Selected Non-Proprietary
Correspondence from Boeing to Powerplants Group Chairman

<u>Subjects:</u>
Engine Fuel Flow FDR Data
11 February 2000

Thrust Management System
25 April 2000

7 pages

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11 February 2000
B-H200-16888-ASI

Mr. Jim Hookey, AS-40
National Transportation Safety Board, AS-40
490 L' Enfant Plaza East, SW
Washington, DC 20594

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Subject: Engine Fuel Flow FDR Data – Egyptair 767-300ER SU-GAP, Accident Off Nantucket, Massachusetts – 31 October, 1999

Reference: Our letter B-H200-16868-ASI, 18 January 2000

Dear Mr. Hookey:

Per your request, please find the contents of the reference letter reiterated below.

Background
During the Egypt Air 990 descent, both engine's Fuel Control Switches were moved to CUTOFF, and as expected the FDR data showed that there were immediate positive indications that fuel was cut to the engine (e.g. rotor speed and EGT decrease). However, the FDR data indicated that Fuel Flow for both engines remained steady at idle levels (approximately 1300 lbs./hr) for four seconds after engine shutdown. From the other indications it can be determined that this Fuel Flow indication was not accurate. A review of the Fuel Flow Indication System was undertaken to explain why this occurred.

Results from the System Review
The factors contributing to the Fuel Flow FDR characteristics are as follows:

1. The Fuel Valve closure rate is on the order of 250 msec once the command from the Fuel Control Switch is moved to CUTOFF.

2. The EICAS incorporates the following filter: 'When no Fuel Flow activity exists or its input sample is less than 300 lbs./hr, and persists for 1.5 seconds, then set the resulting filtered value to zero. While this time delay is running, but not expired, then the previous sampled value prior to the activation of the time delay, shall continue to be input to the filter.' This EICAS filtered Fuel Flow is sent to the Flight Data Recorder (FDR) to be recorded. This 1.5-second time delay will occur every time the engine is shutdown.

3. The Fuel Flow parameter is recorded by the FDR once per second; this could contribute from 0 to 1 second time delay in the Fuel Flow data going to zero when the fuel was turned off.

4. AMETEK recently performed lab testing of the same model of Fuel Flow Transmitter as used by the Egypt Air 767 airplane. The test condition consisted of setting up a steady fuel flow of 1300 lbs./hr, then abruptly closing a Fuel Shut-off Valve upstream of the Fuel Flow Transmitter, while observing the start/stop signal pairs with an oscilloscope. The rotating element of the Fuel Flow Transmitter, which generates the start pulse, was observed to continue to rotate for 4 to 5 seconds following fuel shut-off. All signal generation subsides when the rotor stops spinning. For two representative tests, fuel flow signals greater than 300 lbs./hr continued for 8 start/stop signal pairs (approximately 4 - 5 seconds) following fuel shut-off.

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Results from the Flight Test

Boeing conducted a Fuel Flow FDR test using airplane VS307 on 11 January 2000. The following are the findings from this test with enclosed data plots:

1. The account from the observers was that during the engine shutdown the EICAS fuel flow indication showed that fuel flow remained steady at 600 kg/hr (1300 lbs./hr) for approximately 4 seconds after the Fuel Control Switch was moved to CUTOFF, before briefly dropping to zero, then momentarily spiking up to 1000 kg/hr (2200 lbs./hr), then steady again at zero. Both engines were observed to show these same characteristics. The N2 indication was observed to show an almost immediate decay when the Fuel Control Switch was moved to CUTOFF.

2. Because the FDR parameter for the Fuel Control Switch position records once every four seconds, it can not be determined exactly where the fuel was shutoff. For analysis purposes, the initial decay in EGT, N2 and N1 is used as the "zero time" point for "fuel shutoff". The EGT, N2, N1, and fuel flow data is recorded once every second, therefore the exact occurrence of the event can only be determined to an accuracy of 1 second.

