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European Aviation Safety Agency

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Research Project:

HELMGOP II

**Helicopter Main Gearbox Loss of Oil
Performance Optimisation**

Appendix C



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APPENDIX C – OPERATING PROCEDURES FOR MGB TEST PHASES / SETS

Phase 1 – Partial Commissioning Tests

Partial Commissioning Test #1 (No Load, Normal Lubrication)

Objective:	To ensure functionality of the electric drive system, speed increasing gearbox, oil lubrication and cooling systems and MGB instrumentation system under normal lubrication.			
Procedure:	Description	Test Variables	Limits (if any)	Comments
	a) Ensure all instruments and data acquisition system are in working order	Data Acquisition	Instrument error or no data captured	All data readings to be captured
	b) Start the oil lubrication system pumps (speed increasing gearbox and MGB)	Pressure and Temp readings	< 2.8 bars (speed gearbox oil pressure) < 1.0 bars (MGB oil pressure)	Observe for leaks and correct readings
	c) Start the motor drive unit at an initial speed of 100 rpm and run up to 3000 rpm progressively	Speed	100 < RPM < 3000	Observe for abnormal noise / vibration
	d) Obtain thermal map of MGB with normal oil lubrication	Temperature and Duration	Temp < 150°C Duration < 30 mins	
	e) Safely power down the motor drive unit and shut down oil lubrication system pumps	Speed	RPM = 0	Observe for abnormal noise and vibration during run down
	f) Cool down the MGB reference temperature before commencement of test #2	Temperature	Temp < 40°C	

Partial Commissioning Test #2 (No Load, “Oil-Off Condition”)

Objective:	To ensure functionality of the electric drive system, speed increasing gearbox and MGB instrumentation system under “oil-off” condition.			
Procedure:	Description	Test Variables	Limits (if any)	Comments
	a) Ensure all instruments and data acquisition system are in working order	Data Acquisition	Instrument error or no data captured	All data readings to be captured
	b) Start the oil lubrication system pumps (speed increasing gearbox only)	Pressure and Temp readings	< 2.8 bars (speed gearbox oil pressure) < 1.0 bars (MGB oil pressure)	Observe for leaks and correct readings
	c) Start the motor drive unit at an initial speed of 100 rpm and run up to 3000 rpm progressively	Speed	100 < RPM < 3000	Observe for abnormal noise / vibration
	d) Stop the feed pump supplying the oil lubrication to MGB, followed by the suction pump for MGB lubrication oil after 20 seconds	Maintain operation for oil lubrication system for speed increasing speed gearbox.		
	e) Blow out oil lubricant in MGB lubrication channels with compressed air			Purging of oil lubricant in the oil galleries
	f) Obtain thermal map of MGB without lubrication	Temperature and Duration	Temp < 150°C Duration < 30 mins	
	g) Safely power down the motor drive unit and shut down oil lubrication system.	Speed	RPM = 0	Observe for abnormal noise and vibration during run down
	h) Cool down the MGB reference temperature before commencement of test #3	Temperature	Temp < 40°C	

Partial Commissioning Test #3 (No Load, Thioether Mist Lubrication)

Objective:	To ensure functionality of the electric drive system, speed increasing gearbox, MGB instrumentation system and thioether misting system under thioether mist lubrication.			
Procedure:	Description	Test Variables	Limits (if any)	Comments
	a) Ensure all instruments and data acquisition system are in working order	Data Acquisition	Instrument error or no data captured	All data readings to be captured
	b) Start the oil lubrication system pumps (speed increasing gearbox only)	Pressure and Temp readings	< 2.8 bars (speed gearbox oil pressure) < 1.0 bars (MGB oil pressure)	Observe for leaks and correct readings
	c) Start the motor drive unit at an initial speed of 100 rpm and run up to 3000 rpm progressively	Speed	100 < RPM < 3000	Observe for abnormal noise / vibration
	d) Commence supply of thioether mist lubrication and ensure proper functioning.	Thioether Flowrate & Pressure and Air Delivery Pressure	165 mL/hr & 10.0 bars (thioether delivery) 7.0 bars (air delivery)	Observe for proper misting, leaks at access ports and correct readings
	e) Obtain thermal map of MGB with thioether mist lubrication.	Temperature and Duration	Temp < 150°C Duration < 30 mins	
	f) Safely power down the motor drive unit and shut down oil lubrication system pumps	Speed	RPM = 0	
	g) Stop the thioether mist lubrication system.			
	h) Blow out thioether lubricant in MGB lubrication channels with compressed air.			Purging of thioether in the oil galleries
	i) Start the oil lubrication system pumps for the MGB.			Flushing of thioether within the MGB
	j) Drain and service the MGB oil lubrication tank with new NATO O-155 lubricating oil.			Drain and Service MGB oil lubrication tank

