OPERATING INSTRUCTIONS

for the

PW4000 SERIES COMMERCIAL TURBOFAN ENGINES IN THE A300-600 AND A310 AIRPLANES

FLIGHT OPERATIONS SUPPORT

November 15, 1993

Revision 8 – June 30, 2008

Printed in United States of America

FOREWORD

These Operating Instructions contain Pratt & Whitney’s instructions, recommendations and suggestions for the operation of the PW4000 series engine installed in the Airbus A300-600 and A310 airplanes. Also included in the Operating Instructions, is a brief description of the engine systems necessary for the operation of the PW4000 series engine. Failure to operate the PW4000 series engine in accordance with these operating instructions may void Pratt & Whitney’s service policy coverage.

These Operating Instructions are intended to support the airframe manufacturer in developing the operations manual for the applicable airframe. These Instructions shall not be considered in any way as replacing or superceding the information in the applicable airplane operations manual.

Federal Aviation Administration (FAA) approved operating limits contained in the Type Certificate Data Sheet (TCDS) are included herein. In addition, the Operating Instructions contain certain operating information not requiring FAA approval. Accordingly, this document is not subject to FAA approval.

REVISIONS

These Operating Instructions are subject to revision as new information becomes available to Pratt & Whitney. To receive such revisions, you must be on Pratt & Whitney’s distribution list. Pratt & Whitney will issue the revised Operating Instructions on CD-ROM only. Paper copies will no longer be provided. All revisions will be numbered in sequence. A line will be placed in the left margin next to the revised material on all revised pages.

These Operating Instructions are also available on the Pratt & Whitney Online Services website (http://portal.pw.utc.com). Once you request access to the online version, you will receive e-mail notification of revisions.

All questions related to these instructions should be directed to:

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RECORD OF REVISIONS

Rev. No.	Date	Page	Purpose of this Revision
1	Aug.1/92	Sec.3, p3	Revises ENGINE WINDMILLING requirements and clarifies relight criteria after surge or if engine limits were exceeded.
		Sec.3, p6	Revises REVERSER INFLIGHT MALFUNCTION procedure to require pulling throttle lever to idle if the REV UNLK warning appears. Added MODERATE TO HEAVY RAIN AND HAIL procedure.
		Sec.3, p7	Added OPERATION IN VOLCANIC ASH procedure.
2	Nov.15/93	All	Reissue of entire document with improved format. Major revisions are:
		Sec.1, p3	Explained "non-rated" FADEC mode.
		Sec.1, p6	Corrected typo error- oil filter bypasses at 70 psi, not 90.
		Sec.2, p5	Revised takeoff with autothrottles to be consistent with Airbus FCOM. Also removed statement to "Ascertain that engine operating limits are not exceeded during takeoff" to be consistent with the statement not to adjust thrust after 80 kts during takeoff if EGT limit is exceeded until a safe altitude/airspeed is reached.
		Sec.2, p7	Permits cooldown time between 90 sec and 3 minutes at airline's discretion based on its experience with coking in main engine bearings.
		Sec.2, p8	Changed CAUTION to a NOTE stating that periodic runup in heavy icing "may be performed at the pilots' discretion", and left the CAUTION to recommend a static runup before takeoff.
		Sec.2, p9	Clarified that bleed corrections are automatically applied by the FADEC only in the Normal mode.
		Sec.3, p1	Added sentence requiring an inflight shutdown if all other action cannot restore an engine parameter within limit.

RECORD OF REVISIONS (Cont'd)

Rev. No.	Date	Page	Purpose of this Revision
2 (Cont'd)	Nov.15/93	Sec.3, p2	Moved contents of paragraph "Repetitive Surges Inflight" into "Inflight Non-Recoverable Surges". Replaced "if EGT is within 20°C of the EGT limit" with "if EGT is increasing but not approaching the red-line".
		Sec.3, p3&4	Emphasized that inflight relights may be attempted even if outside the relight envelope. Changed warmup to 2 min. (5 min. if shutdown more than 10 min). Permits start attempt in an emergency if windmilling N2 is less than 15%.
		Sec.3, p4& Appx. (ECAM msg)	Changed ENG OIL TEMP HI procedure to now recommend throttle be pulled back towards idle.
		Sec.3, p5	Clarified dispatch recommendation for oil quantity.
		Sec.3, p6	Clarified benefits of operation above idle during heavy rain/hail.
		Sec.3, p7	Added Ground Operation recommendations to "Operation in Volcanic Ash".
		Sec.3, p8	Added "Emergency Thrust Setting".
3	Jan.31/97	Sec.1, p1	Includes extension of Takeoff engine rating time limit from five minutes to ten minutes.
		Sec.1, p6	Adds paragraph describing an optional SB incorporating a dual element oil filter.
		Sec.2, p2	Expands on NOTE defining normal starting and idle fuel flow indications.
		Sec.2, p3	Add CAUTION describing abnormal indications during start.
		Sec.2, p8	Changes content of GROUND OPERATIONS DURING ICING CONDITIONS.
		Sec.2, p9	Adds TAKEOFF IN ICING CONDITIONS. Deletes USE OF AIRBORNE VIBRATION MONITORING (AVM) SYSTEM.
		Sec.2, p9&10	Adds ENGINE VIBRATION.
		Sec.2, p11	Adds COLD WEATHER OPERATION.
		Sec.3, p1	Adds paragraph to ENGINE TAILPIPE FIRE ON THE GROUND describing Starter reengagement without N2 indication.

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Rev. No.	Date	Page	Purpose of this Revision
3 (Cont'd)	Jan.31/97	Sec.3, p5	Adds a note and a step to OIL FILTER CLOGGING describing action required following illumination of ECAM message.
		Sec.4, p1	Changes Engine Operating Limits Takeoff time to ten minutes; reflects changes in temperature limits for Takeoff and Maximum Continuous Adds Minimum for Start Oil Temperature.
		Sec.4, p2	Changed Note 1 to clarify extension from 5 to 10 minute time at takeoff. Changes Engine Operating Limits Note 2 to reflect new temperature limits for Takeoff and Maximum Continuous.
		App., p1	Changed Recommended Action for ENG OIL FILTER CLOG LIGHT.
4	Mar.15/99	Sec.1, p3–10	Added Full-Authority Digital Electronic Control (FADEC) and repaginated. Added note on no 30 second motoring requirement for air re-start. Modified operation in volcanic ash to land at nearest suitable airfield. Clarified note 2 for FADEC display of EGT limits and note 6 for ground re-starts.
5	Feb.28/03	Foreword	Revised Foreword.
		Rec. of Rev., p1	Removed contact information, included in Foreword.
		Sec.1, p1	Revised Max Continuous definition.
		Sec.1, p3	Corrected "airframer installed" flowmeter.
		Sec.1, p5	Added description of Min and Approach Idle.
		Sec.1, p6	Added description of FMU operation.
		Sec.1, p7	Added dual element oil filter option.
		Sec.1, p8	Added paragraph on oil quantity indication and oil gulp. Rearranged Oil System paragraphs for clarity and consistency.
		Sec.2, p3	Added note to prevent rotor bow.
		Sec 2, p4	Added dual element oil filter option Revised Ground Run Up Warning.

RECORD OF REVISIONS (Cont'd)

Rev. No.	Date	Page	Purpose of this Revision
5 (Cont'd)	Feb.28/03	Sec 2, p7	Revised Shutdown section to increase cooldown recommendation to 5 minutes.
		Sec 2, p8	Added volcanic ash to flight conditions requiring continuous ignition.
		Sec 2, p9	Added use of inlet cowl anti-ice Changed glycol solution to airframer approved deicing solution.
		Sec 3, p2	Revised Engine Surge for clarity and consistency.
		Sec 3, p3	Increased cooldown recommendation to 5 minutes.
		Sec 3, p4	Removed note about not requiring 30 seconds of motoring in flight.
		Sec 3, p5	Added SB reference information for dual element oil filter.
		Sec 3, p8	Added Operation in Sand and Dust section.
		Sec 3, p9	Updated Volcanic Ash recommendation.
		Sec 3, p10	Revised to land at nearest suitable airport.
		Sec 4, p1	Added reference to Note 2 to PW4152 Inflight Start Limit.
		Sec 4, p2	Deleted regulatory approval from Note 1 Added Inflight start EGT limits to Note 2 Revised Note 3 for clarity and consistency.
		App., p2	Clarified Throttle Fault ECAM definition and recommended action.
6	Nov.1/03	Sec.1, p2	Added description of RCC modifications.
		Sec.2, p5	Added effects of RCC modification to Takeoff, Item 4, Notes d and e.
		Sec.4, p1	Updated Starter Duty Limits.
7	Feb.15/06	Foreword	Updated revision, distribution and contact information. Added web access information.
		Sec.2, p3	Updated starter re-engagement speed to 30 % N2 Max. Added information on normal oil quantity reduction during start.

RECORD OF REVISIONS (Cont'd)

Rev. No.	Date	Page	Purpose of this Revision
7 (Cont'd)	Feb.15/06	Sec.2, p5	Under 4. Throttle Levers -- Set Added range to intermediate EPR and N1 for Ring Case configuration. Eliminated redundant notes. Added techniques for any tailwind, and crosswinds above 20 kts.
		Sec.2,p10	Added details of effects of de-icing fluid.
		Sec.3, p1	Updated starter re-engagement speed to 30 % N2 Max.
		Sec.3, p4	Added paragraph on emergency thrust loss and recovery with fuel off followed immediately by fuel on.
		Sec.3, p5	Changed low oil pressure procedure to have indication reading take precedence. Clarified single oil filter clog procedure to require shutdown.
		Sec.4, p1	Corrected Takeoff time limit to 5 minutes. Updated starter re-engagement speed to 30 % N2 Max.
8	Jun.30/08	Foreword, p1	Added e-mail contact for questions related to the OI.
		Glossary, p1	Added ECS (Environmental Control System). Added FADEC (Full Authority Digital Electronic Control). Added MMS (Maximum Motoring Speed). Added OAT (Outside Air Temperature). Added RCC (Ring Case Configuration).
		Glossary, p2	Added SB (Service Bulletin). Added SCC (Segmented Case Configuration). Added TCDS (Type Certificate Data Sheet).
		Sec.1, p5	Expanded detail on Minimum Idle and Approach Idle function.
		Sec.1, p8	Added dual oil filter SB number.
		Sec.1, p10	Changed layout for clarification between LPC/HPC bleeds and updated HPC information to include functionality for RCC HPC.
		Sec.2, p2	Revised Step 4 under "Start" to include expanded definition of MMS. Corrected PPH to KPH conversions.
		Sec.2, p3	Corrected PPH to KPH conversion and updated recommendation for elevated starting fuel flow to carefully monitor start.