3. Following "fuel shutoff" (as defined by the initial decay in engine parameters), the left engine fuel flow remained at idle flow for 2 - 3 seconds, then showed a flow of zero. Five seconds after fuel shutoff, the left engine fuel flow showed a spike to 2400 lbs./hr (1100 kg/hr) for one data point, then back to a steady flow of zero.

4. Following "fuel shutoff", the right engine fuel flow remained at idle flow for 2 - 3 seconds, then showed a flow of zero. Four seconds after fuel shutoff, the right engine fuel flow showed a spike to 2200 lbs./hr (1000 kg/hr) for one data point, then back to a steady flow of zero.

Conclusions

The Fuel Flow FDR data taken from VS307 is comparable with the Fuel Flow FDR data from the Egypt Air 990 accident which indicated a Fuel Flow of 1300 lbs./hr for 4 seconds following engine shutdown. The Egypt Air 990 Fuel Flow data is also supported by the system review and AMETEK laboratory testing.

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Please contact us if you have any questions.

Very truly yours,

[redacted]

for: Ronald J. Hinderberger
Director, Airplane Safety
Org. B-H200, MC 67-PR
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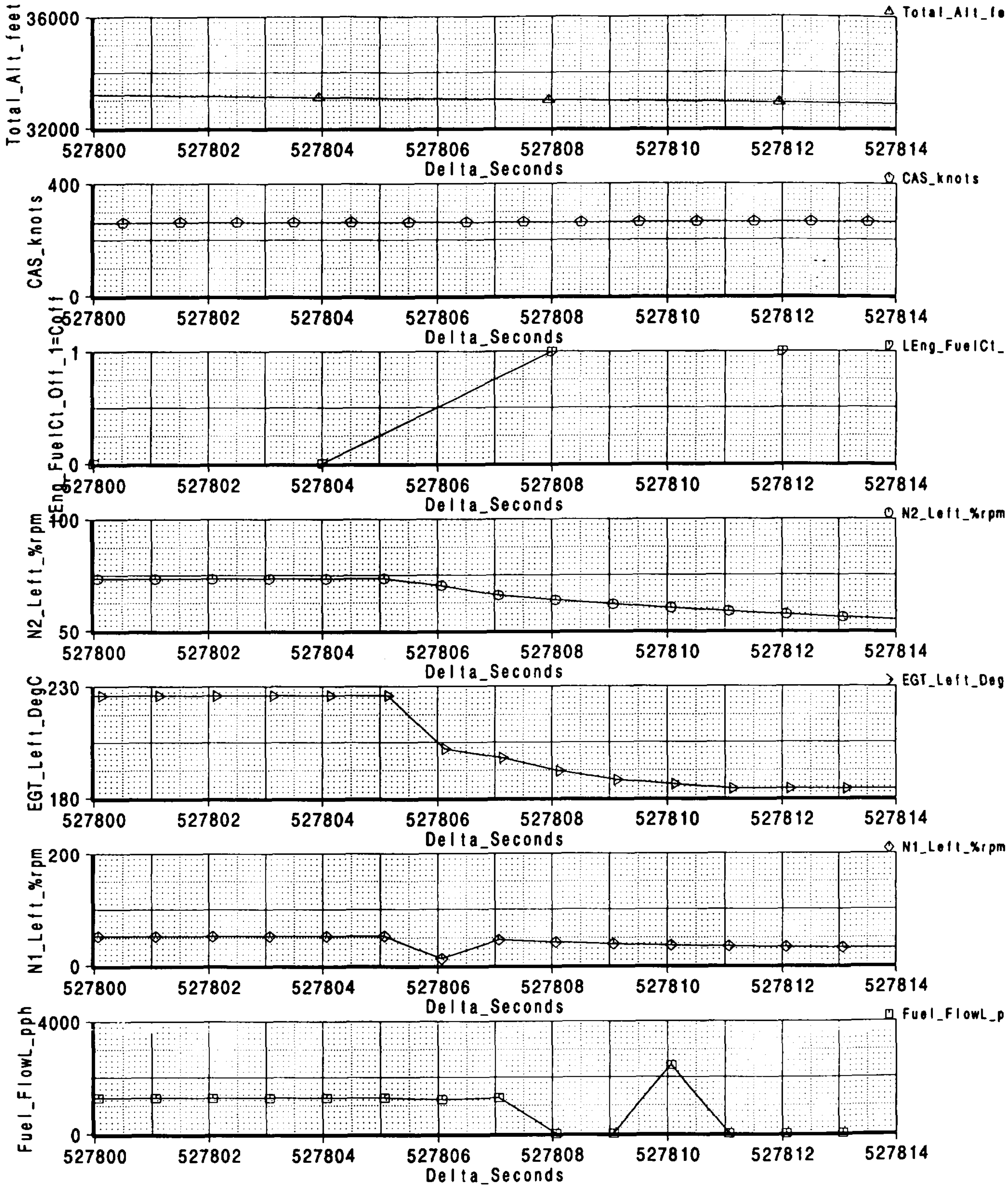
Enclosure:

