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Department of Transportation,
Docket No. FAA 1999-6411- 48
400 Seventh Street SW
Room Plaza 40 1
Washington, DC 20590

Gentlemen,

Long before the TWA Fl 800 disaster many of us were concerned about the design of fuel systems in general, so we are excited about the opportunity to get something done about the problem.

In meetings with FAA Atlanta, Jerry C. Robernette Senior Engineer, Propulsion; David Crews, Senior Engineer, Flight Test; Robert Bosak, Aerospace Engineer Propulsion; and Paul C. Sconyers, Associate Manager, Atlanta Certification Office sat down with our team and went over our schematics in great detail. We have been encouraged by their help and interest and will continue to work with them. We have also received help from Mercer University Engineering Department (Proof of Concept Research) and Dr. Bill Neace, School of Business and Economics, Mercer University, has joined our team. We received our Patent Pending about a year ago and are still working toward our final patent.

In response to your Docket 1999-6411, SHN Aeronautical Technologies submits the enclosed proposal. If you have any question regarding any part of our proposal. Please contact Frank Smisson, President. We commend the FAA, NSTB and others who are dedicated to resolving the "Fire Triangle" problem that is endemic to all large commercial certificated planes. We believe our proposal goes a long way in resolving the issue.

We are excited about this project and are looking forward to hearing from you. Please accept our solution to this problem so that we can get started with the task of making flying safer for us all.

Respectfully,

L. Frank Smisson
President SHN Fuel Systems

RESPONSE TO DOCKET 1999-6411

BY

SHN AERONAUTICAL TECHNOLOGIES

FORT VALLEY, GEORGIA, USA

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INTRODUCTION

Fuel tank explosions in airplanes have been of concern to air crews, airlines, the military, aircraft manufacturers and their component suppliers, and government air safety oversight agencies for many years. Fuel tank explosions first became a significant issue during World War II when aircraft were exposed to enemy fire with the potential of "hits" in fuel tanks.

Since World War II the potential for catastrophic fuel tank explosions has increased dramatically. This increased potential is driven by several factors related to growth of the airline industry.

1. The tremendous increase in the numbers of airline passenger planes in the skies. Large U.S. air carriers increased enplanements 23.3 1 percent from the beginning of 1990 through 1996, and are forecasted to increase enplanements another 54.44 percent from the beginning of 1997 through 2008. Overall, this is a 99 percent increase from the beginning of 1990 through 2008, an average of 5.49 percent a year. (See Table I, Appendix)
2. Increased capacities of large turbojet aircraft (large aircraft, 30+ seats) increased 37.7 percent from 1987 through 1996. (See Table II, Appendix)
3. These larger certificated planes are operating ever-longer flights in terms of miles flown increasing the opportunity for empty fuel tanks and/or unsubmerged pumps, monitoring equipment and other electrical components. For example, revenue aircraft hours flown by the large certificated air carriers from 1987 through 1996 increased from 3.485 hours to 4.015 hours per flight, an increase of over 30 minutes on each flight. (See Table III, Appendix) If international flights could be segmented out of

these figures the time per flight would probably see a much greater increase. This issue, more time in the air per flight, is being exacerbated today by the growing number of flight delays. Flight delay problems are sure to worsen before being resolved.

4. Life-cycles of large certificated air passenger planes are continuing to lengthen in terms of age and total hours flown. (e.g., TWA Fl 800 was a 20 year old 747) Hours flown increased 26.7 percent from 1991 through 1999, and are projected to increase another 44.6 percent from 1999 through 2008. (See Table IV, Appendix)
5. All of the above will require increased inspections and maintenance which has potential for human error. As is well known, inspection and maintenance of pumps, monitoring equipment and other electrical components being inside the fuel tanks is no simple task. Physical limitations of access, the need to use artificial light, and the hazards of gas fumes all contribute to a difficult and serious task.
6. The inherent design flaw in large aircraft fuel systems (electrical pumps, metering equipment, including wiring, insulation, seals and other electrical components located inside the fuel tanks) combined with the 5 factors mentioned above compounds the problem.
7. Consumer demand, the driving force of commercial air traffic, has experienced significant increases over the past decade and is predicted to show even larger gains through 2008. In Senate hearings for FAA finding Senator Kent Conrad (D-ND) commented that there are 600,000,000 passengers today and this figure is expected to rise to 1,000,000,000 in the next decade (C-Span, 3 February 2000). FAA's own forecasts confirm these figures. (See Table V, Appendix)

