250-C47M
ECU Version:	271-6112
ID:	9840
User Name:	u1014711
Engine S/N:	CAE-847850
ECU S/N:	JG7ALW0046
Compressor S/N:	CAC-44509
Turbine S/N:	CAT-44430
HMU S/N:	JGAMU0009
Eng Gearbox S/N:	CAG-42421
Aircraft ID:	N811LH

Current RAM Faults

Fault Name	Description
OSTst4Flt	- Overspeed Test 4 Failed
OSTst7Flt	- Overspeed Test 7 Failed
OSFlt	- Overspeed Fault

Last Engine Run Faults

Fault Name	Description
OSTst4Flt	- Overspeed Test 4 Failed
OSTst7Flt	- Overspeed Test 7 Failed
OSFlt	- Overspeed Fault

Accumulated Faults

Fault Name	Description
OSTst4Flt	- Overspeed Test 4 Failed
OSTst7Flt	- Overspeed Test 7 Failed
OSFlt	- Overspeed Fault
CPFlt	- CP Fault
CPRgFlt	- CP Range Fault
CPAntFlt	- Collective Pitch Hard Fault
WDTFltRG	- Watchdog Timer Fault from Rev. Gov.

Time Stamped Faults

Fault Time	Fault Name	Description
3313:02:50.064	OSTst4Flt	- Overspeed Test 4 Failed
3313:02:50.064	OSTst7Flt	- Overspeed Test 7 Failed
3313:02:50.064	OSFlt	- Overspeed Fault
3312:16:22.104	OSTst4Flt	- Overspeed Test 4 Failed
3312:16:22.104	OSTst7Flt	- Overspeed Test 7 Failed
3312:16:22.104	OSFlt	- Overspeed Fault
3311:36:05.256	OSTst4Flt	- Overspeed Test 4 Failed
3311:36:05.256	OSTst7Flt	- Overspeed Test 7 Failed
3311:36:05.256	OSFlt	- Overspeed Fault
3310:55:19.056	OSTst4Flt	- Overspeed Test 4 Failed
3310:55:19.056	OSTst7Flt	- Overspeed Test 7 Failed
3310:55:19.056	OSFlt	- Overspeed Fault
3307:45:03.456	OSTst4Flt	- Overspeed Test 4 Failed
3307:45:03.456	OSTst7Flt	- Overspeed Test 7 Failed
3307:45:03.456	OSFlt	- Overspeed Fault
3307:34:36.312	OSTst4Flt	- Overspeed Test 4 Failed
3307:34:36.312	OSTst7Flt	- Overspeed Test 7 Failed
3307:34:36.312	OSFlt	- Overspeed Fault
3299:12:12.384	OSTst4Flt	- Overspeed Test 4 Failed
3299:12:12.384	OSTst7Flt	- Overspeed Test 7 Failed
3299:12:12.384	OSFlt	- Overspeed Fault
3298:26:49.656	OSTst4Flt	- Overspeed Test 4 Failed
3298:26:49.656	OSTst7Flt	- Overspeed Test 7 Failed

3298:26:49.656	OSFlt	- Overspeed Fault
3297:42:39.432	OSTst4Flt	- Overspeed Test 4 Failed
3297:42:39.432	OSTst7Flt	- Overspeed Test 7 Failed
3297:42:39.432	OSFlt	- Overspeed Fault
3296:52:04.872	OSTst4Flt	- Overspeed Test 4 Failed
3296:52:04.872	OSTst7Flt	- Overspeed Test 7 Failed
3296:52:04.872	OSFlt	- Overspeed Fault

