National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: August 25, 2006

In reply refer to: A-06-56 through -59

Honorable Marion C. Blakey
Administrator
Federal Aviation Administration
Washington, D.C. 20591

In this letter, the National Transportation Safety Board recommends that the Federal Aviation Administration (FAA) take action to address safety issues identified in the Safety Board's investigations of several high-altitude, dual-engine flameouts that have occurred on Raytheon Beechjet 400 series airplanes powered by Pratt & Whitney Canada (P&WC) JT15D-5 turbofan engines.

Background

On July 12, 2004, a Raytheon Beechjet 400A airplane, N455CW, operated by Flight Options, lost all power in both of the P&WC JT15D-5 engines while descending from flight level (FL) 410[1] to FL 330 in instrument meteorological conditions (IMC) over the Gulf of Mexico about 100 miles west of Sarasota, Florida.[2] After several attempts to restart the engines, the pilots were able to restart the right engine and landed the airplane in Sarasota without further incident. The two pilots and seven passengers on board were not injured. The airplane was operating on an instrument flight rules (IFR) flight plan under the provisions of 14 *Code of Federal Regulations* (CFR) Part 135 from Duncan, Oklahoma, to Fort Myers, Florida.

The pilots reported in a postincident statement that, after being cleared to descend to FL 330 from a cruising altitude of FL 410, they initiated the descent and felt a jolt and heard a bang as they were passing through FL 390. They reported that, about 30 seconds later, they realized that the airplane was losing cabin pressure and donned their oxygen masks. The pilots declared an emergency and went through the emergency checklist for loss of cabin pressure as they initiated an emergency descent. The pilots stated that shortly after they initiated the emergency descent, they noted that "every warning light in the cockpit was illuminated" and that both engines were not operating. A sound spectrum analysis of the recording from the airplane's

[1] Flight level 410 is 41,000 feet mean sea level based on an altimeter setting of 29.92 inches of mercury.

[2] Preliminary information about this incident, ENG04IA021, can be found on the Safety Board's Web site at <http://www.ntsb.gov>.

cockpit voice recorder (CVR) revealed that both engines had, in fact, lost power immediately after the bang the crew reported hearing. According to the CVR, the pilots made several attempts to restart the engines and were able to get the right engine restarted as the airplane was descending through 10,000 feet.

Postincident examination of the airplane at Sarasota revealed that the throttle rigging from the cockpit to both engines conformed to the airplane's maintenance manual requirements. The engines' anti-icing systems were checked and found to be operational. Ground power tests of both engines were accomplished, including power assurance checks that showed that the idle speed for both engines was correct, that maximum power for both engines was attainable without exceeding speed or temperature limitations, and that the engine electronic controls functioned correctly. Before the engines were started for the ground power tests, fuel was collected from each engine's fuel filter bowl for testing.[3] The tests revealed that the fuel conformed to the requirements for Jet A and that the concentration of the fuel system icing inhibitor (FSII)[4] was 0.023 percent by volume.[5] According to the Beechjet 400A airplane flight manual (AFM) and the FAA's type certificate data sheet for the Beechjet 400A, the concentration of the FSII in the fuel should be 0.1 to 0.15 percent by volume. The Safety Board's investigation of this event is ongoing.

On November 28, 2005, the flight crew of a Raytheon Beechjet 400A airplane, N691TA, also operated by Flight Options, had to make a landing without engine power at Jacksonville, Florida, after both P&WC JT15D-5 engines lost all power while descending from FL 380 in visual meteorological conditions (VMC).[6] The two pilots on board were not injured. The airplane was operating on an IFR flight plan under the provisions of 14 CFR Part 91 from Indianapolis, Indiana, to Marco Island, Florida.

The pilots stated in postincident interviews that, just after initiating a descent to FL 330 from a cruising altitude of FL 380, they heard a loud pop from the right engine followed by a loud pop from the left engine about 10 seconds later and that the cockpit power indications for both engines quickly decreased (the pilots' report was later confirmed by a sound spectrum analysis of the CVR). The pilots stated that the rpm indicators for both engines showed 0 rpm. The pilots reported that they donned their oxygen masks and advised air traffic control (ATC) that they needed a lower altitude because they had lost both engines. The pilots elected to divert

[3] The fuel in the wing tanks that were supplying the engines at the time both engines lost power could not be tested postincident because these tanks were inadvertently serviced with 55 gallons of fuel each that was ordered for another Flight Options Beechjet 400A that was parked adjacent to the incident airplane.