RECORD OF REVISIONS (Cont'd)

Rev. No.	Date	Page	Purpose of this Revision
8 (Cont'd)	Jun.30/08	Sec.2, p4	Changed warm-up time wording in Engine Warm-up section for clarification. Updated wording for taxi time less than 5 minutes for consistency with other PW4000 OI's. Updated dual element oil filter SB number.
		Sec.2, p10	Updated wording in Cold Weather Operations section regarding "Type II" oils, for consistency with other PW4000 OI's. Updated interval between run-ups to 30 minutes in Ground Operations During Icing Conditions section. Updated time to first run-up during taxi-out to 30 minutes.
		Sec.2, p11	Updated engine operation during de-icing. Deleted duplicate sentence.
		Sec.3, p1	Changed 20% N2 to 30% N2 to reflect correct maximum starter re-engagement speed.
		Sec.3, p5	Designated procedures pertaining to oil filter design in Oil Filter Clogging section for clarification. Updated dual element oil filter SB number. Added paragraph explaining advisory message/light with oil temperature below 35°C during ground operations.
		Sec.4, p1	Added CAUTION under "Starter."

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GLOSSARY

AC	Alternating Current
ADC	Air Data Computer
APU	Auxiliary Power Unit
ARCCS	Automatic Rotor Clearance Control System
AVM	Airborne Vibration Monitoring
°C	Degrees Celsius
CONT	Continuous
ECAM	Electronic Centralized Aircraft Monitor
ECS	Environmental Control System
EGT	Exhaust Gas Temperature
ENG	Engine
EPR	Engine Pressure Ratio (P4.95/P2)
°F	Degrees Fahrenheit
FAA	Federal Aviation Administration
FADEC	Full Authority Digital Electronic Control
FAR	Federal Aviation Regulations
FLX	Flexible
FM	Flight Manual
FMU	Fuel Metering Unit
FT	Feet
g	Gravity
HP	High Pressure
HPC	High Pressure Compressor
HPT	High Pressure Turbine
IAS	Indicated Airspeed
ID	Inner Diameter
IDGS	Integrated Drive Generator System
km/h	Kilometers Per Hour
KPH	Kilograms Per Hour
LO	Low
LPC	Low Pressure Compressor
LPT	Low Pressure Turbine
M	Meters
MMS	Maximum Motoring Speed
MPH	Miles Per Hour
N1	Low Rotor Speed
N2	High Rotor Speed
OAT	Outside Air Temperature
OD	Outer Diameter
Pamb	Ambient Pressure
PMA	Permanent Magnet Alternator
PPH	Pounds Per Hour
PRESS	Pressure
PSI	Pounds Per Square Inch
PSIG	Pounds Per Square Inch Gauge
P&W	Pratt & Whitney
P2	Engine Inlet Total Pressure
P4.95	Low Turbine Exit Total Pressure
RCC	Ring Case Configuration
REV	Reverse
RPM	Revolutions Per Minute

GLOSSARY (Cont'd)

SB	Service Bulletin
SCC	Segmented Case Configuration
TCDS	Type Certificate Data Sheet
TO	Takeoff
T2	Engine Inlet Total Temperature
T4.95	Low Turbine Exit Total Temperature
UNLK	Unlock
WLDP	Warning Light Display Panel

SECTION 1

DEFINITIONS, DESCRIPTIONS, AND SPECIFICATIONS

WARNINGS, CAUTIONS AND NOTES

The following definitions apply to WARNINGS, CAUTIONS, and NOTES found throughout these instructions.

WARNING: OPERATING PROCEDURES, TECHNIQUES, ETC. WHICH, IF NOT CAREFULLY FOLLOWED, MAY RESULT IN PERSONAL INJURY OR LOSS OF LIFE.

CAUTION: Operating procedures, techniques, etc. which, if not carefully followed, may result in damage to the engine or equipment.

NOTE: An operating procedure, technique, etc. which is considered "essential to emphasize."

ENGINE RATINGS

All PW4000 Ratings are obtained by adjusting the throttle lever to a fixed position when governed by the engine pressure ratio (EPR) mode, or to a specific thrust setting chart N1 value when governed by the alternate N1 Mode.

Takeoff - This is the maximum thrust certified for takeoff and is time limited to five minutes with all engines operating and ten minutes with one engine inoperative.

Maximum Continuous - The Maximum Continuous rating is the maximum thrust certified for continuous use. To prolong engine life, this rating should not be used under normal operating conditions to increase aircraft speed or rate of climb. This rating should be used at the pilot's discretion and is intended for use in an engine out situation and will allow the airplane to continue operating, but at a lower altitude and fly to an alternate airfield, if necessary.

Maximum Climb - The Maximum Climb rating is the maximum thrust approved for normal climb operation.

Maximum Cruise - The Maximum Cruise rating is the maximum thrust approved for normal cruise operation.

Idle - Idle is not an engine rating. Idle thrust is obtained by positioning the airplane throttle lever against the idle stop.

Maximum Reverse - This is not an engine rating. It is a reverse throttle lever position used to obtain maximum reverse thrust during the landing roll, limited by the Full Authority Digital Electronic Control (FADEC).

SPECIFICATIONS

Fuel: Pratt & Whitney Service Bulletin (SB) No. 2016
Oil: Pratt & Whitney SB No. 238

DESCRIPTIONS

BASIC ENGINE

The PW4000 is a third generation high bypass ratio commercial turbofan engine. PW4000 engines have two spools with separate primary and fan duct exhaust systems. The engine has a compression ratio of approximately 30 to 1 and a fan-air to primary-air bypass ratio of approximately 5 to 1.

The low rotor (N1) consists of a single stage fan, four stage low pressure compressor (LPC) and a four stage low pressure turbine (LPT) on a common shaft.

The high rotor (N2) consists of eleven compressor stages driven by a two stage turbine. The first four stages of the high pressure compressor (HPC) incorporate variable stators which are positioned automatically by the FADEC.

RING CASE CONFIGURATION (RCC) HIGH PRESSURE COMPRESSOR (HPC) MODIFICATION

The RCC HPC modification has been made available as a corrective action to prevent high power takeoff surge events. This hardware change improves the consistency of tip clearance in the rear stages of the HPC. There are EEC software compatibility and engine intermix restrictions associated with this configuration. These differences can be identified in the applicable Aircraft Maintenance manuals or the Airframe Flight Manuals.

The RCC HPC has acceleration performance differences when compared to the prior Segmented Case Configuration HPC. These differences are most evident from ground idle to 1.05 EPR when an RCC HPC engine and a segmented case configuration (SCC) HPC engine are intermixed. Existing takeoff thrust setting procedures for Airbus aircraft identify the requirement to set 40% N1, then accelerate to takeoff thrust. With RCC intermix P&W recommends setting 1.05 EPR, allow engines to equalize, then set takeoff thrust. This procedure will minimize most thrust asymmetry.

The diffuser case covers that portion of the engine from the last stage of the high pressure compressor to the front flange of the high pressure turbine (HPT) case. Fuel is delivered through external lines to 24 aerating fuel nozzles. Two ignitor plugs are also located in this section. The number 3 rear bearing (roller type) for the high pressure rotor is supported from the inner wall of the diffuser case.

The accessory gearbox is located beneath the front of the high compressor case of the engine and provides mount pads for accessories required for airframe use. Special attention has been given to accessibility of external components and to provisions for maintenance inspections.

PRIMARY ENGINE PARAMETER INSTRUMENTATION

The primary thrust setting parameter, engine pressure ratio (EPR), is a ratio of the turbine exhaust stream pressure (P4.95) to the engine inlet total pressure (P2). EGT is the average temperature (°C) of the exhaust gas total temperature probes (T4.95). The EPR value and turbine exhaust gas temperature (EGT) are transmitted by the FADEC to the respective cockpit indicators.

The FADEC obtains the N1 speed signal from a magnetic pickup mounted in the intermediate case. A low compressor speed of 100 percent N1 is equivalent to 3,600 revolutions per minute (RPM).

The FADEC Permanent Magnet Alternator (PMA), mounted on the main gearbox, supplies power and the N2 speed signal to the FADEC A and B channels. In addition, a dedicated winding in the FADEC alternator supplies a N2 frequency signal to the airplane system. An N2 speed of 600 RPM (6 percent) or greater is required to ensure that adequate electrical power is available from the PMA to the FADEC. A high compressor speed of 100 percent N2 is equivalent to 9,900 RPM.

Fuel flow is measured by an airframer installed mass flow meter.

FULL AUTHORITY DIGITAL ELECTRONIC CONTROL (FADEC)

The PW4000 Full-Authority Digital Electronic Control (FADEC) system provides a full range of control of engine fuel flow, compressor stator vane angle, low and high pressure stability compressor bleeds, turbine case cooling, air-cooled oil cooler and fuel-cooled oil cooler. The Electronic Engine Control (EEC) is the command & control center of the FADEC system.

The FADEC system on the PW4000 engine simplifies cockpit procedures by automatically controlling the engine thrust rating and idle thrust setting. Regulation of fuel and oil temperatures by the EEC provides protection against the icing of the fuel and the temperature limiting of fuel, engine oil and IDG oil.

The FADEC system is fully redundant. It is a dual channel system designed with each channel being capable of controlling the engine. This system configuration and the redundancy management of the EEC software results in an operational reliability, in terms of inflight shutdown rate, which is equal to or better than hydromechanical systems. Therefore, a backup hydromechanical control is not required.

In addition to redline limiting, if the high or low rotor speed exceeds the overspeed limit of 117% N1 or 110.3% N2, the EEC will command a separate overspeed cutback solenoid in the fuel metering unit (FMU) to reduce engine fuel flow to a predetermined min-flow value. The engine will then operate in an idle or sub-idle condition and flameout is probable at lower altitudes.

The FADEC system also provides engine surge protection. In the event of a surge, the EEC will command open the 2.5 bleed, the 9th stage (2.95) HPC stability bleed, reset the variable stator vanes and down trim of Wf/Pb schedule to recover from the surge condition. When the surge detection signal clears, both bleeds and the variable stators are returned to their normal positions.

If the EEC senses 2 consecutive surges within a 10 second period, foreign object damage (FOD) is assumed to have occurred and the 2.5 bleed is held partially open. Assuming no other damage, this will result in normal engine parameters except for an elevated EGT (typically 30°C). The 2.5 bleed-open FOD command can only be removed by reducing the thrust lever to idle and then resetting the desired thrust level. This action will re-establish normal 2.5 bleed operation and restore EGT to normal.