Engine History Data

Name	Value	Units	Description
EngRnTm	3313.19	Hours	Engine Operating (Running) Time (counter)
NpRLmPk	0.00	%Np	Np Run Limit Exceedance Peak Value
NpRLmTm	0.00	Seconds	Np Run Limit Exceedance Time
NumStrt	4455	Starts	Number of Engine Starts
OSCyc	A	Boolean	Overspeed Cycle
SgCtr	0	Surges	Number of Surge Occurrences Counter
EngRunCtr	306.10	Seconds	Engine Run Time Interval Counter
NpLmPk	0.00	%Np	Np Limit Exceedance Peak Value
NpLmTm	0.00	Seconds	Np Limit Exceedance Time
OSCtr	0	Events	Engine Overspeed Counter
NpLmEvts	0	Counts	Np Limit Exceedance Events
NpRLmEvts	0	Counts	Np Run Limit Exceedance Events
NpMLmEvts	0	Counts	Np Max Limit Exceedance Count
NpExcInd	FALSE	Boolean	Np Exeedance Indication for Engine Maintenance

Appendix C Rolls-Royce Alert Commercial Engine Bulletin CEB-A-73-6059

ALERT
COMMERCIAL ENGINE BULLETIN

Rolls-Royce

ENGINE, FUEL AND CONTROL - OVERSPEED ADAPTER

1. PLANNING INFORMATION

A. Effectivity

(1) Engines

All Rolls-Royce Model M250-C47B and M250-C47M engines with the following ECUs installed:

C47B
23080490
23088484
23088856

C47M
23080491
23088805
23088905
23089311

(2) Spares - Not affected

B. Reason

The adapter modifies the overspeed protection system to reduce the likelihood of a false overspeed activation.

C. Description

The adapter generates an open circuit between the ECU and the HMU that disconnects the low side switch of the channel A overspeed circuit and the high side switch of the channel B overspeed circuit in the ECU. Because of the open circuit, the ECU software will detect faults during power-up Built-In Test. The over speed system is still operational and capable of activating during an actual overspeed event in flight. With Overspeed adapter installed, the overspeed shutdown test must not be used. If the overspeed shutdown test is attempted, the engine will not shutdown and FADEC FAULT(407)/Limit Fault (MD600N) and FADEC DEGRADE(407)/ECU Degraded(MD600N) cautions will illuminate.

A recurring maintenance ground check of the overspeed system is required to verify that the system is functional. New software will be released under a separate CEB for each engine model that will correct the power-up test and overspeed shutdown issues.

D. Approval

Technical aspects are FAA approved.

E. Compliance

Compliance Code 2. Paragraph 2.A. to be complied with no later than June 30, 2014. Paragraph 2.C. to be complied with at each 50 hours thereafter.

F. Interchangeability - Not affected

G. Material Availability

NEW P/N	NAME	QTY/ENG
M250- 10684	Adapter, Main Engine Harness	1

H. Tooling - Not applicable

I. Weight and Balance

The adapter increases the engine weight by 0.4 lbs.

J. Electrical Load Data - Not affected

K. References

(1) Advance Engineering Memorandum (AEM), CW500019604763.

NOTE: The document above is referenced for the internal use of Rolls-Royce only.

(2) CSP21001 Operation and Maintenance Manual, Turboshaft Model C47B (OMM).

(3) CSP21004 Operation and Maintenance Manual, Turboshaft Model C47M (OMM).

(4) CSP23001 Illustrated Parts Catalog, Turboshaft Models M250-C40B, -C47B, -C47M (IPC).

L. Other Publications Affected - None

M. Prerequisites - None

2. ACCOMPLISHMENT INSTRUCTIONS

A. Install the adapter on the main engine harness.

(1) Obtain an adapter (M250-10684) for installation. Contact Rolls-Royce Customer Support via e-mail at Helicoptercustsupp@rolls-royce.com with contact information. Be sure to include ”CEB 73-6059” on the subject line. One adapter per aircraft will be provided free of charge. All additional adapters will be available at regular Aviall pricing.

(2) Disconnect the main engine harness at the engine compartment bulkhead (P3).

(3) Install the adapter on the harness.

(4) Re-connect the harness to the engine bulkhead connector.

(a) Make sure that both connections are complete by observing that the red security line on both the adapter and the fire wall connector (P3) are covered.

NOTE: The use of Stabilant 22 contact enhancer is recommended, but not required. Please reference CSL 6116 for C47 Series engines.

B. Verify that only the expected faults generated by the adapter are present before each flight using either the aircraft indication system or the maintenance terminal.

