



U.S. Department  
of Transportation  
Federal Aviation  
Administration



# Memorandum

Subject: **ACTION:** Raytheon Model 390, Equivalent Level of Safety; for Use of Digital Only Display for Engine Oil Pressure and Temperature, High-Pressure Rotor Speed (N<sub>2</sub>) and Engine Fuel Flow.  
ACE-00-02

Date: January 6, 2000

From: Program Manager, ACE-117W,  
Wichita Aircraft Certification Office

Reply to  
Attn. of: Charles D. Riddle  
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To: Manager, Project Support Section, ACE-112, Small  
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## **BACKGROUND**

Raytheon Aircraft Company (RAC) has requested an Equivalent Level of Safety to 14 CFR 23.1305(a)(2), (a)(3), (c)(2), (c)(5), and part 23.1549(a) through (c) as required by 14CFR Part 21.21(b) on the RAC Model 390 for the use of direct-reading digital only displays for engine oil temperature and pressure, high-pressure turbine speed (N<sub>2</sub>), and fuel flow. RAC has installed a Rockwell Collins electronic multi-function display for engine instruments and proposes to display engine oil temperature and pressure, N<sub>2</sub> and fuel flow information in a digital only format.

## **DISCUSSION OF APPLICABLE REGULATIONS**

14 CFR part 23.1305 with respect to the applicable paragraphs reads as follows:  
The following are required powerplant instruments:

(a) *For all airplanes.*

(2) An oil pressure indicator for each engine.

(3) An oil temperature indicator for each engine.

(c) *For turbine engine powered airplanes.* In addition to the powerplant instruments required by paragraph (a) of this section, the following powerplant instruments are required:

(2) A fuel flowmeter indicator for each engine.

(5) A tachometer indicator (to indicate the speed of the rotors with established limiting speeds) for each engine.

14CFR 23.1549 reads as follows:

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For each required powerplant and auxiliary power unit instrument, as appropriate to the type of instrument--

(a) Each maximum and, if applicable, minimum safe operating limit must be marked with a red radial or a red line;

(b) Each normal operating range must be marked with a green arc or green line, not extending beyond the maximum and minimum safe limits;

(c) Each takeoff and precautionary range must be marked with a yellow arc or a yellow line; and

Other avionics installations in similar airplanes have been granted an Equivalent Level of Safety for direct reading, digital only displays for N<sub>2</sub> and fuel flow. A partial list of these other airplanes are the Cessna Models 550, S550, 552 and 560 airplanes on Type Certificate Data Sheet (TCDS) A22CE, and the Cessna Model 750 on TCDS T00007WI. Although the Cessna Model 750 is a Transport Category airplane, it is noteworthy to state that the regulatory requirements of §23.1549 and §25.1549 are identical.

### **RAYTHEON AIRCRAFT COMPANY POSITION**

Raytheon Aircraft is requesting an equivalent level of safety approval for secondary engine parameters to be displayed in digital format with a declutter mode, on a Collins AFD-3010 Liquid Crystal Display (LCD) integrated Multifunction display. In the declutter mode, N<sub>2</sub>, Fuel Flow, Oil Temp, Oil Pressure are suppressed leaving N<sub>1</sub> and ITT for monitoring the engines. A similar method of display and declutter has been certified on the Beech Model 2000 Starship, reference Project No. CA7250CD-DO, with Special Condition contained in Issue paper S-5, "Electronic Display Units"

Raytheon Aircraft is proposing to certify the display of secondary engine information; i.e., N<sub>2</sub>, Fuel Flow, Oil Temp, Oil Pressure, in a digital only format, and to put parameters on display only when they are either needed or desired by the flight crew, thereby reducing both light and visual clutter in the flight deck. Refer to FARs 23.1305 (a)(2), (a)(3), (c)(2) and (c)(5), 23.1311(a)(1), (a)(2), (a)(3), (a)(4), (a)(6), (a)(7), (b), 23.1321(a), (b), (c), 23.1549(a), (b), and (c) for basis of equivalency.