THRUST MANAGEMENT

The thrust management system for the PW4000 is provided in the dual channel FADEC. The FADEC commands the Fuel Metering Unit (FMU) to set engine fuel flow as required to establish direct closed loop control of EPR, the prime thrust setting parameter.

The primary control mode is a rated mode which utilizes EPR to control the thrust automatically. The FADEC dual channel system has resource sharing capabilities between channels. This allows continued operation in the primary control mode even though one channel may lose an input requiring the use of the redundant input from the other channel. If a critical fault were to exist in one channel that did not exist in the other channel, then the primary control mode switches channels. The FADEC is designed to permit engine operation using N1 as an alternate thrust setting parameter. If the required signals are not available to operate in the primary mode (EPR), the FADEC will automatically revert to the alternate control mode (N1). The alternate control mode also has similar resource sharing capabilities. Transition from the primary control mode to the alternate control mode during takeoff will provide equivalent thrust to that achieved in the primary mode up to 2500 feet above the runway. The alternate control mode can also be manually selected by the flight crew with the cockpit mode selector switch. The airplane is dispatchable in the alternate control mode with an appropriate weight penalty.

In the primary mode, command EPR is calculated in the FADEC as a function of throttle lever angle, altitude, engine total pressure (P2), and engine total temperature (T2). Altitude, P2 and T2 are supplied to the FADEC from the Air Data Computer (ADC), as well as the engine's ambient pressure (Pamb) and P2/T2 sensors. Engine thrust is established through direct closed-loop control of EPR with the following characteristics:

- Linear EPR versus throttle lever angle under all conditions
- Consistent throttle lever sensitivity
- Controlled takeoff thrust lapse rate
- Automatic adjustment of ratings for service bleed extraction

The alternate control mode is a non-rated mode, meaning that the thrust ratings can be set manually to an N1 speed, but the FADEC will not automatically maintain that rating. Consequently, in order to maintain a given thrust rating, the thrust (N1) must be periodically reset as flight conditions change. The alternate control mode schedules N1 as a function of throttle lever position and total air temperature. Therefore, thrust as a function of throttle lever angle will vary throughout the flight envelope. Operation in this mode closely relates to the operation of a hydromechanical fuel control. This includes the conditions where EPR overboost will occur at the full forward throttle lever position. In order to eliminate throttle lever stagger, a MODE selector push button switch is provided in the cockpit for manual selection of the alternate control mode on either engine.

In either control mode, the FADEC N1 and N2 redline limiting loops in conjunction with the FMU serve to prevent the N1 and N2 rotor speeds from exceeding their respective limit values. In the unlikely event of an FMU malfunction, the FADEC will prevent overspeeding the engine high or low rotors by commanding a separate overspeed cutback solenoid in the FMU to reduce engine fuel flow to the minimum fuel flow stop. This failsafe feature is activated if either N1 or N2 exceed their respective trip points of 117.0 percent N1 or 110.3 percent N2. The engine will then operate in an idle or sub-idle condition and flameout is probable at lower altitudes.

Engine control features and airplane systems are integrated to provide operation in either the Minimum Idle or Approach Idle modes automatically, whether on the ground or in flight. Minimum Idle RPM is lower than Approach Idle RPM to minimize brake wear during ground operations and fuel consumption during descent. The higher Approach Idle RPM improves engine acceleration to go-around thrust in flight and protects the transition into reverse thrust immediately after touchdown. The engine will control to Minimum Idle unless it receives the Approach Idle discrete signal from the aircraft, in which case Approach Idle will have the authority.

IGNITION SYSTEM

The engine ignition system consists of two electrically and physically independent AC-powered 4-joule systems, each of which is comprised of a single exciter box electrically connected through a shielded high tension cable to a spark ignitor. The cockpit ignition selector allows individual system operation for ground starts and provides simultaneous system operation for air starts and continuous ignition operation.

The IGNITION selector switch is located overhead on the ENG panel and controls the selection of one or both ignition systems provided the corresponding FUEL LEVER is in the ON position.

There are five positions available on the IGNITION selector switch (OFF, CRANK, START A, START B and CONT RELIGHT). The ignition is inhibited in the OFF and CRANK positions. The CRANK position provides the pilot with the ability for dry or wet motoring. When the IGNITION selector switch is in the START A, START B or CONT RELIGHT position, the ignition system(s) are armed. When the associated FUEL LEVER is on, the ignition system(s) are activated. During engine ground starting, the ignition system (START A or START B) is automatically deactivated at 45% N2.

On the ground, as long as the IGNITION selector is in the START A, START B or CRANK position, the air conditioning pack valves are closed. In flight, the pack valves are only closed when a start valve is open.

STARTING SYSTEM

The engine starting system consists of an air turbine starter and a pneumatically operated, electrically controlled start valve. The starter uses pressurized air to crank the high pressure (N2) rotor up to a sufficient speed to ensure a satisfactory start. The start valve controls the air supply to the starter. The pneumatic power source is provided by the auxiliary power unit (APU), an external ground air cart or the other operating engine.

The ENG panel, used for starting, is located on the overhead panel and is composed of two START push button switches (one per engine).

The start procedure commences when the IGNITION selector is set to START (A or B). When the appropriate IGNITION selector position has been set, the pack valves close, the engine 1 and 2 valve ARM lights illuminate and latching of the start valves is authorized. The start valve opens when the START push button switch (START ENG 1 or START ENG 2) is depressed to OPEN. When the FUEL LEVER is positioned ON, the ignition system is energized and fuel is turned on. The starting sequence is automatically ended at 45% N2 when an electrical signal is sent to the start valve to initiate valve closure and starter disengagement.

FUEL SYSTEM

The FUEL LEVER in the cockpit has two positions: ON and OFF. The ON position is used for starting and all other modes of engine operation. The OFF position is used to shut down the engine by shutting off the fuel.

Engine control features and airplane systems are integrated to provide operation in either the Minimum Idle or Approach Idle modes automatically. Minimum Idle RPM is lower than Approach Idle RPM to minimize brake wear during ground operation and to minimize fuel consumption during descent. The higher Approach Idle RPM improves engine acceleration to go-around thrust in flight.

The FMU features an integral solenoid actuated fuel start and stop control function. Engine start or shutdown is accomplished with the use of the start and run solenoid and the shutoff solenoid to direct pressure to position the condition valve. The valve's position subsequently regulates the pressure to open or close the FMU shut-off valve. The Fuel Control Switch RUN position energizes the start and run solenoid in the FMU which opens the FMU fuel shut-off valve allowing fuel flow to the engine. The FMU shut-off solenoid is de-energized. The CUTOFF position energizes the shut-off solenoid which shuts off the fuel at the shut-off valve in the FMU and de-energizes the start and run solenoid in the FMU.

Fuel heating is automatic, requiring no action by the flight crew. The fuel/oil heat exchanger is installed between stages of the fuel pump and upstream of the fuel filter. The fuel/oil heat exchanger uses both the Integrated Drive Generator System (IDGS) oil and engine oil to heat the fuel.

The FADEC receives fuel and oil temperature data and commands airflow through the air/oil heat exchangers via electro-hydraulically actuated air valves to maintain fuel and oil temperatures within desired operating limits. The FADEC also commands an oil bypass valve on the fuel/oil heat exchanger to prevent excessive fuel temperature during low fuel flow/hot day operating conditions.

A fuel filter differential pressure switch senses the pressure drop across the fuel filter. If an excessive pressure drop across the fuel filter is caused by an accumulation of solid contaminant, an amber FUEL CLOG light illuminates and an amber ENG 1(2) FUEL FILTER CLOG ECAM message will be displayed when the differential pressure exceeds 5.5 psi. Continued engine operation with contaminated fuel will increase the filter pressure differential allowing the filter bypass valve to open at approximately 9 psi.

AUTOMATIC ROTOR CLEARANCE CONTROL SYSTEM (ARCCS)

Engine performance improvement is achieved by optimization of high and low turbine blade tip clearance through automatic discharge of cooling air onto the turbine external cases. ARCCS valves operate on FADEC command to modulate fan discharge air routed to the turbine cases through encircling manifolds.

High pressure turbine external cooling air is deactivated during takeoff and the first 1,500 feet of climb to avoid blade tip rub which is possible under this condition. Low pressure turbine cooling is active during all phases of engine operation.

OIL SYSTEM

The lubrication system is self-contained and thus requires no airframe supplied components other than certain instrumentation and remote fill and drain disconnects. It is a hot tank system that is not pressure regulated. Oil from the oil tank enters the pressure pump and the discharge flow is sent directly to the oil filter. A disposable cartridge filter with a 15 micron nominal rating and a 30 micron absolute rating is employed. An optional dual element oil filter configuration is available and described later in this section.

The engine lubrication system is equipped with an oil pressure indication, an independent red OIL LO PRESS warning light, a red ENG 1(2) OIL LO PR ECAM warning message and a quantity indicator. The oil pressure and quantity are displayed linearly on the ECAM system. In addition, the oil pressure and quantity are displayed on an analog indicator. The low oil pressure light or the quantity indicator, however, should be used to confirm a low oil pressure indication.

Oil pressure is defined as the fuel oil cooler discharge pressure referenced to air pressure in the No. 1-2 bearing compartment. A low pressure warning switch, which is set for 70 psi, is provided in the main oil line before the bearing compartments and after the fuel oil cooler at the same point as the oil pressure sensor. This allows for cockpit monitoring of low oil pressure.

A pressure relief valve at the filter housing limits pump discharge pressure to approximately 540 psig to protect downstream components. The oil pump module includes five scavenge stages which drain the main bearing compartments, main gearbox, and angle gearbox.

A fuel/oil heat exchanger is used for cooling both engine oil and IDGS oil. In addition, an engine air/oil cooler and an IDGS air/oil cooler are used for cooling engine oil and IDGS oil respectively.

Both engine and No. 3 bearing compartment scavenge oil temperatures are sensed by the FADEC. Engine oil temperature is measured in the combined scavenge line to the oil tank and is transmitted by the FADEC to ECAM. The temperature difference between engine scavenge oil temperature and the No. 3 bearing compartment scavenge oil temperature is transmitted by the FADEC to ECAM and displayed as an oil delta temperature on the ENGINE page. This oil delta temperature is to be used as an engine maintenance alert with the advisory level set at 44°C.

The oil quantity indicators display the quantity of oil in the oil tank only. They do not include the quantity of oil in the engine. During starting and takeoff, approximately 8 to 12 quarts of oil can go from the oil tank to the engine. This causes the oil quantity indicators to decrease by the same quantity. During engine shutdown, oil is returned to the tank. As the oil returns to the tank, the oil quantity shows an increase. When the oil quantity is less than 4 quarts, the ECAM oil quantity display flashes.

