Federal Aviation Administration

# Memorandum

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| Date: | March 26, 2015 |
| To: | Manager, Certificate Management and Safety Oversight Branch, ACE-120A |
| From: | Manager, Small Airplane Directorate, ACE-100 |
| Prepared by: | Donald J Young, Certificate Management and Safety Oversight Branch, ACE-120A |
| Subject: | INFORMATION: Equivalent Level of Safety (ELOS) Finding for Honda Aircraft Company, Model HA-420 (HondaJet), Digital Display Only, Project TC9438AT-A |
| ELOS Memo#: | ACE-15-09 |
| Regulatory Ref: | 14 CFR 23.1305(a)(1)(2)(3), 23.1305(c)(2)(5), 23.1321(a), 23.1521(b)(5), 23.1521(c)(4), 23.1337(b)(1), 23.1521(b)(5), 23.1521(c)(4), 23.1549, and 23.1553 |

This memorandum informs the certificate management aircraft certification office of an evaluation made by the Accountable Directorate on the establishment of an equivalent level of safety finding for the Honda Aircraft Company Model HA-420.

**Background:**

The Honda Aircraft CompanyHA-420 airplane is powered by two General Electric Honda Aero Engines (GHAE) Model HF120 medium bypass turbofan engines mounted in a unique over-the-wing configuration. The avionics suite incorporates a Garmin G3000 Integrated Flight Deck with three displays. Two of the displays are configured as pilot and copilot Primary Flight Displays (PFD) and the third is configured as a Multi-Function Display (MFD) and located between the pilot and copilot PFDs. The Fuel Quantity instruments are shown directly below the engine instruments in an area in the upper left corner of the MFD. The HA-420 Fuel Quantity indicating system presents the Fuel Quantity of the Left (L), Right (R), and Center (CTR) fuel tanks as well as the total Fuel Quantity in all tanks in a digital numeric presentation only.

Appropriate display of critical powerplant parameters is essential to the safe operation of an airplane. Certain parameters require the flight crew to assess trend or rate-of-change information. While direct-reading alphanumeric-only displays add a precise, quantitative indication, it may limit the flight crew's ability to assess trend information and result in reduced crew awareness. Direct-reading alphanumeric displays are also limited in their ability to provide a comparison of

parameters from multiple engines or to check the general proximity of differing parameters against their individual limits.

AC 23.1311-1C, Installation of Electronic Display in Part 23 Airplanes, provides guidance for the design, installation, integration, and approval of electronic flight deck displays, components, and systems installed on part 23 airplanes, including the factors to be considered in obtaining an ELOS for digital-only display of powerplant parameters. ELOS for this design feature have been granted for many turbofan-powered part 23 airplanes.

**Applicable regulations:**

14 CFR 23.1305(a)(1)(2)(3), 23.1305(c)(2)(5), 23.1321(a), 23.1521(b)(5), 23.1521(c)(4), 23.1337(b)(1), 23.1521(b)(5), 23.1521(c)(4), 23.1549, and 23.1553.

**Regulations requiring an ELOS finding:**

| 14 CFR | Requirement |
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| § 23.1305(a)(1) | Requires a “Fuel Quantity indicator for each tank” be provided for all airplanes. |
| § 23.1305(a)(2) | Requires an “Oil Pressure indicator for each engine” be provided for all airplanes. |
| § 23.1305(a)(3) | Requires an “Oil Temperature indicator for each engine” be provided for all airplanes. |
| § 23.1305(c)(2) | Requires that “A fuel flowmeter indicator for each engine” be provided for turbine engine-powered airplanes. |
| § 23.1305(c)(5) | Requires that “A tachometer indicator (to indicate the speed of the rotors with established limiting speeds) for each engine” be provided for turbine engine-powered airplanes. |
| § 23.1337(b) | Requires that “There must be a means to indicate to the flight crew members the quantity of usable fuel in each tank during flight.” It also requires that “An indicator calibrated in appropriate units and clearly marked to indicate those units must be used.” |
| § 23.1549 | Requires that powerplant instruments are marked in accordance with the operating limitations of the powerplant(s). |
| § 23.1553 | Requires that “A red radial line must be marked on each indicator at the calibrated zero reading.” |

**Description of compensating design features or alternative Methods of Compliance (MoC) which allow the granting of the ELOS (including changes, limitations, or equipment needed for equivalency):**

The engine operating parameters are presented in the engine indicating partition of the MFD within the pilot and copilot primary field of view. The readability of the displays under a full range of ambient lighting conditions and cockpit vibration levels has been evaluated and determined to be appropriate for all situations.