[4] FSII is not a requirement for Jet A fuel; however, an FSII must be added to jet fuel used on Beechjet 400 series airplanes because they are not currently equipped with fuel heaters. Because of problems with the availability of FSII in Europe, Raytheon and P&WC are jointly working on the development of a fuel heater system for the Beechjet 400A. The change involves modifications to the airplane and engines. According to Raytheon, the fuel heater system is expected to be incorporated on new production airplanes in 2007 and will also be available as a retrofit for existing airplanes.

[5] Fuel samples collected from the trunk tank, which was serviced at a different airport than where the wing tanks were serviced, were also tested and were found to conform to the requirements for Jet A. The FSII concentration was 0.09 percent.

[6] Preliminary information about this incident, DCA06IA007, can be found on the Safety Board's Web site at <http://www.ntsb.gov>.

to Jacksonville where the weather was better and the runways were longer. The pilots reported making three attempts to restart the engines during the descent and that the battery voltage dropped from 28 to 8 volts on each attempt. They also reported hearing the groan-like sound of a stalled electrical motor[7] and that the cockpit indicators continued to show zero engine rotation. The pilots stated that they did not make any further attempts to restart the engines because they had descended into IMC and were concerned about draining the battery, which was needed to power the airplane's attitude displays and navigational equipment.

Postincident examination of the airplane at Jacksonville revealed that the throttle rigging for both engines from the cockpit to the engines conformed to the airplane's maintenance manual requirements. The engines' anti-icing systems were also found to operate properly. The ground power tests that were accomplished on both engines showed that the engines' idle speed was correct and that the engines were able to attain maximum power without exceeding any speed or temperature limitations; the proper operation of the engine electronic controls was also confirmed. Before starting the engines for the ground power tests, the fuel in each engine's fuel filter bowl was collected, along with samples from the trunk and wing tanks, for testing. The tests revealed that the fuel conformed to the requirements for Jet A and that the concentration of the FSII in the trunk and wing tanks ranged from 0.085 to 0.099 percent by volume. The Safety Board's investigation of this event is ongoing.

On June 14, 2006, both P&WC JT15D-5 engines on a Raytheon Beechjet 400A airplane, N440DS, operated by Southern Air Systems, lost all power while in cruise flight at FL 380 near Norfolk, Virginia.[8] The pilots later reported that as the airplane was descending through FL 300, the left engine restarted on its own and the right engine restarted on its own at around FL 240. The pilots diverted to Norfolk and landed without further incident. The two pilots on board were not injured. The airplane was operating on an IFR flight plan under the provisions of 14 CFR Part 91 from Quonset Point, Rhode Island, to Charleston, South Carolina.

During postincident interviews, the pilots reported that, before the incident, they were in VMC above clouds that were remnants of tropical storm Alberto while in cruise flight. They indicated that, because ATC had given them a new heading that would take them toward a cloud deck that appeared to be upsloping and they were concerned about entering the clouds, they decided to turn on the engine anti-ice.[9] The pilots reported that they turned the ignition on and then in accordance with the instructions in the Beechjet 400A AFM for activating engine anti-ice, they reduced the power from 101.5 percent N1 to 89.5 percent N1 before turning on the anti-ice to prevent the engines from exceeding the interturbine temperature (ITT) limit.[10] The pilots

[7] The JT15D engine uses an electrically powered starter-generator for starting.

[8] Preliminary information about this incident, ENG06IA020, can be found on the Safety Board's Web site at <http://www.ntsb.gov>.

[9] Instructions in the Beechjet 400A AFM regarding how to turn on the engine anti-ice system include the following caution, "Do not operate anti-ice systems at ram air temperatures greater than 10ºC unless in actual icing conditions, as indicated by illumination of the ICING annunciator (if installed) or airframe ice accumulation. Ice protection systems should be on prior to encountering actual icing. Turn systems off when clear of icing conditions."