A valve allows oil to bypass the filter when the filter pressure drop exceeds 70 psi. The amber OIL CLOG light and an amber ENG 1(2) OIL FILTER CLOG ECAM message are set to be displayed at 50 psi differential pressure to permit flight crews to take action to prevent bypassing of contaminated oil.

High differential pressure across the oil filter may indicate cold viscous oil, contamination or a combination. High differential pressure indication with oil temperature above 35°C indicates contamination and servicing is required. Once the filter is allowed to clog and bypass contaminated oil, continued operation of the engine may cause clogging of engine oil screens with the resultant loss of lubrication to related bearings and seals.

An optional SB incorporates a dual element oil filter (SB PW4ENG 79-73). The normal flow of oil is through the primary (fine) and the secondary (coarse) filters. A bypass valve provided in the oil filter cap will allow oil to bypass the primary filter if the differential oil pressure reaches a predetermined value. There is no bypass feature across the secondary filter element. The oil filter alert message will be displayed on the ECAM when the oil differential pressure reaches the bypass point of the primary filter.

ANTI-ICING SYSTEM

The engine anti-icing system is actuated by a cockpit push button switch. Engine ice protection is provided by heating of the inlet cowl leading edge using hot air from the HPC. Cockpit FAULT amber light(s) and an ECAM message are provided to indicate when the inlet cowl anti-ice valve position is not in agreement with the selected position. Engine ratings are automatically adjusted by the FADEC for the effect of anti-icing bleed air.

BLEED SYSTEM

SERVICE BLEED

The high compressor 15th and 8th stage service bleeds and fan duct air bleeds are available to the airframe manufacturer for airplane pneumatic system and component use. Engine air bleed is utilized for the Automatic Rotor Clearance Control System, the HPC secondary flow control system, first and second stage turbine vane and blade cooling and engine and IDGS oil cooling.

ENGINE STABILITY BLEED

The engine incorporates two air bleed systems to provide greater compressor stability during starting and engine transient operation. Air is bled from the rear of the fourth stage LPC (station 2.5) and two ninth-stage (station 2.95) bleed ports in the HPC.

The LPC bleed (2.5 bleed) incorporates a low loss bleed valve to increase surge margin at low thrust levels, during reverse operation and thrust transients. This bleed incorporates features which provide for dirt removal from the primary flowpath. The bleed is actuated by a FADEC controlled hydraulic cylinder mounted on the intermediate case. Bleed air is exhausted between the struts into the fan exit case. This provides maximum diffusion of the bleed air into the fan exhaust stream and minimizes the effect on stream flow.

The FADEC controls the bleeds as follows:

- Starting - The FADEC commands both ninth-stage bleeds (2.95 bleeds) open during the motoring and starting sequence for HPC surge protection and commands them closed just below idle N2 speed. The FADEC commands the LPC bleed open both during the starting sequence and at idle.

- Steady state/acceleration - The FADEC controls the LPC bleed during steady state and acceleration operation such that the bleed is full open at idle and modulates to a full closed position at high thrust. The two ninth-stage bleeds are closed.

- Deceleration
  - LPC Bleed: The FADEC opens the LPC bleed during deceleration based upon the severity of the deceleration and the normal modulating schedule.
  - HPC Stability Bleed: Above 16,000 feet (24,500 feet for RCC HPC), one ninth-stage bleed is scheduled open as a function of altitude in the 86%-90% N2 speed range. The bleed will remain open for up to three minutes (30 seconds for RCC HPC) unless an acceleration to above the N2 speed schedule is subsequently conducted. The ninth-stage stability bleed will be closed below the listed altitudes above sea level regardless of N2 speed (except for surge recovery).
- Reverse - The FADEC commands the low pressure compressor bleed full open while keeping the two ninth-stage bleeds closed.

THRUST REVERSER SYSTEM

PW4000 employs a translating sleeve fan thrust reverser which, when deployed, directs fan discharge airflow forward to produce reverse thrust. The primary airflow stream is not reversed. Fixed cascades with directional characteristics are installed around the reverser discharge annulus to provide the desired forward and outward vectoring pattern of the reverser efflux.

The reverser is constructed in two structurally separate halves which are hinged to the airplane pylon at the top and latched together at the bottom. Each reverser half becomes rigidly connected to the engine through circumferential V groove-and-blade joints on the fan case outer diameter (OD) and inner diameter (ID) during the latching process.

When installed and stowed the reverser forms the fan duct through which fan discharge air is accelerated to produce forward thrust, as well as providing protection for accessory components installed on the engine. In conjunction with the fan cowl doors and inlet, the reverser forms the nacelle external aerodynamic flow surface.

Reverser deployment is commanded by raising the reverse lever after placing the throttle lever in the idle position. This initiates operation of the 15th stage bleed powered pneumatic/mechanical actuation system. The two sleeves translate aft on internal tracks, causing blocker doors to extend into the fan discharge flow path to block the normal aft discharge of fan air, while simultaneously exposing the cascade annulus for forward vectoring of the fan discharge airflow.

When sleeve translation has passed 90%, the FADEC will permit thrust modulation above idle up to the reverse thrust N1 limit (3255 RPM = 90.4%).

Stow is commanded by returning the reverse lever to its most forward position. Engine thrust is limited to idle until the stow process is complete.

The reverse actuation system contains two separate lock mechanisms for maintaining the sleeves in the stowed position. The primary lock is a spring-loaded brake applied to the single pneumatic actuating motor, while the secondary locking system is a spring-loaded pintle in each master actuator which prevents rotation of the gear train in the two master actuators. Application of the 15^{th}-stage pressure upon deploy command releases both locking systems allowing reverser translation.

When any of the locks are released or when the sleeve moves aft of the stowed position, an unlock signal is provided to the cockpit to illuminate the amber reverser unlock (REV UNLK) light. When the reverser reaches full deployment, a green REV light is illuminated in the cockpit. With the sleeves fully stowed, no signal is provided to the cockpit. Should an uncommanded deploy occur, the FADEC will immediately command power reduction to idle regardless of throttle lever position.

If an equipment failure causes the reverser sleeve(s) to drift back inadvertently in flight, the REV UNLK light will illuminate. Reverser sleeve drift-back is limited to 1/2-inch of travel, at which position the system automatically locks in position to prevent further deployment. In this condition, the reverser will be inoperable until ground maintenance action is taken.

AIRBORNE VIBRATION MONITORING (AVM) SYSTEM

The vibration monitoring system displays the state of balance of the engine rotors (N1 and N2) on the ECAM system display when the ENGINE or CRUISE pages are displayed.

A piezoelectric type accelerometer mounted on the fan case senses the vibration induced by the low and high rotors and generates an electrical signal. The electrical signal, which is proportional to engine vibration accelerations, is then transmitted to the signal conditioner unit (amplifier) in the electronic bay.

The amplifier also receives N1 and N2 speed signals which are used to set the central frequencies of narrow band filters and correlates these frequencies with the specific rotor. The N1 and N2 vibration signals are then provided by the amplifier as input to the ECAM system display (ENGINE and CRUISE pages).

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SECTION 2

NORMAL OPERATION

STARTING

Each of the steps below should be performed in sequence. In the event of an aborted start, the entire starting sequence may have to be repeated from the beginning. During starting, service air bleed demands and accessory loading should be minimized.

BEFORE START

1. Throttle Lever -- IDLE.

2. Fuel Lever -- OFF.

3. Fire Handle Position -- NORMAL.

4. Airplane Fuel Boost Pump(s) -- ON.

START

1. IGNITION Selector Switch -- START (A or B).

   a. ENGINE START page is displayed on ECAM system display.

   b. Engine 1 and 2 START ARM lights illuminate white.

   c. PACK VALVES close.

      (1) PACK VALVE FAULT lights will momentarily illuminate amber during closure.

2. Check Starter Air Supply Pressure is Available.

3. START Push Button Switch -- Depress.

   a. Start valve opens.

      (1) ARM white light extinguishes.

      (2) OPEN blue light illuminates.

   b. Starter air pressure momentarily decreases then returns to approximately prestart level.

   c. APU RPM increases (if APU bleed air is used).

   d. N2 increases.

   e. Oil pressure increases.

4. Fuel Lever -- ON when N2 reaches 20%.

   NOTES: (1) If 20% N2 is not achieved, use Maximum Motoring Speed (MMS).

   (2) MMS has been reached when there is no significant increase in N2 (less than 1% RPM in approximately 5 seconds), indicating that the starter has achieved its full cranking capability.

   (3) Do not move the Fuel Control Switch to RUN if MMS is less than 15% N2. MMS less than 15% N2 indicates that the starter system is not functioning at the required level.

   a. Ignition (A or B) is activated.

   b. High-pressure (HP) fuel valve opens.

   c. Fuel flow increases.

5. Observe EGT Increase.

   NOTES: (1) Check EGT for normal temperature rise and N1 and N2 for normal acceleration. Continue to monitor until EGT peaks, decreases and stabilizes.

   (2) The start can be aborted by placing the Fuel Lever to OFF. After placing the Fuel Lever to OFF, maintain starter engagement and continue motoring the engine for 30 seconds to clear out trapped fuel and to provide cooling.

   (3) The normal starting fuel flow is approximately 500-600 pounds per hour (PPH) or 227-272 kilograms per hour (KPH) at all field elevations. Once normal idle is achieved, a fuel flow in the range of 1400-1600 PPH (636-727 KPH) is acceptable before the Environmental Control System (ECS) bleed is selected ON.

   CAUTIONS: (1) Monitor both N2 and EGT indicators closely during the start for any abnormal indications. Sluggish N2 acceleration is an indication of either an impending hot start or a hung start.

   (2) Should EGT exceed the starting temperature limit, the engine should be shut down immediately. The duration of overtemperature in seconds and the peak temperature reached should be recorded. A second start attempt should not be made until appropriate maintenance action is taken.

   (3) The start attempt should be discontinued if:

   (a) An indication of N1 rotation is not obtained by 40% N2.

   (b) The engine requires more than 120 seconds to accelerate from fuel ON to idle N2.

(c) An increase in EGT is not obtained within 20 seconds after fuel ON.

(d) Fuel or ignition is inadvertently interrupted.

(e) Dense vapor is emitted from the tailpipe while the FUEL LEVER is OFF.

(4) If starter engagement is interrupted, it is recommended that the starter not be re-engaged above 30% N2.

(5) Should a start be aborted above 48% N2, it is necessary to allow N2 to decrease below 5% N2 prior to attempting a restart. This will remove power from the FADEC and reset the FADEC overspeed protection logic.