Digital-only Display of Fuel Tank Quantities

The Fuel Quantity indicators are presented in the fuel system indicating partition of the MFD within the pilot and copilot primary field of view. The readability of the displays under a full range of ambient lighting conditions and cockpit vibration levels has been evaluated and determined to be appropriate for all situations.

To meet the § 23.1305(a)(1) requirement, the HA-420 design displays fuel quantity in each tank to the pilot and co-pilot only in a digital numeric format rather than the traditional radial-arc gauge format. The digital numeric display of fuel quantity changes color based on the amount of fuel in each of the tanks to meet § 23.1549 requirements.

The compensating features contribute to the ELOS of the digital numeric display of fuel quantity with regard to the ability to—

(1) Assess necessary rate of change information;
(2) Assess how close the indicated parameter is to a limit; and
(3) The ability to compare engine-to-engine data; and
(4) The need to forewarn the crew before the parameter reaches the operating limit.

These compensating features are:

- Digital numeric indications provide a better assessment of rate of change for fuel quantity as opposed to traditional radial-arc dial indications.
- Fuel Quantity indications are calibrated to read “zero” at the unusable Fuel Quantity, therefore making it easy to assess how close the remaining fuel quantity is to the usable fuel limit.
- Low fuel-level indication provides forewarning of approach to limits.
- Fuel Quantity indication provides a compelling indication when fuel quantity has reached the unusable fuel limit.
- Side-by-side arrangement allows for easy comparison of fuel tank quantities.
- Fuel imbalance indication provides an additional indication when the quantities in the fuel tanks are not balanced.
- Fuel system synoptic page provide fuel quantity in both digital numeric and digital pictorial representation display formats.

Digital-only Display of Oil Pressure

To meet the § 23.1305(a)(2) requirement, the HA-420 design displays oil pressure to the pilot and co-pilot in a digital numeric format only rather than the traditional radial-arc gauge format. The digital numeric display of oil pressure changes color based on the operational status of the engines to meet the § 23.1549 requirement.

The compensating features contribute to the ELOS of the digital numeric display of oil pressure with regard to the ability to—

(1) Assess necessary rate of change information;
(2) Assess how close the indicated parameter is to a limit;
(3) The ability to compare engine-to-engine data; and
(4) The need to forewarn the crew before the parameter reaches the operating limit.

These compensating features are:

- Oil Pressure is not used in power setting or starting
- Monitoring rate of change and proximity to limit information using a radial-arc dial indication would not be practical for normal engine operation.
- A precautionary range is implemented to forewarn the crew before the parameter reaches the operating limit.
- Appropriate Crew Alerting System (CAS) messages are included to supplement the digital numeric indication when Oil Pressure approaches or reaches an operating limit.
- Oil Pressure exceedance is an indication of engine malfunction, which cannot be prevented by pilot action.
- Ability to compare engine-to-engine oil pressure indication provides the ability to detect a change in oil system function before reaching an operating limit.

Digital-only Display of Oil Temperature

To meet the § 23.1305(a)(3) requirement, the HA-420 design displays *Oil Temperature* to the pilot and co-pilot only in a digital numeric format rather than the traditional radial-arc gauge format. The digital numeric display of oil temperature changes color based on the operational status of the engines to meet the § 23.1549 requirement.

The compensating features contribute to the ELOS for the digital numeric display of oil temperature with regard to—

(1) The ability to assess necessary rate of change information;
(2) Assess how close the indicated parameter is to a limit;
(3) The ability to compare engine to engine data; and
(4) The need to forewarn the crew before the parameter reaches the operating limit.

These compensating features are:

- Oil Temperature is not used in power setting or starting.
- Oil Temperature changes slowly over time.
- A precautionary range is implemented to forewarn the crew before the parameter reaches the operating limit.
- Appropriate CAS messages are included to supplement the digital numeric indication when Oil Temperature approaches or reaches an operating limit.
- Ability to compare engine to engine Oil Temperature indication provides the ability to detect a change in oil system function before reaching an operating limit.

Digital-only Display of Engine Fuel Flow

To meet the § 23.1305(c)(2) requirement, the HA-420 design displays fuel flow to the pilot and co-pilot only in a digital numeric format.

The compensating features contribute to the ELOS of the digital-only display of fuel flow with regard to the ability to—

(1) Assess necessary rate of change information;
(2) Assess how close the indicated parameter is to a limit
(3) The ability to compare engine-to-engine data; and
(4) The need to forewarn the crew before the parameter reaches the operating limit.