Even though air passenger flight safety has a remarkable record of improvement the potential for catastrophic fuel tank explosions is increasing because improvements are being overwhelmed by the growth factors mentioned above. Even though the probability of a fuel tank explosion is very low when it does occur it is most often catastrophic with many lives lost. Economic costs, both direct and indirect, will also continue to escalate on a per accident basis as seating capacities increase, load factors increase (FAA Forecasts 1997) and as commercial air carriers take more responsibility in settling disputes in a timely manner. (Wall Street Journal, 15 February 2000: Swiss Air Fl 111, Alaska Airline Fl 261)

It is time to correct the fuel system design flaw and eliminate the consequences of the "Fire Triangle." The following paragraphs describe a fuel system concept that resolves the "Fire Triangle" problem, saves lives, and significantly reduces operating and long-term costs.

RESPONSE TO FAA DOCKET 1999-6411

In several readings of your Docket 1999-6411 the three principals of SHN Aeronautical Technologies developed specific objectives to resolve the problem of potential fuel tank explosions. First, those objectives are identified and the relationship of the SHN fuel system to each of those objectives is made evident. Second, an overview scheme of the SHN fuel system is presented with a summary description of its primary characteristics. (See Figure 1) Detailed discussions of the system are integrated into the objectives with specific reference(s) to particular components or multiple components as appropriate. Third, each objective is discussed clearly showing and/or illustrating how the SHN fuel system satisfies, and in many cases exceeds, FAA's desired requirements. During these discussions the SHN fuel system is presented as both a total unit and its various system elements as an integrated interdependent holistic system whose purpose is to satisfy the objectives in Docket 1999-64 11 and eliminate the inherent design flaw now endemic in all large commercial certificated jet aircraft. Where appropriate, references are made to the overview model of the SHN fuel system.