(6) Stabilized fuel flow indications in excess of 1200 PPH (545.5 KPH) within a few seconds after turning fuel on may be an indication of an impending hot start and the start should be carefully monitored.

6. Check Start Valve closed.

a. Start valve should be fully closed (OPEN light extinguished) by engine idle speed.

7. IGNITION Selector Switch -- OFF (after both engines started).

a. Pack valves will open.

(1) PACK VALVE FAULT lights will momentarily illuminate during opening.

8. Oil Quantity Reduction.

a. Normal oil quantity reduction from start up to stabilized idle is approximately 8 to 12 quarts. (Oil quantity reduction for a cold engine could be as much as 13 to 16 quarts during initial start up but should return to the 8 to 12 range at stabilized idle.)

ENGINE WARM-UP

No minimum warm-up time is required following an engine shutdown of 2 hours or less.

Note: If the engine is restarted after having been shutdown for approximately one hour, a very definite low frequency vibration may be felt throughout the airplane. This will subside after approximately 5 minutes or with engine acceleration. A bowed rotor may cause this vibration. To prevent bowed rotor, refer to “Engine Shutdown” section.

In order to minimize any adverse thermal stress, it is desirable that engines started after a shutdown period of greater than 2 hours be warmed up at thrust settings normally used for taxi operation for at least 5 minutes. It is not, however, necessary to delay the takeoff to warm-up the engine, but when it is anticipated that the taxi time will be less than 5 minutes, it is recommended that engines which have been shut down for more than 2 hours be started at the gate or as early as is feasible.

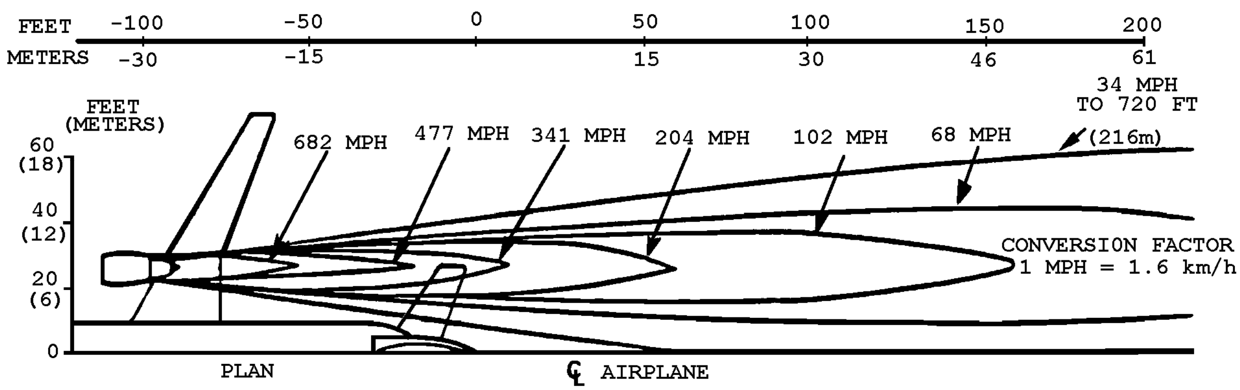
If indication of a high pressure differential across the single element oil filter occurs with oil temperature below 35°C, maintain the engine at idle until the indication disappears or until the temperature is above 35°C. When oil temperature is above 35°C at idle, high oil filter pressure differential indicates the presence of contaminants alone and the filter should be serviced immediately. If the optional dual element oil filter (SB. PW4ENG 79-73) is installed, and the message disappears as the oil temperature rises, the flight may proceed, but a log book entry must be made and the filter must be changed prior to the next flight. If the message remains on, maintenance action must be taken prior to flight.

The engine must be warmed up until the oil temperature is at or above 50°C prior to takeoff. This will ensure that there is adequate heat available to prevent fuel icing under takeoff conditions.

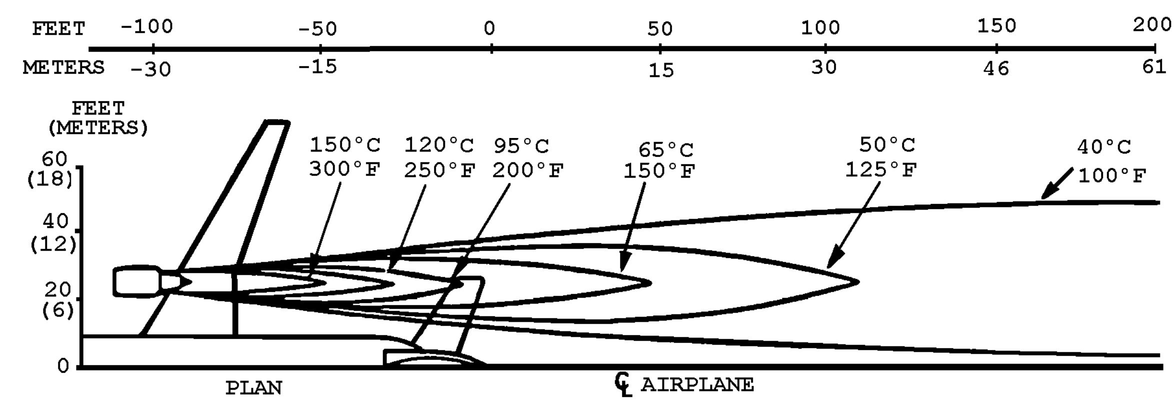
GROUND RUN-UP

WARNING: DURING GROUND OPERATIONS, EXTREME CARE SHOULD BE EXERCISED WHEN OPERATING ENGINES TO PROTECT PERSONNEL AND GROUND OBJECTS FROM THE VERY STRONG JET WAKE BLAST AND INLET SUCTION. REFER TO THE DIAGRAM BELOW FOR HAZARD AREAS.

JET WAKE DIAGRAM - VELOCITY



JET WAKE DIAGRAM - TEMPERATURE



TAKEOFF

The rolling takeoff thrust setting technique is recommended.

1. PACK VALVES -- As required.

2. Appropriate Fuel Boost Pump Push Button Switches -- Check ON.

3. IGNITION Selector Switch -- CONT RELIGHT.

   NOTE: Refer to USE OF IGNITION SYSTEM in this section.

4. Throttle Levers –- Set.

   NOTES: (1) For a normal takeoff, advance the thrust levers to an intermediate setting of approximately 1.05 EPR and allow engines to stabilize. Both engines should be aligned and stabilized between 1.05 and 1.10 EPR with no more than 0.02 EPR difference between engines. Select the desired autothrottle mode and verify that the thrust levers advance and that symmetrical engine spool up is achieved. When any tailwind component exists or a crosswind component is greater than 20 knots, a manual takeoff is recommended.

   (2) For a manual takeoff, advance the thrust levers to an intermediate setting of approximately 1.05 EPR and allow engines to stabilize. Both engines should be aligned and stabilized between 1.05 and 1.10 EPR with no more than 0.02 EPR difference between engines. Advance thrust levers promptly and smoothly to the target thrust setting and verify that symmetrical engine spool up is achieved.

   When any tailwind component exists or a crosswind component is greater than 20 knots, aircraft speed is needed to minimize the effect of ground winds on engine stability:

   After the intermediate thrust setting, promptly advance EPR to 1.25, then advance thrust progressively to be at the takeoff position at 50 knots indicated airspeed (IAS).

   (3) Alternate control mode takeoff is manual. Both FADEC's must be operating in the alternate control mode. The intermediate setting will be between 40 and 60% N1 with no more than 4% N1 difference between engines. The throttle lever position required to reach the target N1 when in the alternate mode will be less than the full forward position.

5. Takeoff Thrust Setting -- Check.

   NOTES: (1) For autothrottle takeoff, check that the target EPR has been achieved by 80 knots.

(2) For manual takeoff, the target EPR (or N1 if in the alternate control mode) should be checked and reset as required prior to an airplane speed of 80 knots to ensure takeoff thrust is achieved. No further throttle lever adjustments for normal engine variations should be made for the remainder of the takeoff.

6. Normal Engine Operation -- Check.

NOTES: (1) Monitor primary engine indications for normal engine operation.

(2) If EGT exceeds redline during takeoff and occurs when:

(a) Setting takeoff thrust (IAS less than 80 knots) - Reject takeoff.

(b) After setting takeoff thrust (IAS greater than 80 knots) - Do not adjust throttle levers until reaching safe altitude and airspeed. Then adjust throttle lever(s) to reduce EGT within limits.

FLEXIBLE TAKEOFF THRUST

The use of flexible takeoff (FLX TO) thrust, when airplane performance requirements permit, is a recommended means of extending engine hot section life.

CLIMB

The FADEC will automatically maintain the climb rating once set when operating in the EPR mode.

NOTE: When operating in the alternate control mode (N1), the thrust settings should be monitored by the crew throughout the climb and throttle levers reset, as necessary, to ensure that the climb rating is not exceeded.

LANDING REVERSE

1. Throttle Levers –- IDLE.

   a. No REV or REV UNLK lights displayed.

2. Reverse Levers -- Immediately after touchdown of main landing gear, pull reverse levers to the idle reverse point.

   a. REV UNLK amber light indicates reverser unlocked or unstowed and in transition toward the deployed position.

b. REV green light indicates reverser is beyond 90% of its travel from the stowed position to the fully deployed position.

3. Reverse Levers -- When REV green light appears, apply maximum reverse thrust.

4. Reverse Levers -- At 80 knots or IAS fluctuations (whichever occurs first), reduce thrust smoothly to idle. Set reverse levers to stowed position when taxi speed is reached or before leaving the runway.

   a. REV UNLK amber light indicates the reverser in transition from the fully deployed position.

   b. REV UNLK amber light extinguished when the reverser is stowed.

   CAUTION: The potential for incurring engine damage from the ingestion of runway debris is directly related to runway conditions. Therefore, while landings on wet, icy or short runways may require high levels of reverse thrust, judgment should be exercised, where possible, to moderate the use of reverse thrust commensurate with runway conditions. High reverse thrust levels at low airplane speeds should be avoided. Reverse thrust should not be used to control ground speed while taxiing, except in an emergency.

SHUTDOWN

It is suggested that the engine be operated at or near idle for a 5-minute cooling period after landing to minimize the potential for a bowed rotor. The 5-minute cooling period will also minimize the potential for oil coking in the main bearing compartments. If, in the interest of fuel conservation, it is desired to shut down one engine during taxi-in, it is suggested that the engine be operated at or near idle for up to a 5-minute cooling period before shutdown.

A cooling period of less than 90 seconds may increase the potential for oil coking in the main bearing compartment components. A cooling period between 90 seconds and 5 minutes may be utilized at the airline's discretion, based on its experience.