(1) Procedure using aircraft indication system:

(a) With throttle in cut-off, apply power to aircraft/ECU.

(b) Verify that FADEC Degraded (407)/ECU Degraded (MD600N) and FADEC Fault (407)/Limit Fault (MD600N) indications are displayed.

(c) For aircraft with Glass Cockpit displays (407GX), verify that the faults indicated are OSFLT, prim_gov_fail, and hmu_os_sol.

1 This is indicated on the Engine/ECU Fault page.

2 If the faults are not present, cycle the auto manual switch from auto to manual to auto.

3 The faults in step (c) will now appear in yellow, as well as a HardFlt indicated in white.

(d) Roll the throttle to idle.

(e) Select Manual Mode.

(f) For aircraft without Glass Cockpit displays (remaining 407s, MD600Ns) perform flashing light procedure (73-25-01 Paragraph 2, Maintenance Mode in Operations and Maintenance Manual).

1 Confirm that 8 flashes of the FADEC fault lamp (407) or 8 flashes of the Limit Fault Lamp (MD 600N) are the only faults indicated.

(g) If either step (c) or (f) identify faults other than those expected, perform maintenance to address these issues.

(h) Select Auto Mode.

(i) Verify no FADEC system indications are present.

1 For glass cockpit aircraft, the indicated faults should change from yellow text to white text indicating inactive (historical) faults.

2 The historical faults should clear during the engine start.

(j) Proceed with engine start.

(2) Procedure using Maintenance Terminal:

(a) With throttle in cut-off, apply power to aircraft/ECU.

(b) Connect Maintenance Terminal.

(c) Navigate to ECU summary page in Maintenance Terminal.

(d) Verify that the following faults are present under current faults:

1 OSTst4Flt

2 OSTst7Flt

3 OSFlt

(e) If step (d) identifies other faults than those listed, perform maintenance to address these issues.

(f) Roll the throttle to idle.

(g) Select Manual.

(h) Select Auto.

(i) Verify no current faults are indicated.

(j) Disconnect Maintenance Terminal.

(k) Proceed with engine start.

C. Perform the overspeed shutdown test:

The overspeed shutdown test is inoperative with the current software and adapter installed. In order to verify that the system is operational, two overspeed shutdown tests in a row must be performed every 50 hours, one for each channel. After first test, system will switch to test the second channel:

(1) Remove the adapter from the system.

(2) Reconnect the harness to the bulkhead connector without the adapter.

(3) Power up the aircraft/ECU.

(4) Verify no faults are present.

(5) Start the engine.

(6) Stabilize at ground idle.

(7) Initiate the overspeed shutdown test.

(8) Verify that the engine passes the overspeed test by successfully shutting down.

(9) Repeat steps 5 through 8.

(10) Verify that no faults are present.

(11) Re-install the adapter.

D. Record compliance with this bulletin in engine log.

(1) Compliance with the 50 hour recurring checks can be recorded on a separate page from the engine log book and kept with the engine records (Ref. FIG. 1).

Report the confirmation of compliance back to Rolls-Royce and Triumph by completing and emailing the following information to:

helicoptercustsupp@rolls-royce.com, llmcknight@triumphgroup.com, rwanderson@triumphgroup.com

Operator:

Contact Name:

Address:

e-mail:

Phone:

Fax:

Aircraft Type:

Aircraft Serial Number:

Engine Serial Number:

ECU Part Number:

ECU Serial Number:

ECU Time Since New:

Date of Compliance:

3. MATERIAL INFORMATION

A. Configuration Chart

NEW P/N	QTY/ ENG	NAME	INSTRUCTIONS/ DISPOSITION
M250-10684	1	Adapter, Main Engine Harness	1

INSTRUCTIONS/DISPOSITION NOTES

1. New item.

CUSTOMER SUPPORT
ROLLS-ROYCE

Engine serial number :_____

Airframe serial number:_____

Date	Time	Cycles	Signature and Certificate Number	Date	Time	Cycles	Signature and Certificate Number

Recurring Compliance Record Sheet
FIG. 1