- Boeing Plots, *767/PW4000/AMETEK Flow Meter, B1 Flight, 1-11-2000, Left (and Right) Engine Shutdown*

Cc: ✓Greg Phillips, AS-10

Enclosure to B-H200
16888-ASI
2 pages



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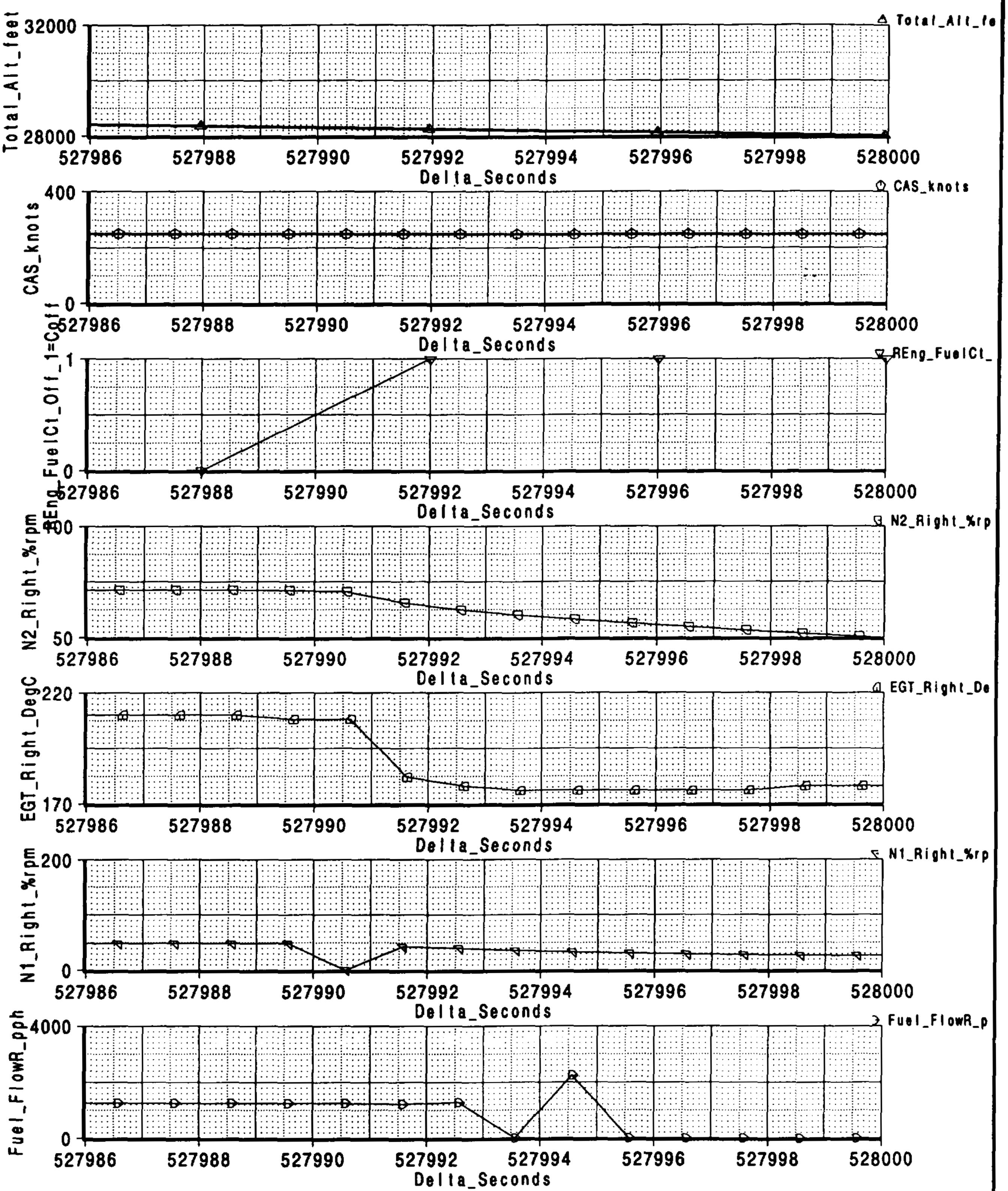