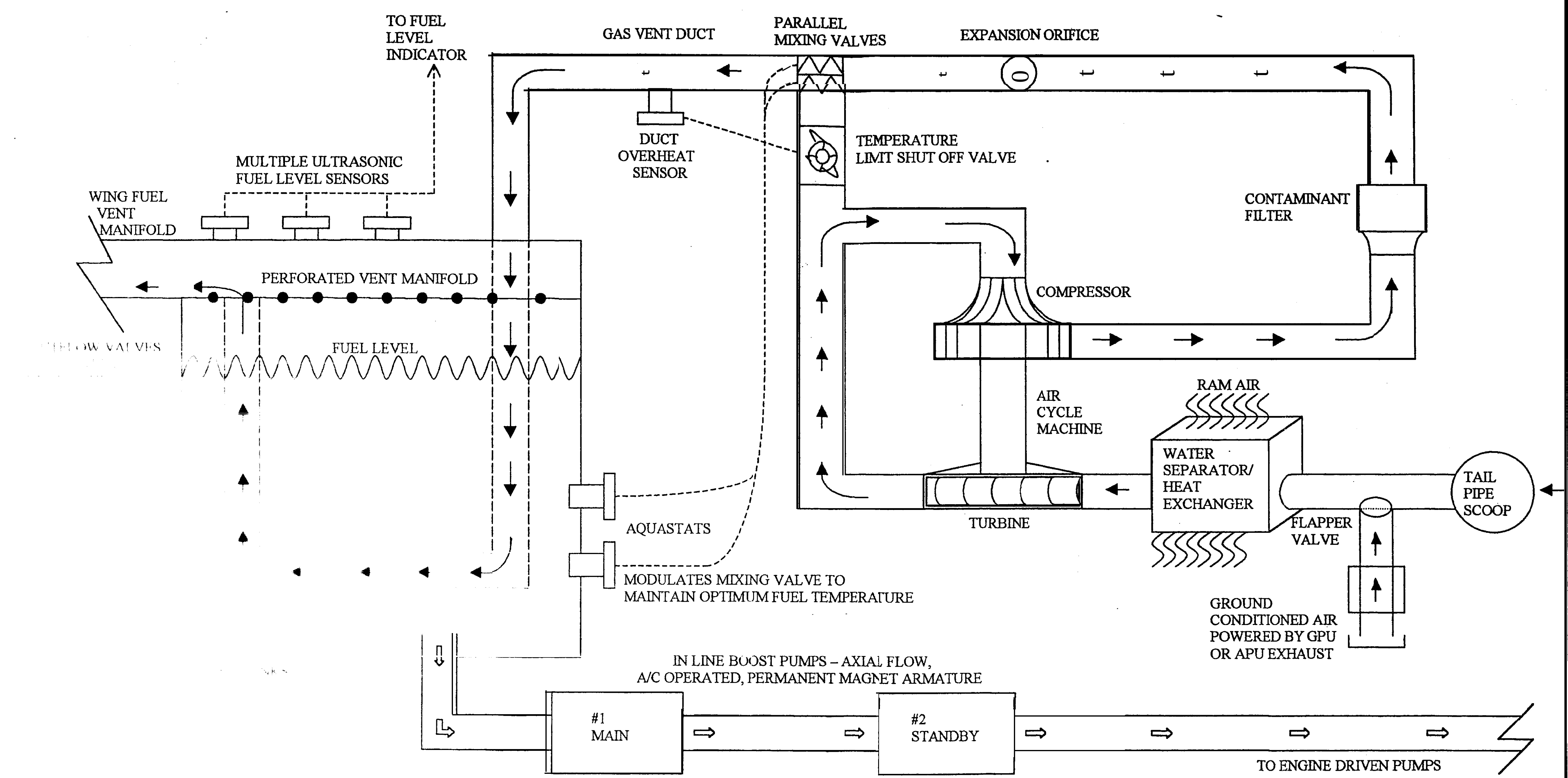
EARLY HISTORY AND BASICS OF THE SHN FUEL SYSTEM

During World War II, (as early as 1938), the Russians developed a fuel tank safety procedure (used in their LN-7 and LN-8 fighters, and other ground attack aircraft) of pumping exhaust gases into and around fuel tanks to reduce fuel tank explosions by purging explosive fumes. The exhaust of an operating jet engine contains carbon monoxide, carbon dioxide, nitric oxide plus several other noncombustible gases, as well as ten parts of water in the form of steam, with more than ample pressure and continuous flow to operate an air cycle machine.

The SHN fuel system is unique in that it uses this flow of noncombustible inert gases to provide a continuous flow of gases after they have been dried, chilled and filtered of all contaminants to flush all fuel fumes from the tanks overboard through outflow valves located in fuel vent surge tanks in the wing tips. The air cycle machine, along with its water separator/heat exchanger, expansion orifice, mixing valves and other associated apparatus provide a 2.7 pounds pressure differential and a continuous outflow of fuel fumes and excess noncombustible gases that have been chilled or heated to the optimum temperature. Aquastats in the fuel tanks modulates the mixing valves to provide this temperature control.

The air cycle machine, built to SHN specifications, incorporates a quick disconnect coupler to the turbine inlet so exhausts of a GPU can provide power and noncombustible inert gases for safe refueling and chilling of potential overheated fuel. (See NTSB Comment: Docket No. FAA 1999-6411; Notice No. 99-18, pp. 4-5)

FIGURE 1. OVERVIEW OF THE SHN FUEL SYSTEM



The #2 standby boost pump operates as a fuel flow generator during normal conditions. In the eventof a drop in fuel pressure in the #1 main boost pump indicating a possible failure of this boost pump, #2 standby pump is activated automatically. Pump impeller vanes on allSHN axial flow boost pumps are designed and spaced to allow ample fuel flow through either or both pumps in the unlikely event both are nonoperating so that full engine power can be maintained by the engine driven fuel pumps.