Phase 2 – Full Commissioning Tests

Full Commissioning Test (500 to 3000 RPM, 25 to 293 kW, Normal Lubrication)				
Objective:	To ensure complete functionality of the MGB test rig including the loading system under normal lubrication at 500 RPM, 25 kW			
Procedure: Set 1	Description	Test Variables	Limits (if any)	Comments
	a) Ensure all instruments and data acquisition system are in working order	Data Acquisition	Instrument error or no data captured	All data readings to be captured
	b) Start the oil lubrication system pumps (speed increasing gearbox and MGB)	Pressure and Temp readings	< 2.8 bars (speed gearbox oil pressure) < 1.0 bars (MGB oil pressure)	Observe for leaks and correct readings
	c) Start the motor drive unit at an initial speed of 100 rpm and run up to 500 rpm progressively	Speed	100 < RPM < 500	Observe for abnormal noise / vibration
	d) Introduce 25 kW loading at motor drive speed of 500 rpm to MGB by adjusting air pressure	Air Pressure Motor Current	Approx. 0.57 (bars) 107 (Amperes)	Observe for leaks in water cooling pipes and correct readings
e) Obtain thermal map of MGB with normal oil lubrication	Temperature and Duration	Temp < 150°C Duration < 10 mins	Normal Lubrication	
Objective:	To ensure complete functionality of the MGB test rig including the loading system under normal lubrication at 1000 RPM, 50 kW			
Procedure: Set 2	Description	Test Variables	Limits (if any)	Comments
	a) Ensure all instruments and data acquisition system are in working order	Data Acquisition	Instrument error or no data captured	All data readings to be captured
	b) Increase the motor drive unit to 1000 rpm progressively	Speed	500 < RPM < 1000	Observe for abnormal noise / vibration
	c) Introduce 50 kW loading at motor drive speed of 1000 rpm to MGB by adjusting air pressure	Air Pressure Motor Current	Approx. 0.63 (bars) 117 (Amperes)	Observe for leaks in water cooling pipes and correct readings
d) Obtain thermal map of MGB with normal oil lubrication	Temperature and Duration	Temp < 150°C Duration < 10 mins	Normal Lubrication	
Objective:	To ensure complete functionality of the MGB test rig including the loading system under normal lubrication at 1000 RPM, 100 kW			
Procedure: Set 3	Description	Test Variables	Limits (if any)	Comments
	a) Ensure all instruments and data acquisition system are in working order	Data Acquisition	Instrument error or no data captured	All data readings to be captured
	b) Increase the motor drive unit to 1000 rpm progressively	Speed	500 < RPM < 1000	Observe for abnormal noise / vibration
	c) Introduce 100 kW loading at motor drive speed of 1000 rpm to MGB by adjusting air pressure	Air Pressure Motor Current	Approx. 1.38 (bars) 234 (Amperes)	Observe for leaks in water cooling pipes and correct readings
d) Obtain thermal map of MGB with normal oil lubrication	Temperature and Duration	Temp < 150°C Duration < 10 mins	Normal Lubrication	

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Objective:	To ensure complete functionality of the MGB test rig including the loading system under normal lubrication at 1500 RPM, 150 kW			
Procedure: Set 4	Description	Test Variables	Limits (if any)	Comments
	a) Ensure all instruments and data acquisition system are in working order	Data Acquisition	Instrument error or no data captured	All data readings to be captured
	b) Increase the motor drive unit to 1500 rpm progressively	Speed	1000 < RPM < 1500	Observe for abnormal noise / vibration
	c) Introduce 150 kW loading at motor drive speed of 1500 rpm to MGB by adjusting air pressure	Air Pressure Motor Current	Approx. 1.38 (bars) 241 (Amperes)	Observe for leaks in water cooling pipes and correct readings
	d) Obtain thermal map of MGB with normal oil lubrication	Temperature and Duration	Temp < 150°C Duration < 10 mins	Normal Lubrication
Objective:	To ensure complete functionality of the MGB test rig including the loading system under normal lubrication at 2000 RPM, 200 kW			
Procedure: Set 5	Description	Test Variables	Limits (if any)	Comments
	a) Ensure all instruments and data acquisition system are in working order	Data Acquisition	Instrument error or no data captured	All data readings to be captured
	b) Increase the motor drive unit to 2000 rpm progressively	Speed	1000 < RPM < 2000	Observe for abnormal noise / vibration
	c) Introduce 200 kW loading at motor drive speed of 2000 rpm to MGB by adjusting air pressure	Air Pressure Motor Current	Approx. 1.42 (bars) 245 (Amperes)	Observe for leaks in water cooling pipes and correct readings
	d) Obtain thermal map of MGB with normal oil lubrication	Temperature and Duration	Temp < 150°C Duration < 10 mins	Normal Lubrication
Objective:	To ensure complete functionality of the MGB test rig including the loading system under normal lubrication at 3000 RPM, 293 kW			
Procedure: Set 6	Description	Test Variables	Limits (if any)	Comments
	a) Ensure all instruments and data acquisition system are in working order	Data Acquisition	Instrument error or no data captured	All data readings to be captured
	b) Increase the motor drive unit to 3000 rpm progressively	Speed	2000 < RPM < 3000	Observe for abnormal noise / vibration
	c) Introduce 293 kW loading at motor drive speed of 3000 rpm to MGB by adjusting air pressure	Air Pressure Motor Current	Approx. 1.38 (bars) 267 (Amperes)	Observe for leaks in water cooling pipes and correct readings
	d) Obtain thermal map of MGB with normal oil lubrication until thermal equilibrium	Temperature and Duration	Temp < 150°C Duration < 120 mins*	Thermal equilibrium = <2°C/5mins
	e) Obtain vibration signature of MGB test rig	Vibration	Vibration < 5.0 mms ⁻¹	Axial and vertical readings
	f) Safely power down the motor drive unit and shut down oil lubrication systems.	Speed	RPM = 0	Observe for abnormal noise and vibration during run down
	g) Cool down MGB to reference temperature before full load test #1	Temperature	Temp < 40°C	