[10] The Safety Board is aware that, as a result of this event, Raytheon is in the process of rescinding the requirement to reduce engine power to below 90 percent N1 before activating the engine anti-ice. This requirement was carried over from earlier models of the JT15D engine, which did not have sufficient ITT margin when anti-ice

reported that both engines flamed out simultaneously as soon as they retarded the throttles but before they could turn on the engine anti-ice. The pilots stated that they donned their oxygen masks, declared an emergency, and turned towards Norfolk. After landing, maintenance personnel checked the airplane and engines and noted no discrepancies. The airplane was completely defueled and new fuel was added. The airplane then continued on to Charleston.[11] A sample of the fuel that was drained from the airplane at Norfolk was sent to a laboratory for testing, which indicated that the fuel conformed to the requirements for Jet A. The FSII concentration was 0.13 percent. The Safety Board's investigation of this event is ongoing.

In addition to these three events, Raytheon reported another event that occurred in Brazil on April 23, 2000.[12] A Brazilian-registered Beechjet 400A airplane, en route from Curaçao, Netherlands Antilles, to Belem, Brazil, was cruising at FL 410 when the left engine flamed out followed 2 seconds later by the right engine. The pilots were able to restart the left engine as they were descending through FL 260 but were unable to restart the right engine. The pilots diverted the airplane to Macapa, Brazil, and landed. According to service records, the airplane had been refueled in Curaçao. In a letter to Raytheon, the fixed base operator in Curaçao stated that it sold Jet A-1 fuel[13] but did not provide anti-icing additives nor did it allow its employees to use customer-supplied additives.

The Safety Board's assessment of these events initially considered FSII concentration levels as a potential cause of the dual-engine flameouts (fuel collected from the airplane involved in the Sarasota event had 0.023 percent concentration compared to the required concentration of 0.10 to 0.15 percent by volume, and the airplane involved in the Brazil event had no FSII in its fuel). However, FSII concentration levels in the fuel from the airplanes involved in the more recent events at Jacksonville and Norfolk both were near or at required levels. Additionally, Flight Options subsequently informed the Safety Board that, after directing its Beechjet 400 pilots to ensure that the FSII was added to fuel following the Sarasota event, several pilots reported that they had found that refuelers were neglecting to turn on the FSII injection system, thus the FSII was not being added to the fuel as it was pumped into the airplane. Thus, it is likely that numerous other flights have taken place without the proper levels of FSII in the tank without apparent incident. This suggests that some phenomenon other than low FSII concentration is causing these engines to flameout.

Effect of High-Altitude Water and Ice Crystals on Turbojet Engine Performance

According to the FAA's specialist on engine icing, convective storms can pump significant amounts of moisture into the upper atmosphere, and the blowoff from the tops of

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was activated. The JT15D-5 engine used on the Beechjet 400A airplane has sufficient ITT margin such that power does not need to be reduced when engine anti-ice is selected.

[11] The Safety Board did not learn of this event until 2 days after the airplane had departed Norfolk and, therefore, was not able to perform any tests on the airplane. However, the Board was able to have the fuel sample taken from the airplane at Norfolk tested.

[12] Raytheon learned of this event through its field service representative network. It was not reported to nor investigated by any aviation investigative agency.

[13] Jet A-1 is a kerosene-based fuel with a maximum freeze point of -58°F. In comparison, Jet A has a maximum freeze point of -40°F.

convective storms can contain significant amounts of ice crystals. At the time the engines flamed out on the airplane involved in the Sarasota event, the airplane was flying in IMC, and the CVR recorded the pilots commenting about convective storms in the area where they were flying. The pilots of the airplane involved in the Jacksonville event reported that they were flying in VMC when the engines flamed out. They also reported, however, that they had been in and out of the cloud tops shortly before the engines flamed out. Overlays of these airplanes' flightpaths on weather satellite imagery showed that both airplanes were transiting areas with blowoff from the tops of convective storms. At the time the engines flamed out on the airplane involved in the Norfolk event, the airplane was approaching the remnants of tropical storm Alberto from the north. Weather satellite imagery showed that convective storms with tops to 55,000 feet were in the area where the flight was operating. Although it is not known what the weather was in the area of the Brazilian event at the time the engines flamed out, it is well known that convective storms are nearly a daily occurrence in that part of the world.