These compensating features are:

- The fuel flow parameter does not have an operating limit
- Engine starting and fuel-on selection is automatic
- Ability to compare engine to engine fuel flow indication

Digital-only Display of High Pressure Shaft (Turbine) Speed, N2

To meet the § 23.1305(c)(5) requirement, the HA-420 design displays N2 to the pilot and co-pilot only in a digital numeric format rather than the traditional radial gauge format. The digital numeric display of N2 changes color based on the operational status of the engines to meet the § 23.1549 requirement.

The compensating features contribute to the ELOS of the digital-only display of N2 with regard to the ability to—

(1) Assess necessary rate of change information;
(2) Assess how close the indicated parameter is to a limit;
(3) The ability to compare engine-to-engine data; and
(4) The need to forewarn the crew before the parameter reaches the operating limit.

These compensating features are:

- Automatic FADEC power setting eliminates the need to monitor N2 during power setting
- The FADEC engine speed governing logic includes an N2 limiter.
- Engine starting and fuel-on selection is automatic.
- High rotor over-speed protection.
- Ability to compare engine to engine N2 indication.
- N2 exceedance is annunciated with additional sensory queues.

Zero wing fuel tank quantities shown by red background field color

The HA-420 Fuel Quantity indicating system presents the Fuel Quantity of the Left (L), Right (R), and Center (CTR) fuel tanks as well as the total Fuel Quantity in all tanks only in a digital numeric presentation. The primary Fuel Quantity indicator display is shown in figure 1.

The Fuel Quantity indicator displays the Fuel Quantity in each tank and the total Fuel Quantity in green digital numeric values on a black background (see figure 1) whenever the Fuel Quantity is greater than the low-fuel-level indication quantity for that tank. Note that there is no low-fuel-level indication quantity for the CTR fuel tank because the CTR tank fuel is fed only to the L and R fuel tanks (not directly to the engines) and the fuel in the CTR fuel tank is intended to be fully consumed during normal operations.

Once the Fuel Quantity in the L or R fuel tanks drops below the low-fuel-level indication quantity, an amber Crew Alerting System (CAS) message is displayed and the Fuel Quantity digital numeric indication turns to amber digits on a black background (see figure 2). The CAS message and the amber indication of the Fuel Quantity for that tank will remain as displayed until the indicated Fuel Quantity reaches zero, at which point, the digital numeric indication of the Fuel Quantity will change from amber digits on a black background to white digits on a red background (see figure 2).

**Figure 1: Model HA-420** Fuel Quantity **Indicator (Normal Condition)**

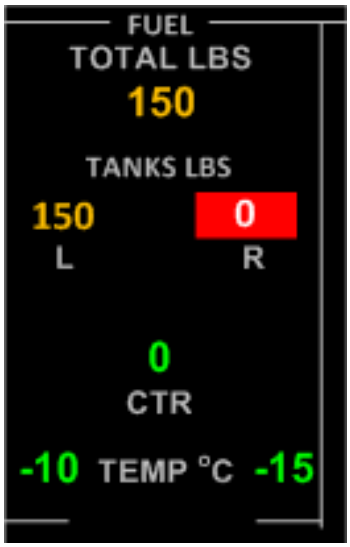


**Figure 2: Model HA-420** Fuel Quantity **Indicator (Abnormal Condition)**

In addition, the HA-420 fuel system provides the crew with access to a fuel system synoptic page that provides a secondary Fuel Quantity display. The fuel system synoptic page presents the fuel quantity in digital numeric and digital pictorial representation display formats. The digital pictorial representation for the left and right wing fuel tanks shows the normal and cautionary (fuel quantities below the low-fuel-level indication quantity) levels and a red line at zero usable fuel as specified in § 23.1337(b)(1).

**Explanation of how design features or alternative Methods of Compliance (MoC) provide an equivalent level of safety intended by the regulation:**

The engine indicating display is located within the pilot and co-pilot primary field of view on the MFD. The readability of the displays under a full range of ambient lighting conditions (day, night, and direct sunlight) and cockpit vibration levels is adequate. The presentation of the engine operating parameters are designed to use the colors in accordance with § 23.1549 to indicate the state of operation.

<u>Digital-only Digital Display of Fuel Tank Quantities</u>

The fuel system indicating display is located within the pilot and co-pilot primary field of view on the MFD. The readability of the displays under a full range of ambient lighting conditions (day, night, and direct sunlight) and cockpit vibration levels is adequate. The presentation of the engine operating parameters are designed to use the colors in accordance with § 23.1549 to indicate the state of operation. The following provides an explanation of the compensating features:

(1) Digital numeric indications provide a better assessment of rate of change for fuel quantity as opposed to traditional radial-arc dial indications.