(Note: words in Italics are text taken from 14CFR23)

Discussion per Applicable FAR parts follows.

***FAR 23.1305 (a)(2), (a)(3), (c)(2) and (c)(5)***

*The following are required powerplant instruments:*

*(a) For all airplanes.*

*(2) An oil pressure indicator for each engine.*

*(3) An oil temperature indicator for each engine.*

*(c) For turbine engine powered airplanes. In addition to the powerplant instruments required by paragraph (a) of this section, the following powerplant instruments are required:*

*(2) A fuel flowmeter indicator for each engine.*

*(5) A tachometer indicator (to indicate the speed of the rotors with established limiting speeds) for each engine.*

This section adds the reference to AC 23.1311-1A paragraph 8.5.6. and rationale for a demonstration of an equivalent level of safety.

8.5.6 The required FAR 23.1305 powerplant instruments referred to as “Indicators”, i.e., Oil Temp/Pressure and Engine High Pressure Rotor Speed (N<sub>2</sub>) and Fuel Flow, should have the ability to provide trend or rate-of-change information, unless a finding of equivalence is made for direct-reading alphanumeric displays. The finding of equivalence should consider the following factors:

8.5.6.1 The visibility and relative location of the indicated parameter should be reviewed, including appropriate conditions of lighting and instrument panel vibration.

Equivalency Discussion

The display of N<sub>2</sub>, Oil Temp/Pressure, fuel flow is located so that the pilot seated at the controls can monitor the secondary powerplant instruments with minimum head and eye movement. The visibility and relative location of the indicated parameters including lighting conditions will be evaluated during certification flight-testing. Instrument panel vibration will be flight tested per Flight Test Plans FTP 5.27 and FTP 5.31.

8.5.6.2 The ability to assess necessary trend or rate-of-change information quickly, including if and when this information may be needed during in-flight engine restarts.

Equivalency Discussion

The secondary parameters are always presented to the pilot, when an engine is not running. The necessary trend or rate-of-change and the ability of the flight crew to quickly assess trends will be evaluated during certification flight-testing.

8.5.6.3 The ability to assess how close the indicated parameter is relative to a limit.

Equivalency Discussion

The required display alerts the pilot of improper or unsafe powerplant operating conditions, by providing visual color change between normal (Green) maximum (or minimum) continuous operating limit, cautionary/transient (Yellow) an operational region above (or below) the normal limit. When operating in a transient limit region, information is typically presented in yellow to indicate the possible need for future corrective action. Redline (Red) limit for a given parameter is usually the next higher or lower increment of resolution, as displayed to the pilot, above (below) the yellow limit. These limits are distinct and commensurate with other cockpit warnings as seen by the pilot. These limits have been set by the engine manufactures operating limits.

8.5.6.4 For multiengine aircraft, the value to the crew of quickly and accurately comparing engine-to-engine data.

Equivalency Discussion

All secondary engine parameters are automatically displayed if any parameter has an out of limit condition occur, or if an engine miscompare occurs. The engine parameter labels are displayed between the left and right engine digital readouts, allowing quick and accurate comparing engine-to-engine data.

8.5.6.5 Compensating engine design features or characteristics that would forewarn the pilot prior to the parameter reaching the operating limit (e.g., redline).

Equivalency Discussion

Transient limits have been designed into the engine indicating system to forewarn the pilot prior to exceeding a Red Line limit (high or low) by giving a yellow/cautionary indication.

***FAR 23.1311(a)(1 and 2)***

Electronic display indicators, including those with features that make isolation and independence between powerplant instrument systems impractical, must:

- (1) Meet the arrangement and visibility requirements of § 23.1321.*
- (2) Be easily legible under all lighting conditions encountered in the cockpit, including direct sunlight, considering the expected electronic display brightness level at the end of an electronic display indicator's useful life. Specific limitations on display system useful life must be contained in the Instructions for Continued Airworthiness required by § 23.1529.*

Equivalency Discussion

Arrangement, visibility, and legibility will be determined in flight test.