Following the Sarasota and Jacksonville events, P&WC accomplished a study to determine if it was possible for high-altitude ice crystals to adhere to and build up inside the JT15D-5 engine to the point that the engine would flame out. The analysis revealed that with the engine anti-ice turned off it was possible for ice crystals to build up on the leading edges of the JT15D-5 engine's front inner compressor stator[14] (see figure 1) and that the buildup could lead to a compressor surge and/or flameout. The study results suggest that the ice crystals melt as they pass through the fan section (due to an increase in temperature from air being compressed) then adhere to and refreeze on the front inner compressor stator leading edges.

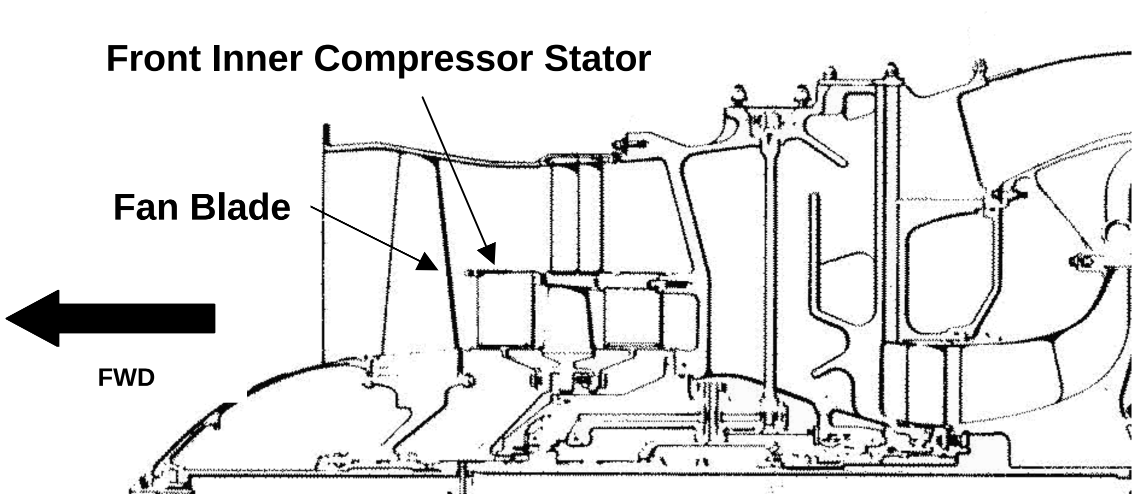

Figure 1. View of forward half of JT15D-5 engine showing front inner compressor stator

[14] The JT15D-5 engine low pressure compressor rotor consists of the fan and booster stages. On the front and rear sides of the booster stage are the front and rear inner compressor stators, respectively. When engine anti-ice is activated, the engine's front and rear inner compressor stators as well as the inlet cone are heated with warm air from the high pressure compressor to prevent ice formation. The lip of the airplane's inlet duct is also heated when engine anti-ice is activated.

The Safety Board is well aware of the threat that ice crystals can pose to turbine engines. On June 4, 2002, Spirit Airlines flight 970, a Boeing MD-82 airplane,[15] experienced a dual-engine flameout of its Pratt & Whitney JT8D-219 engines after high altitude ice crystals blocked the engines' inlet pressure probes while the airplane was in cruise flight at FL 330.[16] At the time the engines lost power and flamed out, the airplane was in VMC; however, an overlay of the airplane's flightpath on weather satellite imagery showed that it had transited an area of high-altitude ice crystals just before the engines flamed out. Although the ice did not accrete on the usual places where the pilots would be able to see it and initiate the appropriate action, it was still able to build up on the engines' inlet pressure probes to cause the engines to lose power and flame out. As a result of its investigation of the Spirit Airlines flight 970 event, the Safety Board issued Safety Recommendation A-04-34, which asked the FAA to do the following:

> Issue a flight standards information bulletin to principal operations inspectors to alert all affected air carrier flight crews about the icing situation encountered by Spirit Airlines flight 970 and to emphasize the need to maintain vigilance for the signs of high-altitude icing conditions, the effect these conditions can have on airplane and engine performance, and the need for the appropriate use of the engine anti-ice system.[17]