(a) The digital numeric indication provides a more precise way to assess rate of change information than a traditional radial-arc dial indication. The increments of fuel quantity used by the digital numeric display (10 lbs.) are small compared to the full range of the tank quantity (630 lbs. for the wing tanks and 1550 lbs. for the center tank). These small increments in fuel

quantity are difficult to discern using a traditional radial-arc gauge. A digital numeric indication provides a better way to display small changes in fuel quantity so the crew will have an enhanced ability to assess rate of change using the digital numeric indication compared to a traditional radial-arc dial indication.

(b) Fuel Quantity rate of change is not critical for in-flight restarting and does not need to be assessed quickly for any operational situations. Fuel Quantity changes relatively slowly during all flight operations. Therefore, the Fuel Quantity indication would need to be observed continuously for a long period of time to assess the rate of change of Fuel Quantity. This is not the function of the Fuel Quantity indications. The Fuel Quantity indications provide an instantaneous status of fuel tank quantity which is used to determine whether an imbalance condition exists or whether the fuel level is approaching the limit. As such, the digital numeric indication provides an ELOS for these functions.

(2) Fuel Quantity indications are calibrated to read “zero” at the unusable Fuel Quantity, therefore making it easy to assess how close the remaining Fuel Quantity is to the usable fuel limit.

The calibration of the Fuel Quantity indicator to read “zero” when the fuel level in the tank reaches the unusable Fuel Quantity allows the pilot to assess the proximity to the limit. Since the limiting value is “0” (as displayed on the digital numeric indication), the Fuel Quantity displayed is the quantity of usable fuel remaining (as specified by § 23.1337(b)). Thus, the displayed Fuel Quantity provides an indication of the proximity to the limit. The digital numeric indicators provide an accurate assessment of the proximity to the limit that affords an ELOS to a traditional radial-arc dial indicator.

(3) Low-fuel-level indication provides forewarning of approach to limits.

The Fuel Quantity indicators display the Fuel Quantity in each wing tank as well as the combined Fuel Quantity in all of the fuel tanks with amber digits on a black background when the quantity of fuel in that tank is less than the low-fuel-level indication quantity. In addition, an amber Crew Alerting System (CAS) message is provided when the Fuel Quantity in the respective fuel tank drops below the low fuel level indication quantity. This provides a forewarning to the flightcrew that the Fuel Quantity in that tank is low and approaching the unusable Fuel Quantity, which affords an ELOS to a traditional radial-arc gauge.

(4) Fuel Quantity indication provides a compelling indication when Fuel Quantity has reached the unusable fuel limit.

If the Fuel Quantity in a wing tank reaches zero usable fuel, the digital numeric indication for that tank changes to a white digital numeric “0” on a red background. This provides a compelling indication that the Fuel Quantity has reached the zero usable Fuel Quantity. This indication provides an equivalent indication to a red radial line on a traditional radial-arc gauge and therefore provides an ELOS to a traditional radial-arc dial indicator.

(5) Side-by-side arrangement allows for easy comparison of fuel tank quantities.

The arrangement of the Fuel Quantity indications on the MFD position the left and right wing tank quantities side-by-side to allow easy comparison of the Fuel Quantity in each wing tank. Although the *Fuel quantities* will generally be similar if the engines have been operated in unison during the flight, a difference between the two wing tanks is not necessarily indicative of a fuel system or engine problem. The primary reason to assess the Fuel Quantity

between the two wing tanks is to maintain the balance of the aircraft within approved imbalance levels for aerodynamic handling reasons. Because the digital numeric indication provides a better resolution than a traditional radial-arc dial indication, it is easier to assess the level of imbalance with digital numeric indicators than it is with traditional radial-arc gauges.

(6) Fuel imbalance indication provides an additional indication when the quantities in the fuel tanks are not balanced.

In addition to the side-by-side arrangement of the wing tank Fuel Quantity indications, the Fuel Quantity display also incorporates a fuel imbalance indication. The imbalance indication is a textual indication displayed in amber text on the fuel system indicating display, whenever the difference between the left and right wing tank Fuel Quantity is greater than the maximum imbalance quantity. There is also an accompanying amber caution CAS message. These imbalance indications enhance the pilot awareness that a fuel imbalance condition exists and serve as a compensating feature that provides an ELOS to traditional radial-arc dial indicators.

(7) Fuel system synoptic page provides Fuel Quantity in both digital numeric and digital pictorial representation display formats.