***FAR 23.1311(a)(3, 4, 6 and 7)***

*(3) Not inhibit the primary display of attitude, airspeed, altitude, or powerplant parameters needed by any pilot to set power within established limitations, in any normal mode of operation.*

*(4) Not inhibit the primary display of engine parameters needed by any pilot to properly set or monitor powerplant limitations during the engine-starting mode of operation.*

*(6) Incorporate sensory cues for the pilot that are equivalent to those in the instrument being replaced by the electronic display indicators.*

*(7) Incorporate visual displays of instrument markings, required by §§ 23.1541 through 23.1553, or visual displays that alert the pilot to abnormal operational values or approaches to established limitation values, for each parameter required to be displayed by this part.*

**Equivalency Discussion**

N2, Oil Pressure, Oil Temperature, Fuel Flow, and Fuel Temp displays are displayed continuously during takeoff, and may be inhibited, i.e., not displayed, automatically after takeoff only after the pilot has reduced the engine power from takeoff to max. continuous or lower. These parameters are electronically monitored at all times however, and if any secondary engine parameters are not in the normal range, displays for both engines will automatically pop- up for display without pilot action. Once displayed, these parameters cannot be inhibited unless all parameters are once again in the normal range. The crew also has the capability to call up the parameters for display at any time by pressing the ENGINE push button on the Display Control Panel (DCP). The parameters displayed will remain until the ENGINE button is pushed again. The secondary engine parameters are displayed continuously during an engine start. Monitoring N2 is only required during an engine start and has no cautionary/transient limitation.

The N2, FUEL FLOW, OIL TEMP, or OIL PRESS Normal limit display is Green in color. The above parameters are monitored in the Multi-Function Display (MFD) and in the event a limit is exceeded the Green digital display flashes YELLOW for 5 seconds then steady YELLOW indicating a transient limits/cautionary has been exceeded. When a redline limit is exceeded the YELLOW digit will change and flash RED for 5 seconds and then turn steady RED indicating a limit is exceeded and is displayed. The fault will also cause the corresponding Yellow cautionary or red warning fault lights to flash, until the crew acknowledges the occurrence by depressing the master CAUTION or WARNING reset button.

***FAR 23.1311(b)***

*The electronic display indicators, including their systems and installations, and considering other airplane systems, must be designed so that one display of information essential for continued safe flight and landing will remain available to the crew, without need for immediate action by any pilot for continued safe operation, after any single failure or probable combination of failures.*

**Equivalency Discussion**

Automatic source selection between data sources is provided. Left Data Concentrator Unit (L DCU) is priority source for left engine. Right Data Concentrator Unit (R DCU) is priority source for right engine. Cross-side DCU is secondary source. The Williams Engine Control Unit's (ECU) are third priority.

***FAR 23.1321(a)***

Each flight, navigation, and powerplant instrument for use by any required pilot during takeoff, initial climb, final approach, and landing must be located so that any pilot seated at the controls can monitor the airplane's flight path and these instruments with minimum head and eye movement. The powerplant instruments for these flight conditions are those needed to set power within powerplant limitations.

**Equivalency Discussion**

The display of N2, Oil Temp/Pressure, Fuel Flow is located so that the pilot seated at the controls can monitor the airplane's flight path and these secondary powerplant instruments with minimum head and eye movement. The powerplant instruments for these flight conditions are not needed to set power within powerplant limitations.

***FAR 23.1321(b)***

*For each multiengine airplane, identical powerplant instruments must be located so as to prevent confusion as to which engine each instrument relates.*

**Equivalency Discussion**

The N2, FUEL FLOW, OIL TEMP, and OIL PRESS labels are displayed between the left and right engine digital readout so as to prevent confusion as to which engine instrument relates.