* Note: Duration taken to reach thermal equilibrium may exceed beyond 120 mins

Phase 3 – Full Load Tests

Full Load Test #1 (3000 RPM, 293 kW, “Oil-Off” Condition)				
Objective:	To conduct full load test on MGB under “oil-off” condition.			
Procedure:	Description	Test Variables	Limits (if any)	Comments
	a) Ensure all instruments and data acquisition system are in working order	Data Acquisition	Instrument error or no data captured	All data readings to be captured
	b) Start the oil lubrication system pumps (speed increasing gearbox and MGB)	Pressure and Temp readings	< 2.8 bars (speed gearbox oil pressure) < 1.0 bars (MGB oil pressure)	Observe for leaks and correct readings
	c) Start the motor drive unit at an initial speed of 100 rpm and run up to 3000 rpm progressively	Speed	100 < RPM < 3000	Observe for abnormal noise / vibration
	d) Introduce 293 kW loading at motor drive speed of 3000 rpm to MGB by adjusting air pressure	Air Pressure Motor Current	Approx. 1.38 (bars) 267 (Amperes)	Observe for leaks in water cooling pipes and correct readings
	e) Obtain thermal map of MGB with normal lubrication until thermal equilibrium	Temperature and Duration	Temp < 150°C Duration < 120 mins*	Thermal equilibrium = <2°C/5mins
	f) Remove loading to MGB by dynamometer	Air Pressure	0 (bars)	Safety procedure
	g) Stop the feed pump supplying the oil lubrication to MGB, followed by the suction pump for MGB lubrication oil after 20 seconds	Maintain operation for oil lubrication system for speed increasing speed gearbox.		
	h) Lower speed of motor drive unit to 1000 rpm	Speed	100 < RPM < 1000	Safety Procedure
	i) Blow out oil lubricant in MGB lubrication channels with compressed air			Purging of oil lubricant in the oil galleries
	j) Increase speed of motor drive unit to 3000 rpm	Speed	100 < RPM < 3000	Observe for abnormal noise / vibration
	k) Re-introduce 293 kW loading at motor drive speed of 3000 rpm to MGB by adjusting air pressure	Air Pressure Motor Current	Approx. 1.38 (bars) 267 (Amperes)	Observe for leaks in water cooling pipes and correct readings
	l) Obtain thermal map of MGB without lubrication for 10 mins	Temperature and Duration	Temp < 200°C Duration < 10 mins	200°C to preserve integrity of MGB
	m) Obtain vibration signature of MGB test rig	Vibration	Vibration < 5.0 mms ⁻¹	Axial and vertical readings
	n) Safely power down the motor drive unit and shut down oil lubrication systems.	Speed	RPM = 0	Observe for abnormal noise and vibration during run down
	o) Cool down MGB to reference temperature before full load test #2	Temperature	Temp < 40°C	
	p) Perform borescope inspection of MGB internal gears and bearings	Physical Condition	Thermal damage of surface wear defects	Observe for signs of thermal damage or surface wear defects

* Note: Duration taken to reach thermal equilibrium may exceed beyond 120 mins

Full Load Test #2 (3000 RPM, 293 kW, Thioether Mist Lubrication)