The fuel system synoptic page provides a secondary Fuel Quantity display that presents the Fuel Quantity in digital numeric and digital pictorial representation display formats. The digital pictorial representation for the left and right wing fuel tanks shows the normal, cautionary (fuel quantities below the low-fuel-level indication quantity), and unusable (red line at zero usable fuel as specified in § 23.1553) fuel quantities. This graphical format, while not required for Fuel Quantity indication, is a compensating feature that provides an ELOS to a traditional radial-arc dial indication of Fuel Quantity during routine monitoring as well as an intuitive representation of fuel system status and increased awareness during abnormal operations such as cross feed.

<u>Digital-only Display of Oil Pressure</u>

(1) Oil Pressure is not used in power setting or starting.

The primary thrust setting parameter is fan speed (N1). Oil Pressure is not used in the power setting process and is not monitored during engine starting. Further, the oil pressure operating limits only apply to the engine speed range between idle and redline.

(2) Monitoring rate of change and proximity to limit information using a radial-arc dial indication would not be practical for normal engine operation.

(a) The lubrication system on the HF120 engine is an unregulated system such that Oil Pressure varies with the lubrication pump speed and Oil Temperature. The corresponding operating limits for Oil Pressure also change as a function of turbine speed (N2) as defined in the HF120 Operating Instructions.

(b) The advantage of an unregulated oil system is that the engine-oil-pressure indication can provide an assessment of the health of the engine lubrication system. Low Oil Pressure on the engine is an indication of internal leakage in the flow circuit or an oil starvation condition while high Oil Pressure on the engine is an indication of flow blockage. However, because the oil pressure limits and Oil Pressure itself are constantly changing with engine speed, it is impractical to use a radial-arc dial indication to assess rate of change or proximity to limits because it would be difficult and confusing.

(3) A precautionary range is implemented to forewarn the crew before the parameter reaches the operating limit.

Since Oil Pressure and the oil pressure limits vary with engine speed, a typical radial-arc dial indicator is impractical. To compensate for this condition, the oil-pressure indication has implemented a precautionary range with sufficient margin to alert the crew before Oil Pressure reaches the low oil pressure-operating limit. If the engine Oil Pressure drops into the precautionary range, the digital numeric indication changes from green digits on a black background (normal operating indication) to amber digits on a black background. By utilizing a precautionary range, the digital numeric indication provides adequate warning that Oil Pressure is approaching an operating limit and therefore offers an ELOS to a traditional radial-arc gauge.

(4) Appropriate Crew Alerting System (CAS) messages are included to supplement the digital numeric indication when Oil Pressure approaches or reaches an operating limit.

If Oil Pressure increases or decreases beyond the oil pressure-operating limits, a red warning CAS message and the master warning indication is provided in addition to the digital numeric oil pressure indication changing to white digits on a red background. The CAS messages supplement the digital numeric indication to provide the crew with increased awareness and recognition of oil pressure exceedance conditions and serve as a compensating feature that offers an ELOS to a traditional radial-arc gauge.

(5) Oil Pressure exceedance is an indication of engine malfunction, which cannot be prevented by pilot action.

Oil-pressure indication exceedance (low pressure or high pressure) either is typically caused by a failure of the oil pressure indicating system or is an indication of an actual engine malfunction. Except for an oil starvation condition that is caused by negative acceleration, oil pressure exceedance conditions are not the result of pilot inputs and therefore cannot be avoided by pilot action. The HF120 Engine Operating Instructions indicate the pilot response to an oil limit exceedance is to monitor the other engine indications to determine if the engine is showing other signs of malfunction. If Oil Pressure cannot be maintained above the low oil pressure-operating limit, the only corrective action available to the pilot is to perform a voluntary in-flight shutdown. This would only be done, if, in the pilot’s judgment, it were safe to do so and maintain continued safe flight and landing. Likewise, if the oil pressure cannot be maintained below the high oil pressure-operating limit after the engine has warmed up following a start, the only corrective action available to the pilot is to perform a voluntary shutdown. High oil pressure indications in flight do not require a shutdown, but do require that the condition be corrected before the next operation. Therefore, providing the pilot with forewarning of approach to a limit does not allow the pilot to prevent the exceedance and only provides additional time to make decisions regarding how to respond.

(6) Ability to compare engine to engine oil-pressure indication provides the ability to detect a change in oil system function before reaching an operating limit.

(a) Most engine malfunctions that lead to oil pressure exceedance conditions are progressive over long time periods and many flights. The most common way to detect these conditions is to compare Oil Pressure between the two engines and look for differences between the engines when they are set at the same operating condition (i.e. at idle during engine warm up or during a climb with both engines at maximum continuous thrust (MCT)). The most practical way to detect these malfunctions is to monitor the long-term trend of the engine to engine

variation in Oil Pressure. The design of the digital-only display facilitates this comparison by arranging the left and right engine oil pressure indications in a side-by-side layout to enable easy comparison between the two engines.