***FAR 23.1321(c)***

*Instrument panel vibration may not damage, or impair the accuracy of any instrument.*

**Equivalency Discussion**

Instrument panel vibration will be flight tested per FTP 5.27 and FTP 5.31.

***FAR 23.1321(e)***

*If a visual indicator is provided to indicate malfunction of an instrument, it must be effective under all probable cockpit lighting conditions.*

**Equivalency Discussion**

Any time the parameter is not available YELLOW dashes replace the digital display of information.

***FAR 23.1549(a)***

*Each maximum and, if applicable, minimum safe operating limit must be marked with a red radial or a red line;*

**Equivalency Discussion**

The display of each maximum and where appropriate, minimum safe operating limit is displayed in RED color.

***FAR 23.1549(b)***

*Each normal operating range must be marked with a green arc or green line, not extending beyond the maximum and minimum continuous safe limits;*

**Equivalency Discussion**

The display of each normal operating range is displayed in GREEN color.

***FAR 23.1549(c)***

*Each takeoff and precautionary range must be marked with a yellow arc or a yellow line; and*

**Equivalency Discussion**

The display of each cautionary/transient limit is displayed in YELLOW color.

**Conclusion:**

The visibility and relative location of the indicated parameters including lighting conditions will be evaluated during certification flight-testing. The ability of the crew to assess how close the indicated parameter is relative to a cautionary or redline limit and the value to the crew of quickly and accurately comparing engine to engine data will be evaluated during certification flight testing. N<sub>2</sub>, Oil Temp/Press, and Fuel Flow are considered secondary engine parameters, and are always displayed on the ground and in the air when the engine is in the start mode. The parameters when decluttered will pop-up automatically, when any normal operating limit is reached or exceeded and remain displayed continuously until the parameter changes back into the normal range. The required displays and alerts for each phase of flight and airplane configuration are provided in a timely manner and in a form to direct the flight crew's attention to the display, and carry out necessary remedial actions. The electronic display of secondary engine parameters provides the pilot with visual

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discernible annunciators that alert the pilot of improper or unsafe powerplant operating conditions. The visual color changes between normal, cautionary/transient, and redline limits are distinctive under all normal lighting conditions, and are commensurate with other cockpit warnings. Therefore we feel that the electronic display of secondary engine parameters provides an equivalent level of safety to that intended by the regulation. Raytheon Aircraft requests the FAA's concurrence with the stated equivalent level of safety for the aforementioned FARs.

**FAA POSITION**

In addition to the requirements of 14CFR part 23.1305 and 23.1549 and the guidance provided in Advisory Circulars AC20-88A, recently released AC23.1311-1A contains criteria which should be considered when seeking an Equivalent Level of Safety for powerplant displays. Per AC23.1311-1A, Section 8.5 "Powerplant Displays", paragraphs 8.5.6 through 8.5.6.5. state the following factors should be considered:

- (a) The ability to assess necessary trend or rate information quickly, including if and when this information may be needed during in-flight engine restarts.
- (b) The ability to assess how close the indicated parameter is relative to the redline limit.
- (c) Value to the crew of quickly and accurately comparing engine to engine data.
- (d) Compensating engine design features or characteristics that would forewarn the crew prior to the parameter reaching redline limit

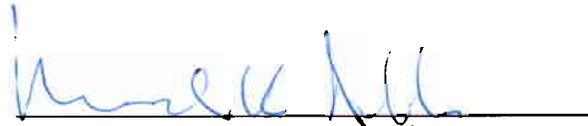
**RECOMMENDATION**

The FAA concurs with the Raytheon Aircraft Company position and finds that an Equivalent Level of Safety to 14 CFR part 23.1305(a)(2), (a)(3), (c)(2), (c)(5), and 23.1549(a) through (c) as required by 14CFR Part 21.21(b) may be granted for the use of direct reading, digital only displays for Engine oil pressure and temperature, high-pressure turbine speed (N<sub>2</sub>), and fuel flow.

**CONCURRENCE**



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