In response to Safety Recommendation A-04-34, on June 30, 2004, the FAA issued Flight Standards Information Bulletin for Air Transportation (FSAT) 04-02, "High Altitude Icing Conditions," which provided guidance regarding icing encounters at high altitude.[18]

The Safety Board is aware that the Beechjet 400 has been in service since May 1985 and had no apparent problems with dual-engine flameouts until the incident in Brazil in 2000 and then the incidents in Sarasota, Jacksonville, and Norfolk in 2004, 2005, and 2006, respectively. At this juncture in its investigations of these events, the Safety Board has not identified any specific operational or mechanical changes that could be the cause of these dual-engine flameouts on Beechjet 400 airplanes. However, as has been discussed, each event is similar in that the airplanes were operating at high altitude and near convective storm activity when the flameouts occurred, and, in the Sarasota, Jacksonville, and Norfolk events, the flameouts occurred after a power reduction. Also as stated previously, Raytheon is in the process of rescinding the requirement in the Beechjet 400A AFM to reduce engine power before activating the engine anti-ice because the JT15D-5 engine has sufficient ITT margin such that power does not need to be reduced when engine anti-ice is selected.

The Safety Board is concerned about the recent onset of dual-engine failures involving Beechjet 400As and that the interval between events appears to be decreasing. The Board is also concerned about the sustained loss of power that occurred in each event after several attempts to

[15] McDonnell Douglas originally manufactured the airplane. In August 1997, the Boeing Company and McDonnell Douglas merged and now operate under the Boeing name.

[16] The description of this incident, CHI02IA151, can be found on the Safety Board's Web site at <http://www.ntsb.gov>.

[17] The MD-80 Flight Crew Operating Manual calls for activating the engine anti-ice system whenever the outside air temperature is less than 6ºC and visible moisture is present.

[18] Safety Recommendation A-04-34 is classified "Closed—Acceptable Action."

restart the engines. Dual-engine failure is an unacceptable risk that should be mitigated to the maximum extent possible, and urgent action is necessary to prevent any additional dual-engine flameout events. Because the ignition system would provide the energy source to reignite the fuel-air mixture in the event of a flameout and because the anti-ice system heats the JT15D-5 engine's front and rear inner stator vanes (where it is believed ice is forming) when activated, the Safety Board believes that the FAA should immediately require Beechjet 400 pilots to activate the engine ignition and anti-ice systems at high altitude whenever they are in or near visible moisture, or near convective storm activity, or before any power reduction unless the pilots can verify that the airplane is not in or near visible moisture or convective storm activity.

During the investigation of the dual-engine flameout events, it was learned that a general perception exists among flight crews of airplanes that fly at high altitudes that ice is not a threat at the higher altitudes because it is "too cold." This perception is reinforced by the fact that the ice crystals that are of concern do not accrete on the usual places that pilots look for ice such as the wings, windshield wiper blade arms, or the arm retaining bolts. At the request of a Safety Board investigator following the Jacksonville incident, Raytheon issued Safety Communiqué No. 269 to operators, which stated, in part, the following:

> Operators are also reminded that no lower temperature limit exists for the operation of anti-ice systems. Operators should be aware that air moving through the engine experiences a significant temperature increase as it passes through the compressor section. This increase could bring the air temperature to a range where internal ice formation might occur if Engine Anti-Ice were not operating. Operators should not assume ice formation to be impossible at very low ambient temperatures (i.e. -30 deg C or colder).

The Safety Board considers the guidance about anti-ice operation and ice formation contained in Raytheon's Safety Communiqué No. 269 to be valuable information that should be available to Beechjet 400 pilots in a more formal document, such as the AFM. Inclusion in the AFM will ensure that flight crews receive standardized training about this issue and that they will be required to comply with the documented procedures. Therefore, the Safety Board believes that the FAA should require Raytheon to incorporate the information regarding anti-ice operation and ice formation contained in Safety Communiqué No. 269 into the Beechjet 400 AFM.

The Safety Board is aware that JT15D-5 engines, as well as other models of the JT15D engine, are used on airplanes other than Beechjet 400s. Although the Safety Board is not aware of any other dual-engine flameout events or engine operation problems due to icing on JT15D-powered airplanes, the information regarding anti-ice operation and ice formation contained within Raytheon's Safety Communiqué No. 269 could be of value on other JT15D-powered airplanes. Therefore, the Safety Board believes that the FAA should incorporate the information regarding anti-ice operation and ice formation contained in Raytheon's Safety Communiqué No. 269 into the AFMs of other JT15D-powered airplanes.