(b) Since observing these differences in the engine indications relies upon the engines operating at stabilized conditions, rate of change information is not an important aspect of this evaluation. Often the differences between the engines will be small (less than 5 psi) relative to the full scale of the gauge (300 psi) such that a digital numeric indication gives a more precise way to assess these engine to engine variations as opposed to a traditional radial-arc gauge. By providing a precise way to compare Oil Pressure between the engines, the digital numeric indication offers an enhanced ability to detect the progression of an engine malfunction before Oil Pressure reaches an operating limit and therefore provides an ELOS to a traditional radial-arc gauge.

Digital-only Display of Oil Temperature

(1) Oil Temperature is not used in power setting or starting.

The primary thrust setting parameter is fan speed (N1). The Oil Temperature indication is only used to verify the engine Oil Temperature is above -40ºC prior to engine start and above 10ºC prior to selecting high power as required by the HF120 Engine Operating Instructions. In order to enhance the pilot awareness of this limitation, the Oil Temperature indication is displayed as amber digits on a black background (as opposed to green digits on a black background) if Oil Temperature is below 10ºC to remind the pilot to allow the engine to warm up before selecting takeoff power. This amber indication provides an ELOS to an amber band on a traditional radial-arc gauge.

(2) Oil Temperature changes slowly over time.

Engine Oil Temperature does not exhibit rapid changes. Increases in Oil Temperature that are indicative of an engine failure increase slowly over the course of several minutes. Digital numeric indications are better suited to point out slow-changing trends because it is easier to detect small variations using a digital numeric indication as opposed to a radial-arc dial indicator where the needle movement would be very slow and difficult to perceive. Since Oil Temperature changes are slow, rate of change information can be monitored with a digital numeric indicator with an ELOS to a traditional radial-arc gauge.

(3) A precautionary range is implemented to forewarn the crew before the parameter reaches the operating limit.

The HF120 Engine Operating Instructions specify a maximum operating limit for engine Oil Temperature of 165ºC for 15 minutes and a maximum continuous operating limit for engine Oil Temperature of 143ºC. The engine FADEC software incorporates the timer and the annunciation of the appropriate operating limits. The HF120 Engine Operating Instructions also specify that short-term transient excursions above the maximum continuous operating limit are normal following a rapid reduction in thrust if the engine has been operating at high power for an extended period of time. In order to prevent a caution indication for an expected normal condition, the engine FADEC software suppresses the precautionary range for the first 5 minutes of the 15-minute time limit. If Oil Temperature remains above the continuous operating limit after 5 minutes, the Oil Temperature indication changes from green digits on a black background (normal operating indication) to amber digits on a black background. This precautionary range

affords sufficient margin to forewarn the crew when Oil Temperature is approaching the operating limit. The final 10 minutes of the time limit is sufficient for the crew to monitor Oil Temperature and ensure that Oil Temperature drops below the continuous operating limit or take appropriate action to reduce Oil Temperature if it does not return to the normal operating range on its own. This precautionary range provides an ELOS to a traditional radial-arc gauge.

(4) Appropriate CAS messages are included to supplement the digital numeric indication when Oil Temperature approaches or reaches an operating limit.

If Oil Temperature rises into the cautionary range, an amber caution CAS message and the master caution indication is provided in addition to the digital numeric Oil Temperature indication changing to amber digits on a black background. If Oil Temperature rises above the operating limit, a red warning CAS message and the master warning indication is provided in addition to the digital numeric Oil Temperature indication changing to white digits on a red background. The CAS messages supplement the digital numeric indication to provide the flightcrew with increased awareness and recognition of Oil Temperature exceedance conditions and serve as a compensating feature that offers an ELOS to a traditional radial-arc gauge.

(5) Ability to compare engine-to-engine Oil Temperature indication provides the ability to detect a change in oil system function before reaching an operating limit.

(a) Most engine malfunctions that lead to Oil Temperature exceedance conditions are progressive over long time periods. Oil Temperature increases typically occur when there is either excessive heat generation within the engine due to an impending failure condition or the oil cooling system has become clogged. The most common way to detect these conditions is to compare Oil Temperature between the two engines and look for differences between the engines when they are set at the same operating condition (i.e. during a climb with both engines at MCT). The most practical way to detect these malfunctions is to monitor the long-term trend of the engine-to-engine variation in Oil Temperature. The design of the digital-only display facilitates this comparison by arranging the left and right engine Oil Temperature indications in a side-by-side layout to enable easy comparison between the two engines.