If the airplane arrives at the gate in less than 5 minutes, while there is no requirement to continue cooling until 5 minutes have elapsed, the airline should be aware of the relationship between potential oil coke formation and cooldown time.

After observing the cooldown recommendations stated above, the following sequence should be followed to shut down the engine:

1. Throttle Lever –- IDLE.

2. Fuel Lever –- OFF.

CAUTION: Ascertain that an immediate engine shutdown occurs as evidenced by indication of fuel flow decrease to zero. Continued engine operation after placing the master lever OFF indicates a malfunction. Maintenance action is mandatory before the next engine start.

Ground test power should not be applied to the FADEC while the engine is being shut down (until N2 is below 5%) to avoid erroneous overspeed system fault detection signals.

USE OF IGNITION SYSTEM

Either ignitor may be used for ground starts. The CONT RELIGHT position (both ignitors) should be used for an inflight start.

The PW4000 ignition system is capable of continuous operation; however, both ignitors should be turned off to conserve the life of the ignition system components whenever ignition is not needed in flight or on the ground.

The CONT RELIGHT position should be used during the following flight conditions:

1. Takeoff - Ignition should remain on until the airplane has been cleaned up.

2. Approach and Landing - Ignition should be on to avoid a possible flameout that might result from bird ingestion while operating near the ground.

3. Icing Conditions - Prior to activating the engine anti-icing system, placing the ignition on will serve to preclude the possibility of a flameout which might result from the ingestion of ice. Engine ignition may be turned off after the engine has stabilized with anti-ice on.

4. Turbulence, Heavy Rain or Volcanic Ash - Whenever moderate to severe turbulence or operation in heavy rain or volcanic ash is encountered, ignition should be on to avoid possible flameout. In light turbulence, ignition is not required.

COLD WEATHER OPERATIONS

The PW4000 engine should be started with existing procedures in cold weather. During starting in cold temperatures, engine start characteristics may change. However, all existing limits and restrictions apply. The time to accelerate to idle may be longer, but the time from fuel-on to idle should be less than 120 seconds. The oil filter clog indication may come on during engine warm-up with oil temperature colder than +35°C. Maintain the engine at idle until the light/message disappears. Engine oil temperature must be warmer than +50°C before takeoff.

Before start-up, if engine oil temperature is -40°C or warmer, no pre-heat is required. The PW4000 engine is certified to use “Type II” oil. Because of the significant increase in viscosity of “TYPE II” oils at lower temperatures, engine pre-heat is required when oil temperature is colder than -40°C. Warm air must be blown inside the nacelle to raise the indicated oil temperature to -40°C or warmer.

The necessity for pre-heating the engine can be eliminated with periodic engine runs. Before oil temperature decreases to colder than -40°C, the engine can be started and warmed-up at idle. This warm-up should be repeated as necessary to maintain oil temperature indication at -40°C or warmer prior to start-up for dispatch.

Installing engine inlet and exhaust plugs/coverings after shutdown, per the aircraft maintenance manual, will minimize engine heat loss.

To view engine oil temperature indication, with the engine shutdown, aircraft electrical DC power must be applied to the engine FADEC. The FADEC ENG1 / ENG2 must be selected and the OFF / TEST / BITE DISPLAY switch must be placed in the TEST position. Oil temperature can be read from the FADEC GRND TEST display on the right ECAM screen. It should be noted that when oil temperature is colder than -50°C, the indication will appear as “XXX.X.”

USE OF ANTI-ICING SYSTEM

The engine anti-icing system should be used during all engine operation, including ground operation and takeoff, whenever icing conditions exist or are anticipated as defined by the airplane Flight Manual (FM).

Erratic or abnormal vibration may be an indication of engine icing.

GROUND OPERATIONS DURING ICING CONDITIONS

Whenever engine air inlet icing conditions exist, as defined by the AFM, inlet cowl anti-icing heat should be employed during ground operation.

During ground operations when engine anti-ice is required and OAT is +3°C or less, periodic engine run-ups should be performed to shed ice from the spinner, fan blades and low pressure compressor stators. Run-ups must be to a minimum of 50% N1. There is no requirement to maintain the high N1. Run-ups should be performed at intervals no greater than 30 minutes, and are equally important during taxi-out, ground holding, and taxi-in. The first run-up during taxi-out should be done as soon as practical, but not more than 30 minutes after engine start.

AIRPLANE DE-ICING

The procedure of de-icing the airplane with the engine running, using an airframer approved solution, is acceptable provided the following precautions are observed:

1. Prior to engine start, deposits of ice and snow should be removed from engine nacelles.

2. Engine should be operated at idle during spraying, with inlet cowl anti-ice on and all airplane air systems that could send bleed air into the cabin turned off.

   CAUTION: Do not spray deicing fluid into the engine inlet with engines operating. Deicing fluid can:

   - Leave a residue on compressor airfoils which reduces compressor efficiency;
   - Cause bleed valves to stick;
   - Clog probes resulting in incorrect readings;
   - Result in the passage of noxious fumes into the airplane.

TAKEOFF IN ICING CONDITIONS

All takeoffs, when anti-ice is required, must be preceded by a static run-up to a minimum of 50% N1 with observation of all primary engine parameters to ensure normal operation.

When the engine anti-icing system is used during takeoff, no thrust penalty is imposed at ambient air temperatures of 8°C (46°F) or below. The system should not normally be used for takeoff at ambient temperatures above 8°C (46°F). If a nacelle anti-ice valve is inoperative in the open position, an appropriate EPR penalty must be applied.

IN-FLIGHT OPERATIONS DURING ICING CONDITIONS

When the engine anti-icing system is used in flight, the FADEC will automatically apply an EPR correction to the Maximum Continuous, Maximum Climb and Maximum Cruise thrust ratings, when operating in the Normal (EPR) Control mode. Bleed corrections must be manually applied if the FADEC is operating in the Alternate Mode. During inflight use, the FADEC will automatically limit N1 to no lower than 20% (720 RPM).

If inlet ice is suspected to have formed prior to turning on the anti-ice system, throttle levers should be retarded individually to Idle, the ignition turned on and anti-icing heat applied before reestablishing normal thrust. Reducing the RPM will minimize the danger of internal damage to the engine as ice which has already formed breaks loose and is ingested. Activating ignition should preclude the possibility of engine flameout due to ice ingestion.

USE OF AIRBORNE VIBRATION MONITORING (AVM) SYSTEM

Actual or incipient engine difficulties may be detected by the Airborne Vibration Monitoring Equipment (AVM) equipment. Vibration trends are monitored by maintenance personnel as part of an engine conditioning monitoring program to detect any sudden increases in level, which may indicate an engine problem. Vibration indication trends over a period of time are important provided readings are taken regularly during comparable, stabilized flight conditions. Indicated N1 and N2 vibration levels under stabilized cruise conditions should be recorded at least once a day.

Since vibration characteristics are unique to each engine, installation and instrumentation, a single reading is not very meaningful unless a sudden significant increase is encountered. Therefore, specific limits to define abnormally high vibration levels are not established. The VIB ADVISORY on the ECAM indicates a level in excess of 3 units on the N1 compressor and in excess of 5 units on the N2 compressor and is intended to induce flight crews to closely monitor and cross-check engine parameters.

High vibration indication can be corroborated by any of the following conditions on the affected engine:

- Vibration reading increases and decreases with corresponding throttle movement;
- High vibration readings are accompanied by vibration in the aircraft structure;
- Abnormal engine noise or rumble accompanies an increased vibration level;
- High vibration readings are accompanied by changes in other engine parameters such as EGT, N1/N2 relationship, OIL PRESS, OIL TEMP, OIL QUANTITY, and/or NACELLE TEMP.

If during stabilized cruise a sudden increase in vibration in excess of one unit is encountered and the reading is corroborated as noted above, attempt to operate the engine to reduce the vibration level to within one unit of the original indication. Consider engine shutdown, based on acceptability of indicators other than vibration reading, and/or parameters beyond limits.

If a significant increase in vibration is encountered when engine thrust has been reduced to IDLE, an increase in engine power may result in a reduction of N2 vibration level.

It is not necessary to shut down an engine solely because of abnormal vibration indication readings, or large differences in readings between engines. The flight crew may choose to reduce thrust on an engine to control abnormal indications and maintain engine operation. Any abnormal vibration indication, however, should be recorded for maintenance action.

SECTION 3

ABNORMAL OPERATION

Abnormal procedures, in particular, require the careful integration of factors involving all associated systems. The content of this section, therefore, should be used primarily for guidance over which the airplane Flight Manual content takes precedence.

ENGINE FIRE WARNING

The engine fire warning system indicates presence of a fire within the nacelle. If a fire warning is registered, it must be assumed that a fire exists.

If a fire is encountered, either in flight or on the ground, retard the throttle lever, shut down the engine and pull the fire handle. If the fire warning continues, discharge the fire extinguishers in accordance with the airplane manufacturer's procedures.

ENGINE TAILPIPE FIRE ON GROUND

When ground fires are encountered, they are most likely to be engine tailpipe fires which occur during engine start or engine shutdown. The best method of arresting such a fire is to shut off fuel and ignition and motor the engine by means of the starter with minimum delay to reduce internal temperatures and to blow out both the fire and residual fuel and vapor.

Maximum starter re-engagement speed is 30% N2 RPM. In the event of an engine tailpipe fire on the ground with an aircraft that has been dispatched with an inoperative N2 RPM indicating system, starter re-engagement should be based on time since fuel shutoff. Data shows that on the PW4000 engine, the time from fuel shut-off to 30% N2 RPM is approximately 20 seconds.

CAUTION: Dry chemical powder fire extinguishing agents can cause severe corrosive damage to the engine and, therefore, should only be considered as a last resort.

ENGINE LIMIT EXCEEDANCE

Whenever the operating limits shown are exceeded, the operating crew must take whatever action is necessary, flight conditions permitting, to return operation within limits. ECAM will display an ENG OVER LIMIT message if N1, N2 or EGT redlines are exceeded. Engine operation can continue after operating limits have been restored providing the incident has not resulted in any evident damage. If any of these engine parameters cannot be restored within limits, the engine should be shut down, flight conditions permitting.

All such incidents should be recorded in the log book and reported to maintenance upon landing, stating the maximum values observed and the length of time above limits, or (in the case of low oil pressure) below the limit. This information is essential for effective corrective action by maintenance personnel.

Whenever an engine EGT overtemperature is experienced during ground operation, the engine should be shut down immediately and motored for 30 seconds to cool.