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25 April 2000
B-H200-16936-ASI

Mr. Jim Hookey, AS-40
National Transportation Safety Board, AS-40
490 L' Enfant Plaza East, SW
Washington, DC 20594

Subject: Thrust Management System – Egyptair 767-300ER SU-GAP, Accident Off Nantucket, Massachusetts – 31 October, 1999

Reference: Your letter to Rick Howes, 24 March 2000

Dear Mr. Hookey:

The Egyptian investigation committee requested Boeing to address the following questions in the reference letter. Our response to each question is provided below.

Q1. With the trust management computer system engaged, how much movement of the power levers is required before the system automatically disengages?

Response: The autothrottle (A/T) will not automatically disengage based upon movement of the thrust levers. The autothrottle will disengage if it detects a fault which prevents the system from performing its function, if manually disengaged via the A/T disconnect switch on the thrust levers or by the arm switch on the mode control panel (MCP), or if reverse thrust is detected.

Q2. What is the expected response of the thrust management computer on the power lever position if there is a rapid increase in airspeed and decrease in altitude?

Response: This autothrottle response to rapid increase in speed and decrease in altitude will depend upon the autothrottle mode. In speed mode, the throttles should retard to a calculated thrust setting, which minimizes thrust while keeping the engine spooled up sufficiently to provide rapid response when increased thrust is requested. If the speed continues to be above the speed target, the autothrottle will slowly retard the thrust levers to the idle position. The autothrottle will not retard the thrust levers to the mechanical stop while in speed mode.

At speeds and altitude rates outside the design envelope, internal variables within the Thrust Management Computer can bump up against limits resulting in unpredictable autothrottle behavior. Simulations of extreme maneuvers have shown the autothrottle to advance the throttles under these conditions.

Q3. How long will it take for the thrust management computer to retard the power levers from a cruise flight position to idle if the airplane's airspeed is increasing?

Response: The rate at which the autothrottle retards the thrust levers varies with altitude, temperature, mach and speed error. The autothrottle movement is best identified by the characteristic of a low initial rate that increases as the speed error increases.

Q4. Based on flight 990's DFDR data, is the power lever movement consitant with movement commanded by the thrust management computer system of physical input by a person in the cockpit?

Response: Based upon the high initial rate and relatively constant rate, combined with the fact that the thrust levers were retarded all the way to the mechanical stop, the movement is more consistent with a manual input.

We are prepared to discuss any of this material until a satisfactory understanding is achieved with participants in the subject investigation. Please contact us if you have any questions.

Very truly yours,

[redacted]

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