(b) Since these temperature differences start small and then gradually increase over time, a digital numeric indication provides enhanced awareness of these small differences compared to a traditional radial-arc gauge. With a traditional radial-arc gauge, a difference of 10 or 20 degrees would not result in a noticeable difference in needle position. However, this level of difference is easily perceptible with a digital numeric indication. Therefore, the digital numeric indication provides an ELOS to a traditional radial-arc gauge.

<u>Digital-only Display of Engine Fuel Flow</u>

(1) The fuel flow parameter does not have an operating limit.

The primary power setting parameter is N1. The commanded N1 is achieved by the FADEC through metered fuel supply to the engine single spool gas generator. The Fuel Flow delivered to achieve the commanded N1 varies as required by closed loop control to maintain the selected N1. Therefore, the information about level, direction, and rate of change of Fuel Flow, typically provided by radial-arc dial indicators, is not applicable to Fuel Flow in the power setting process.

(2) Engine starting and fuel-on selection is automatic.

Fuel-on selection during engine starts is automatically commanded by the FADEC, ensuring consistent engine start procedures both in flight and on the ground. All engine control parameters relevant for engine starting such as Fuel Flow rate and compressor stability bleed schedules are set and limited by the FADEC. The FADEC start logic does not introduce fuel into the engine or engage the igniters until sufficient N2 is achieved. During the engine start procedure, the crew monitors Fuel Flow, but this is just to verify that Fuel Flow has been initiated (prior to light off as indicated by ITT rise) as part of monitoring the progression of the automatic start sequence. Monitoring of Fuel Flow is more important during maintenance activities such as dry (ensuring that no fuel is flowing into the engine) or wet motoring (ensuring that fuel is flowing into the engine). A digital indication is adequate to provide this level of detection. The automatic control of the Fuel Flow provided by the FADEC during engine starting provides an ELOS to pilot monitoring of Fuel Flow that would necessitate a radial-arc dial gauge.

(3) Ability to compare engine-to-engine fuel flow indication.

As indicated above, Fuel Flow is typically only monitored to ensure that fuel is flowing when it is supposed to be flowing such as prior to light off during engine starting or when performing wet or dry motor maintenance procedures. At steady operating conditions, engine-to-engine comparison of Fuel Flow can be used to detect abnormal engine behavior that might indicate a deterioration of engine health. The crew with digital-only Fuel Flow indication can effectively perform cross comparison of Fuel Flow values between the two engines and verification that Fuel Flow is in the expected range. The digital indication provides a higher degree of resolution for small engine-to-engine differences that could not be detected with radial-arc dial gauges. The left and right engine indications are provided in a side-by-side arrangement to facilitate easy comparison between the two engines.

<u>Digital-only Display of High Pressure Shaft (Turbine) Speed, N2</u>

(1) Automatic FADEC power setting eliminates the need to monitor N2 during power setting.

The primary power setting parameter is N1. N2 varies as required by closed loop control to maintain the selected N1. The FADEC power management software has been designed to ensure all operating parameters (N1, ITT, and N2) do not exceed their operating limits within the full operating envelope of the aircraft. This includes the effects of engine performance deterioration over the life of the engine so that pilot intervention is not required in the power setting process to avoid exceedances. While there is a maximum operating limit for N2, the FADEC provides automatic power setting control and therefore eliminates the need to monitor N2 during power setting.

(2) The FADEC engine speed governing logic includes an N2 limiter.

The FADEC engine speed governing includes an N2 limiter function that prevents N2 from reaching the redline condition. However, for an unhealthy engine (an engine with abnormal deterioration) or for abnormal operating conditions such as takeoff in excessive tailwind conditions, N2 may exceed the designed power setting speeds. In these abnormal conditions, the N2 limiter function intervenes to prevent N2 from reaching the operating limit. Because this N2 limiter prevents N2 from reaching the limiting value during normal and abnormal engine

operation, pilot intervention is not required to prevent N2 from reaching an operating limit. Therefore, the information about level, direction, and rate of change of N2, typically provided by traditional radial-arc dial indications, is not required during normal and abnormal engine operation.

(3) Engine starting and fuel-on selection is automatic.

Fuel-on selection during engine starts is automatically commanded by the FADEC, ensuring consistent engine start procedures both in flight and on the ground. During the engine start procedure, the crew monitors the high pressure rotor speed but this is simply to determine if the engine conditions sufficient for starting have been achieved. Monitoring and determining whether these conditions have been met is easier with a digital indication rather than a radial-arc dial indication. The crew also uses the N2 indication to monitor the progress of the start to detect engine abnormalities during the start sequence (such as a hung start). However, there is no requirement for the crew to monitor N2 in order to command Fuel Flow at a specific N2 since this is automatically commanded by the FADEC.