ENGINE SURGE

IN-FLIGHT NONRECOVERABLE SURGES

Engine surges are categorized as either recoverable or nonrecoverable. A recoverable surge is a momentary disruption of airflow through the engine which ceases immediately without the need for the operator to take any corrective action. A nonrecoverable surge requires operator action to restore normal operation. This can include retarding the thrust lever, increasing engine bleed or engine shutdown.

Nonrecoverable surges can be either audible or silent and are generally accompanied by increasing EGT. These surges will frequently recover if the throttle lever is immediately and rapidly retarded to idle. The IGNITION selector switch should also be placed to CONT RELIGHT to protect against flameout.

When the throttle lever is at idle, check EGT to determine if the engine has recovered from the surge condition. Do not shut down an engine if EGT is significantly cooler than the inflight limit or is decreasing.

Shut the engine down if EGT continues to rapidly increase toward the EGT limit.

If the engine recovers from the surge condition, as detected by a decreasing EGT, consider using engine bleed (engine/wing anti-ice) to improve surge margin.

If EGT is below the limit and stabilized or decreasing:

1. Advance the throttle lever slowly. Check that N1 and N2 follow throttle lever movement.

2. If surge does not recur and throttle lever response is normal, continue normal engine operation.

3. If surge recurs, operate the engine at a reduced thrust level which is surge free.

If EGT is increasing but not approaching the redline, increase engine bleed (engine and wing anti-ice) to try to stop the surge. If the engine recovers from the surge condition, as detected by a decreasing EGT, turn the engine anti-ice OFF prior to advancing the thrust lever to facilitate engine acceleration.

REPETITIVE SURGES AT LOW ALTITUDE

In the event of repetitive surges at a critically low altitude (takeoff), the engine should be operated at the minimum thrust required to attain a safe altitude and airspeed. Once reaching that altitude and airspeed, the affected engine(s) should be reduced in thrust to clear the surges.

REPETITIVE SURGES IN FLIGHT

Avoid operating an engine in a persistent surging condition. Multiple surges can cause blade clashing within the compressor and possible engine failure. Reduce thrust to the point where the surge condition is cleared.

IN-FLIGHT SHUTDOWN

A cooling period between 90 seconds and 5 minutes may be utilized at the airlines discretion, based on its experience, provided operation will not affect flight safety or cause further engine damage.

After observing this cooldown suggestion, the following sequence should be used to shut down the engine.

1. Throttle Lever –- IDLE.

2. Fuel Lever –- OFF.

ENGINE WINDMILLING

All engines which have windmilled as a result of an emergency shutdown due to a malfunction in flight must be inspected upon landing. The type of inspection required depends on the circumstances outlined in the applicable Maintenance Manual. A notation should, therefore, be made by the flight crew stating whether or not the engine windmilled with continuous positive indication of oil pressure.

IN-FLIGHT START

No attempt should be made to restart an engine if there are indications of engine damage, the engine had been shut down because of an engine fire or there is a recognizable possibility that an attempted relight may result in a fire.

If an engine is shut down because of a nonrecoverable surge or because an engine operating limit was exceeded, it may be restarted provided the above conditions are met. The engine should, however, be carefully monitored after restart and for the remainder of the flight to ensure that the operation above engine limits has not resulted in evident engine damage.

A technique which has proved very successful is to initiate a rapid relight immediately after a flameout occurs by retarding the throttle levers to idle and selecting continuous relight ignition. Successful relights may be obtained at high altitude provided that action is taken before the compressor RPM has decreased substantially.

In an emergency situation involving thrust loss, another technique should be considered. The probability of thrust recovery may be improved by selecting CONT RELIGHT, then moving the ENG FUEL LEVER to OFF and immediately back to ON. This technique should clear a thrust loss due to non-recoverable surge and or flame-out and permit the engine to re-accelerate back to power.

Inflight starts may be attempted regardless of altitude or airspeed, following the procedural considerations listed below and observing the published inflight start EGT limit. The probability of a successful start is enhanced by observing the boundaries of the Inflight Start Envelope published in the Flight Manual.

The limits and criteria presented in Section 2 for ground starts also apply to air starts except:

1. The start attempt should be discontinued if a relight is not obtained within 30 seconds after fuel on.

2. Flight conditions permitting, run the engine at idle for 2 minutes (5 minutes if the engine was shut down for more than 10 minutes), prior to setting cruise thrust.

3. The use of both ignitors is desirable for an air start.

4. A minimum of 15% N2 is recommended for placing the Fuel Lever to ON. Starter assist procedures should be used, if necessary, to achieve this level.

   NOTE: In an emergency situation, if 15% N2 can not be achieved and starter assist is not available, the start should be attempted at the maximum windmilling speed attainable.

START VALVE OPEN IN FLIGHT

In case the engine start valve opens in flight (START 1 or 2 OPEN light illuminates blue), all bleed air should be removed from the starter and icing conditions avoided. If bleed air is not removed, the starter may be damaged.

HIGH OIL TEMPERATURE

High oil temperature is indicated on the ECAM ENGINE page by the temperature display on the affected engine flashing green if it exceeds the Maximum Continuous limit (163°). The display will change to amber if it exceeds the Maximum Continuous Limit for more than 20 minutes or the Maximum Transient limit (177°) anytime. During engine operation, should the oil temperature exceed the Maximum Continuous limit as stipulated in Section 4 - Engine Operating Limits, reduce the throttle lever towards idle to reduce the oil temperature. If the oil temperature returns below the Maximum Transient Limit (177°C) and also within 20 minutes returns below the Maximum Continuous Limit (163°C), continue normal operation.

When oil temperature cannot be reduced below the Maximum Continuous limit within 20 minutes, or cannot be reduced below the Maximum Transient limit, the engine should be shut down. If conditions do not permit engine shutdown, operate at the minimum thrust required to sustain flight until a landing can be made.

LOW OIL PRESSURE

Oil pressure encountered in flight, which decreases to 75 psi, will be displayed as a flashing green digital reading on the ECAM system ENGINE page. However, the engine can be operated normally for the remainder of the flight.

Low oil pressure indication reading (less than 70 psi), as displayed in red on the ECAM system display, requires corrective flight crew action. The engine should be shut down. If conditions do not permit engine shutdown, operate at the minimum thrust required to sustain flight until a landing can be made.

If the oil pressure is greater than 70 psi but accompanied by an OIL LO PRESS warning light, ECAM warning message and master warning or ENG WLDP light, monitor oil quantity and oil temperature. If these engine parameters are normal, continue engine operation and report for maintenance action after the flight.

OIL FILTER CLOGGING

The amber advisory-level OIL CLOG light and amber ENG 1(2) OIL FILTER CLOG ECAM message indicates filter clogging. The following procedures are recommended when these warnings are displayed in flight:

- With single oil filter configuration:

  1. A thrust reduction should be made to extinguish the oil filter warning indications. The engine can be operated at a thrust level which will keep the oil filter warnings extinguished.

  2. If the message continues to be displayed, the engine should be shut down.

  NOTE: The filter clogging message should be reported as an engine discrepancy.

- With optional dual element oil filter (SB PW4ENG 79-73) installed:

  No crew action is required, but the filter clogging message should be reported as an engine discrepancy.

The ENG 1(2) OIL FILTER CLOG ECAM message or illumination of the OIL CLOG light may be displayed with oil temperature below 35°C, during or shortly after engine start, even if only for a few seconds. This may be an early indication that the filter is becoming clogged. If the warning disappears with oil temperature above 35°C during ground operations, the flight may proceed, but a log book entry should be made and the filter must be changed prior to the next flight. If the warning remains displayed above 35°C during ground operations, the filter must be changed prior to flight.

LOW OIL QUANTITY

There is no minimum oil quantity limit inflight. For dispatch, the airline should determine if oil quantity is sufficient for a given flight based on the engine's known oil consumption rate and estimated flight time. While engine operation is governed by both oil pressure and oil temperature limits, oil quantity indications may enable the crew to recognize a deteriorating oil system.

When abnormal oil quantity indications are observed, monitor oil pressure and temperature to confirm the abnormal quantity indication. A sudden or complete loss of oil quantity without abnormal indications of pressure or temperature is most probably indicative of quantity indicating system failure. Engine operation under these circumstances should be monitored - oil pressure and oil temperature as well as other parameters. If all indications are normal, operate the engine normally. If any operating limit is reached, take the appropriate action.

When a steady decrease in engine oil quantity is observed over a period of time, monitor oil pressure and oil temperature and anticipate an engine shutdown. When any operating limit is reached, take the appropriate action.

IN-FLIGHT REVERSION TO ALTERNATE CONTROL MODE (N1)

Automatic reversion to the alternate control mode (N1) is recognized by the engine mode selector FAULT light illuminating amber and an amber ENG 1(2) EPR MODE FAULT ECAM message. Should this automatic reversion occur, it is recommended that re-selection of the primary control mode (EPR) be attempted through the mode selector switch in anticipation of the fault having cleared. This is accomplished by reducing thrust on the affected engine and pressing the mode selector switch twice. The initial pressing will manually select the alternate control mode (N1 light illuminates white).

CAUTION: Prior to manual selection of the alternate control mode (N1), engine thrust should be reduced to 1.1 EPR (70% N1) or less. A substantial overboost can occur if the alternate control mode is selected at a high thrust level.

Pressing the N1 mode selector switch a second time (white light extinguishes) will attempt to re-select the primary control mode (EPR). If the amber fault light does not illuminate, a successful re-selection of the primary control mode has been accomplished.

If EPR re-selection is not successful or exercised, it is recommended that both engines be placed in the alternate control mode (N1) for the remainder of the flight.

REVERSER IN-FLIGHT MALFUNCTION

Inflight malfunction of the thrust reverser system will be indicated by the reverser unlock (REV UNLK) warning light illumination. If this occurs, the throttle lever on the affected engine should be retarded to idle, in order to be prepared should an inadvertent deployment occur. If the display of the REV UNLK light is accompanied by abnormal engine/airplane behavior, the engine should then be shut down.

OPERATION IN MODERATE-TO-HEAVY RAIN AND HAIL

Flight should be conducted to avoid thunderstorm activity. To the maximum extent possible, moderate-to-heavy rain and hail should also be avoided. Ground based radar reports and pilot reports should be used by the flight crew when moderate to heavy rain or hail is anticipated. The airplane radar should be properly adjusted for range and tilt to adequately scan the route of flight for areas of heavy precipitation.

When operating in or near moderate-to-heavy rain and hail, accomplish the following:

1. N1 RPM

   a. While Idle RPM provides sufficient protection, above idle RPM significantly increases the capability of the engine to ingest water without experiencing rundown, flameout or surge.

   CAUTION: Shutdown should not be accomplished if the engine does not respond to an acceleration command from the throttle lever and if EGT is within limits and is stable. Normal engine response will return upon leaving the area of heavy precipitation.