As a result of its investigation of the dual-engine flameout involving Spirit Airlines flight 970, the Safety Board also issued Safety Recommendation A-04-35, which asked the FAA to do the following:

> Actively pursue research with airplane and engine manufacturers and other industry personnel to develop an ice detector that would alert pilots of inlet pressure probe icing and require that it be installed on new production turbojet airplanes, as well as retrofitted to existing turbojet airplanes.

The FAA responded on July 16, 2004, that it was reviewing the inlet probe icing service history on engines with probes mounted in the nose dome and that it needed to complete this activity before pursuing a new research program for development of a dedicated ice detector for alerting flight crews to potential engine inlet pressure probe icing conditions.[19]

In the letter that transmitted Safety Recommendation A-04-35, the Board noted its concern that because high-altitude ice crystals do not accrete in the typical places that pilots look for ice (such as on the wings, windshield wiper blades and blade attachment bolts, etc.) pilots of turbojet airplanes have no verifiable means to determine whether ice is building up within the engine. The Board continues to have this concern. Such awareness of the formation of ice is important for the timely activation of the engine anti-ice system before the ice can accrete to the point of causing an engine to surge and/or flameout. Additionally, there may be situations, such as at night, in which pilots may not be able to see the atmospheric conditions that could be indicative of high-altitude ice crystals. The Safety Board notes that the problem of multi-engine losses of power due to icing is not limited to the JT15D-5 engine and that General Electric CF6-80 series engines have also experienced in-flight losses of power due to internal icing.[20]

The action recommended in Safety Recommendation A-04-35 addresses the need to alert pilots if high-altitude ice crystals are impacting and accreting on the inlet pressure probe of turbojet engines. With the Beechjet dual-engine flameouts discussed in this letter, the source of concern is once again high-altitude ice crystals. However, the ice is believed to be building up on the compressor stator airfoils deep within the engine. Because the structure and operating conditions in the inlet of a turbojet engine such as the JT8D (where the icing occurred in the Spirit Airlines event) are totally different from the structure and operating conditions deep within a jet engine (where the icing is believed to be occurring in the Beechjet's JT15D-5 engines), a strategy besides that recommended in Safety Recommendation A-04-35 may be necessary to detect internal engine icing. Therefore, the Safety Board believes that the FAA should work with engine and airplane manufacturers and other industry personnel as well as the appropriate international airworthiness authorities to actively pursue research to develop an ice detector that would alert pilots to internal engine icing and require that it be installed on new production turbojet engines, as well as retrofitted to existing turbojet engines.

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[19] Safety Recommendation A-04-35 is currently classified "Open—Acceptable Response."

[20] The Safety Board is aware of a June 1, 2006, dual-engine flameout that occurred on a Qatar Airways A-330 airplane equipped with General Electric CF6-80E1 engines while the airplane was descending through IMC for landing at Shanghai, Peoples Republic of China.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Immediately require Beechjet 400 pilots to activate the engine ignition and anti-ice systems at high altitude whenever they are in or near visible moisture, or near convective storm activity, or before any power reduction unless the pilots can verify that the airplane is not in or near visible moisture or near convective storm activity. (A-06-56) Urgent
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> Require Raytheon to incorporate the information regarding anti-ice operation and ice formation contained in Safety Communiqué No. 269 into the Beechjet 400 airplane flight manual. (A-06-57)
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> Incorporate the information regarding anti-ice operation and ice formation contained in Raytheon's Safety Communiqué No. 269 into the airplane flight manuals of other JT15D-powered airplanes. (A-06-58)
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> Work with engine and airplane manufacturers and other industry personnel as well as the appropriate international airworthiness authorities to actively pursue research to develop an ice detector that would alert pilots to internal engine icing and require that it be installed on new production turbojet engines, as well as retrofitted to existing turbojet engines. (A-06-59)

Chairman ROSENKER, Vice Chairman SUMWALT, and Members HERSMAN and HIGGINS concurred with these recommendations.

[Original Signed]

By: Mark V. Rosenker
Chairman