(4) High rotor over-speed protection.

Given the continuous monitoring of N2 by the FADEC N2 limiter described above, an N2 exceedance can only occur if the N2 increase occurs extremely rapidly such that the FADEC cannot react quickly enough to prevent the exceedance. For such a rapid N2 increase, flightcrew intervention before the threshold is reached is highly unlikely due to the required recognition-reaction time. To prevent a hazardous over-speed event for this condition, the HF120 FADEC incorporates a dual channel active-active over-speed protection system that is separate from the fuel management system. In the event that the over-speed protection system detects a rotor over-speed event, the over-speed protection system activates the fuel shutoff valve in the FPMU, which is separate from the fuel-metering valve. Consequently, there is no need to take credit for crew recognition-reaction time for either preventive or corrective action for this particular failure mode. The over-speed protection system provides an ELOS to the pilot monitoring and intervention that would necessitate radial-arc dial gauges.

(5) Ability to compare engine-to-engine N2 indication.

The flightcrew can effectively perform a cross comparison of N2 values between the two engines and verify that N2 is in the expected range using the digital only N2 indication. The left and right engine indications are provided in a side-by-side arrangement to facilitate easy comparison between the two engines.

(6) N2 exceedance is annunciated with additional sensory queues

If for any reason N2 is allowed to reach or exceed the redline limit, the N2 digital indication for the affected engine changes accordingly: the digital indication is displayed as white digits on a red background. The indication flashes between the display of white digits on a red background and the display of red digits on a black background for the first 5 seconds to provide an additional visual sensory cue that the operating limit has been exceeded. Furthermore, the limit exceedance is accompanied by an ENG EXCEEDANCE red CAS message and a master warning alarm (light and aural indication) to provide additional sensory cues.

Zero wing fuel tank quantities shown by red background field color

While the digital numeric Fuel Quantity indicator does not literally meet the requirements of § 23.1553, the HA-420 Fuel Quantity indicator does provide an ELOS supported by the following compensating features:

- During operations with the Fuel Quantity greater than the low fuel level indication quantity, the displays indicate Fuel Quantity with green digital numeric values on a black background. This provides the crew with an indication that the Fuel Quantity is within normal operating limits.
- Once the Fuel Quantity in the L or R fuel tank is less than the low fuel-level indication quantity, the crew receives an amber CAS message and the Fuel Quantity digital numeric display turns to amber digits on a black background for that tank. This provides the flightcrew with an early indication that the Fuel Quantity is approaching a red line condition.
- Once the Fuel Quantity in the L or R fuel tank reaches zero, the Fuel Quantity digital numeric display for that tank turns to a white digital numeric “0” on a red background. The HA-420 Fuel Quantity indication system is calibrated so that a digital numeric display of “0” indicated fuel is equated to zero usable fuel remaining. This provides the flightcrew with an indication that the applicable fuel tank(s) have zero usable fuel remaining, which is the intent of § 23.1553.
- The Model HA-420 also provides the availability of a secondary indication of the Fuel Quantity in the fuel synoptic page which meets the requirements of § 23.1553.

**FAA approval and documentation of the ELOS finding:**

The FAA has approved the aforementioned equivalent level of safety finding in project issue paper P-9. This memorandum provides standardized documentation of the ELOS finding that is non-proprietary and can be made available to the public. The Accountable Directorate has assigned a unique ELOS Memorandum number (see front page) to facilitate archiving and retrieval of this ELOS. This ELOS Memorandum number must be listed in the Type Certificate Data Sheet under the Certification Basis section (TCs & ATCs) or in the Limitations and Conditions section of the STC.

Equivalent Level of Safety Findings have been made for the following regulations and are document in ELOS Memo ACE-15-09:

| | |
|---|---|
| § 23.1305(a)(1)(2)(3) | Powerplant instruments |
| § 23.1305(c)(2)(5) | Powerplant instruments |
| § 23.1337(b) | Powerplant instruments installation |
| § 23.1549 | Powerplant and auxiliary power unit instruments |
| § 23.1553 | Fuel Quantity indicator |

//SIGNED//

_____ ___March 26, 2015___

Pat Mullen, Acting Manager, Small Airplane Directorate Date
Aircraft Certification Service

| | | |
|---|---|---|
| ELOS Originated by:<br>Atlanta ACO:<br>Donald J Young | Manager, Certificate Management and Safety Oversight Branch:<br>Christina Underwood | Routing Symbol:<br>ACE-120A |