2. THROTTLE LEVERS

   a. Autothrottles should be OFF.

   WARNING: TURBULENCE WHICH IS LIKELY TO BE ENCOUNTERED IN SEVERE WEATHER CAN RESULT IN UNCOMMANDED THRUST CHANGES IF THE AUTOTHROTTLE IS ON.

   b. Do not make rapid throttle lever movements in heavy precipitation unless excessive airspeed variations occur. If thrust changes are necessary, move the throttle lever very slowly. Avoid changing throttle lever direction until engines have stabilized at a selected setting.

   c. Do not make throttle lever movements to correct for fluctuations in engine parameters. Engine parameters will return to normal immediately upon leaving the area of heavy precipitation.

3. IGNITION

   a. Position the IGNITION selector to CONT RELIGHT. This selection offers maximum flameout protection and restart capability in the event of a multiple engine thrust loss.

4. ANTI-ICE

   a. Engine and Wing Anti-ice Switches as required.

5. APU

   a. The APU, if available, should be started. The APU can be used to power the electrical system and to provide a pneumatic air source for improved engine starting in the event of a multiple engine thrust loss.

OPERATION IN SAND OR DUST

Sand and dust can cause premature engine deterioration. Although it is not an immediate threat like volcanic ash, it is best to minimize the time spent in a sand or dust environment. Flight crews should make a log book entry for any encounter with sand or dust so that the appropriate maintenance action can be taken.

In the event an in-flight encounter with sand or dust cannot be avoided, the following are recommendations for engine operation:

1. Minimize time spent in cloud.

2. For takeoff, use unrestricted climb.

3. Deviate around cloud or select less dense areas.

4. For descent, avoid holds in the cloud.

It is also recommended that operators avoid ground operation at airports affected by sand or dust until all runways, taxiways aprons and areas directly adjacent are clear of sand or dust. If operations must continue, the following are recommended procedures:

1. Limit reverse usage.

2. Avoid static operation above idle.

3. Taxi with all engines.

4. Limit taxi thrust.

5. Use rolling takeoff thrust setting technique.

OPERATION IN VOLCANIC ASH

It is our recommendation that engines are not to be operated in volcanic ash, either in flight or on the ground. In the event, however, that an inadvertent encounter occurs, the following recommended operating procedures are intended to maximize engine surge margin and to lower engine turbine temperatures in order to reduce the accumulation of volcanic material on the turbine vanes:

GROUND OPERATION

1. During landings, limit reverse thrust. Reverse thrust, if possible should be avoided unless stopping distance is critical. The use of maximum reverse thrust may impair visibility and ingest dust into the engines.

2. Avoid static operation of engines above idle power.

3. Use both engines for taxi. This will reduce the thrust needed from each engine and consequently keep turbine temperatures low.

4. Thrust operation during taxi should be limited to the minimum needed to sustain a slow taxi speed.

5. Restrict ground use of APU to engine starting only.

6. Use a rolling takeoff procedure. Ash and dust should be allowed to settle prior to initiating a takeoff roll.

7. Avoid use of air conditioning packs on the ground. Use no packs for takeoff if operating procedures permit.

FLIGHT OPERATION

1. Reduce thrust to idle, altitude permitting. This will provide additional surge margin and lower engine turbine temperatures.

2. Exit the volcanic cloud as quickly as possible.

3. Disengage autothrottle. This will prevent the autothrottle from increasing engine thrust.

4. Turn on all accessory airbleeds including all air conditioning packs, engine and wing anti-ice. This will provide additional engine surge margin.

5. Start the APU if available, to assist relight in the event of an engine flameout.

6. Set the ENGINE START selector to the CONT RELIGHT position.

7. Monitor EGT.

8. In the event an engine shutdown becomes necessary during volcanic ash ingestion, restart engine using published procedures.

9. If an engine fails to start, repeated attempts should be made immediately. A successful engine start may not be possible until the airplane is out of the volcanic cloud and the airspeed and altitude are within the airstart envelope. Engines are very slow to accelerate to idle at high altitude. This should not be interpreted as a failure to start or as an engine malfunction.

10. Upon exiting the volcanic cloud, land at the nearest suitable airport.

EMERGENCY THRUST SETTING

In an emergency situation, where ground contact is imminent, the engines may be operated with the throttle levers in the full-forward position, regardless of mode of operation.

SECTION 4

ENGINE OPERATING LIMITS

	PW4152	PW4156A PW4156	PW4158
N1	111.4% (4,012 RPM)	111.4% (4,012 RPM)	111.4% (4,012 RPM)
N2	104.0% (10,300 RPM)	105.5% (10,450 RPM)	105.5% (10,450 RPM)
Indicated EGT			
Takeoff (5 minutes)[1]	625°C[2]	650°C[3]	650°C[3]
Maximum Continuous	600°C[2]	625°C[3]	625°C[3]
Ground Start	535°C	535°C	535°C
In-flight Start[4]	625°C[2]	650°C	650°C
Oil Pressure			
Minimum[5]	70 PSI	70 PSI	70 PSI
Oil Temperature			
Minimum for Start	-40°C	-40°C	-40°C
Minimum for Takeoff	50°C	50°C	50°C
Maximum Continuous	163°C	163°C	163°C
Maximum Transient (20 minutes)	177°C	177°C	177°C
Fuel Temperature			
Minimum prior to takeoff			
IDGS operational	-49°C	-46°C	-43°C
IDGS inoperative	-42°C	-39°C	-37°C
IDGS air/oil cooler stuck open	-47°C	-44°C	-42°C
Engine or both air/oil coolers stuck open	-38°C	-36°C	-34°C
Both air/oil coolers stuck open and IDGS inoperative	-33°C	-31°C	-30°C

Starter

Start Attempts	2
Cooling period following 2 start attempts[6]	30 Minutes
Maximum re-engagement speed (including for emergencies)	30% N2

CAUTION: Do not exceed starter re-engagement speed of 30% N2.

ENGINE OPERATING LIMITS

NOTES:

1. For the engine-out contingency and with authorization by the airplane Flight Manual, the application of takeoff thrust can be extended from five to ten minutes provided the following conditions are observed:

   a. Use of the extended time period for training flights is excluded.

   b. Use of the ten minute takeoff period will not alter the maximum gross weight of the airplane (Limitations Section I of the FAA approved Airplane Flight Manual) certified under current Federal Aviation Regulations (FAR) with the current engine rating structure.

   c. The engine will be operated and maintained in accordance with instructions and limits authorized or issued by P&W and current at the time.

2. These limits of 625°C, 600°C and 625°C are the Takeoff, Max Continuous, and In-flight start limits displayed on the EGT indicator. These indicated EGT limits correspond to the certified EGT limits of 644°C, 619°C and 640°C, respectively, with FADEC software, resulting from EGT modifier logic that shunts the output value of EGT.

3. These limits of 650°C and 625°C are the Takeoff and Max Continuous limits displayed on the EGT indicator. These indicated EGT limits correspond to the certified limits of 654°C and 629°C, respectively, with FADEC software version SCN11B/AB and later, resulting from EGT modifier logic that shunts the output value of EGT.

4. For in-flight starts that result in exceedance of the ground start limit, the maximum temperature and duration must be recorded for maintenance action, per the PW4000 Maintenance Manual.

5. Temporary interruption associated with negative "g" operation is limited to 30 seconds maximum. Normal oil pressure will be restored rapidly once the negative "g" effect has been eliminated.

6. Engine motoring for (30) seconds is required following an aborted start.

APPENDIX

ENGINE-RELATED ECAM MESSAGES

MESSAGES	DEFINITION	RECOMMENDED ACTION
ENG OIL LO PR	Oil pressure is less than 70 psi	If unable to maintain a minimum of 70 psi and the message is accompanied by a red OIL LO PRESS warning light and the master warning or ENG WLDP light, engine should be shut down. If conditions do not permit engine shutdown, operate at the minimum thrust required to sustain flight until a landing can be made.
ENG 1(2) OIL FILTER CLOG	Pressure differential across the oil filter is at least 50 psi. Oil will bypass filter at 70 psi.	On ground, if oil temperature is less than 35°C, warm engine at idle. On ground, if oil temperature is greater than 35°C and warning disappears as oil temperature rises, flight may proceed, but log entry must be made and filter must be changed prior to next flight. If light cannot be extinguished, filter must be changed prior to flight. In flight, reduce thrust to extinguish warning. Operate engine at thrust levels to keep warning extinguished. If indication continues, engine should be shut down.
	If dual element oil filter is installed, primary filter has bypassed. Secondary filter does not incorporate bypass feature.	If dual element oil filter is installed and applicable ECAM software changes have been incorporated or airline is operating under Airbus Special Operating Procedure, engine power reduction and shutdown is not required. Log entry should be made for appropriate maintenance action.
ENG OIL TEMP HI	Oil temperature exceeds limits (exceeds 163°C for more than 20 min. or exceeds 177°C at any time).	Move throttle lever toward idle. If oil temperature does not return within limits, shut down engine.
ENG OIL TEMP LO	Oil temperature below 50°C when a takeoff is attempted.	Do not perform takeoff. Warm engine at idle until oil temperature is at least 50°C to ensure adequate heat to prevent fuel icing.

APPENDIX

ENGINE-RELATED ECAM MESSAGES (Cont'd)

MESSAGES	DEFINITION	RECOMMENDED ACTION
ENG EPR MODE FAULT	FADEC is unable to control in the EPR mode and has reverted to the N1 mode.	When conditions permit, reduce thrust to approximately 1.1 EPR (70% N1). Cycle mode selector switch to N1 then back to EPR to reset FADEC. If successful, continue operation. If unsuccessful, reduce throttle levers, as above, and select N1 mode on both engines.
ENG OVER LIMIT	N1, N2 or EGT over certified limits.	Retard throttle levers to return engine parameters within limits and continue operation. Record exceedances for maintenance action.
ENG OVERSPEED DETECTED	N1 has exceeded 117% or N2 has exceeded 110.3%.	Monitor engine parameters for possible flameout.
ENG FUEL FILTER CLOG	Fuel filter differential pressure has reached 5.5 psi. Fuel will bypass filter at 9 psi.	Continue operation and monitor engine parameters.
THROTTLE FAULT	FADEC detects disagreement between the two throttle resolvers or failure of both throttle resolvers.	In flight, the FADEC controls the engine to the thrust corresponding to the last valid throttle lever position. On ground, engine thrust is limited to idle thrust Engine should only be shut down if excess thrust cannot be balanced by the other engine. Engine can be restarted for electrical power and bleed extraction.