Objective:	To conduct full load test on MGB under thioether mist lubrication.			
Procedure:	Description	Test Variables	Limits (if any)	Comments
	a) Ensure all instruments and data acquisition system are in working order	Data Acquisition	Instrument error or no data captured	All data readings to be captured
	b) Start the oil lubrication system pumps (speed increasing gearbox and MGB)	Pressure and Temp readings	< 2.8 bars (speed gearbox oil pressure) < 1.0 bars (MGB oil pressure)	Observe for leaks and correct readings
	c) Start the motor drive unit at an initial speed of 100 rpm and run up to 3000 rpm progressively	Speed	100 < RPM < 3000	Observe for abnormal noise / vibration
	d) Introduce 293 kW loading at motor drive speed of 3000 rpm to MGB by adjusting air pressure	Air Pressure Motor Current	Approx. 1.38 (bars) 267 (Amperes)	Observe for leaks in water cooling pipes and correct readings
	e) Obtain thermal map of MGB with normal lubrication until thermal equilibrium	Temperature and Duration	Temp < 150°C Duration < 120 mins*	Thermal equilibrium = <2°C/5mins
	f) Remove loading to MGB by dynamometer	Air Pressure	0 (bars)	Safety procedure
	g) Stop the feed pump supplying the oil lubrication to MGB, followed by the suction pump for MGB lubrication oil after 20 seconds	Maintain operation for oil lubrication system for speed increasing speed gearbox.		
	h) Lower speed of motor drive unit to 1000 rpm	Speed	100 < RPM < 1000	Safety Procedure
	i) Blow out oil lubricant in MGB lubrication channels with compressed air			Purging of oil lubricant in the oil galleries
	j) Commence supply of thioether mist lubrication and ensure proper functioning.	Thioether Flowrate & Pressure and Air Delivery Pressure	165 mL/hr & 10.0 bars (thioether delivery) 7.0 bars (air delivery)	Observe for proper misting, leaks at access ports and correct readings
	k) Increase speed of motor drive unit to 3000 rpm	Speed	100 < RPM < 3000	Observe for abnormal noise / vibration
	l) Re-introduce 293 kW loading at motor drive speed of 3000 rpm to MGB by adjusting air pressure	Air Pressure Motor Current	Approx. 1.38 (bars) 267 (Amperes)	Observe for leaks in water cooling pipes and correct readings
	m) Obtain thermal map of MGB with thioether mist lubrication for 30 mins	Temperature and Duration	Temp < 200°C Duration < 30 mins	200°C to preserve integrity of MGB
	n) Obtain vibration signature of MGB test rig	Vibration	Vibration < 5.0 mms ⁻¹	Axial and vertical readings
	o) Safely power down the motor drive unit and shut down oil lubrication systems.	Speed	RPM = 0	Observe for abnormal noise and vibration during run down
	p) Stop the thioether mist lubrication system.			

	q) Cool down MGB to reference temperature before full load test #2	Temperature	Temp < 40°C	
	r) Perform borescope inspection of MGB internal gears and bearings	Physical Condition	Thermal damage of surface wear defects	Observe for signs of thermal damage or surface wear defects
	s) Blow out thioether lubricant in MGB lubrication channels with compressed air.			Purging of thioether in the oil galleries
	t) Start the oil lubrication system pumps for the MGB.			Flushing of thioether within the MGB
	u) Drain and service the MGB oil lubrication tank with new NATO O-155 lubricating oil.			Drain and Service MGB oil lubrication tank

* Note: Duration taken to reach thermal equilibrium may exceed beyond 120 mins

CAUTION:

During Phase 3 full load tests, emergency cooling of the MGB using the lubrication oil shall only be carried out when the highest recorded temperature is less than 222°C. This is due to the flash point of the NATO O-155 lubricant.

Safety Measures

To ensure the safety of personnel and safeguard the integrity of the MGB and test rig systems during the test phases, the following measures were adopted.

1. Non-essential personnel are restricted from entering the test facility during the conduct of the experiments.
2. A safety action plan is set up in the test facility control room to reference against during an emergency.
3. An industrial spillage kit is on site to tackle oil leaks and spills.
4. Personnel operating new the MGB test rig during the experiments are to don Personnel Protective Equipment (PPE) such as safety goggles, ear defenders and hard hats.
5. Critical operating parameters are monitored live in the control room.
6. Test abort will be made whenever any of the systems' parameters are deviating from their operational values.
7. Abort controls for the electric drive system, the lubrication and cooling system pumps as well as the air pressure system for the dynamometer are housed in the control room.
8. Speed control of the electric drive system will be via the control room.
9. High current measurement will be carried using wireless modules for live monitoring and recording in the control room.
10. The test plan for each experiment will be briefed to all personnel involved for common understanding and awareness.
11. The fire department will be informed whenever MGB test rig is being operated.
12. In the event the magnesium alloy of the MGB casing catches fire, all personnel will evacuate the test facility and assemble at an open area away from the facility.

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