SHN FUEL SYSTEM

1. Scoop in the tail pipe collects engine exhaust and directs it, via ducting, to a:
2. Water separator/Heat exchanger where exhausts are precooled and steam is condensed into water carrying away some contaminants with it overboard. Since outside air temperature at cruise altitude is most often minus 55 degrees Celsius, the water separator/heat exchanger includes a heating element that is activated when required to keep the water from freezing. Approximately ten percent of exhaust gases is water in the form of steam. The dried gases are ducted to:
3. The turbine side of the air cycle machine where dried exhaust gases release more heat as they spin the turbine and then are ducted to:
4. The compressor end of the air cycle machine where the gases are compressed to provide adequate pressure differential for expansion/cooling prior to reaching the expansion orifice.
5. Compressed gases then pass through a contaminant filter removing the remaining impurities prior to passing through the expansion orifice.
6. Gases passing through the expansion orifice expand, chilling the gases to a temperature below freezing and are then routed to:
7. Two in parallel mixing: valves that blend hot air from the turbine side of the air cycle unit with the chilled and dried inert gases passing through the expansion orifice.
8. The two parallel mixing valves, modulated by aquastats located in the fuel tanks, are programmed to regulate these inert gas temperatures. These gases are then routed through the fuel tanks, continuously purging fuel fumes negating their buildup, removing a major leg of the "Fire Triangle." This feature is significantly more

critical if a fuel tank is empty on take-off and when fuel levels decline during flight. Additionally, this purging feature is operable while a plane is on the ground being refueled or undergoing maintenance with the use of a GPU, or if necessary the plane's APU.

9. Inert gases are now vented through the fuel tanks to maintain appropriate fuel temperature significantly, reducing any possibility of explosion due to autoignition.

10. Multiple ultrasonic fuel level sensors located in the top of each fuel tank provide accurate readings of fuel quantity in any aircraft attitude. The number of sensors on each fuel tank will depend on its size and configuration.

11. At the top of each fuel tank is a perforated vent manifold that permits escape of over pressurized fuel levels and also vents the temperature control gases, that are then ducted to:

12. Two outflow valves located in each vent surge tank automatically programmed to maintain an appropriate positive pressure to prevent siphoning and allow gas fumes and the inert temperature control gases to escape. Outflow valves are calibrated to meet the requirements of each model aircraft providing sufficient pressure differential so gases and fuel fumes are purged from fuel tanks continuously at all attitudes This feature will also prevent the collapse of fuel tanks due to a potential siphoning vacuum.

OVERVIEW OF OBJECTIVES

1. How the SHN fuel system eliminates all three sides of the "Fire Triangle."
2. All requirements in the Docket 1999-6411 are met or exceeded with adoption of the SHN fuel system.
3. The SHN fuel system is being prepared for submission and approval as an STC.
4. Catastrophic failure conditions in fuel systems will not occur in fleets that have incorporated the SHN fuel system and when fuel system elements are properly inspected and maintained.
5. Proper inspection and maintenance are key elements in the design and operation of the SHN fuel system.
6. Redundancy and fail-safe procedures are built into all critical components and processes of the SHN fuel system to ensure adequate fuel system operation if a malfunction were to occur.
7. The SHN fuel system has a warning mechanism for the detection of failures or failure indications of critical components.
8. Functional verification of various components' condition is one of the operational capabilities of the SHN fuel system.
9. Proven reliability and integrity to ensure that multiple component failures cannot, (a) occur in the fuel system during the same flight, (b) built-in damage tolerance that limits effects of a failure, and (c) a design failure path that controls and directs failure by design to limit failure impacts.
10. Flight crew manuals are an integral part of the total package of every SHN fuel system, describing, among other things, procedures to use in the event of a fuel

system component malfunction or failure, to assure continued safe flight by specific crew actions. Built in redundancy will automatically be activated in most cases of a malfunction or failure. Historically, plane manufacturers (e.g., Boeing) are required to provide maintenance related information for fuel tank systems in the same manner as for other systems. SHN will work closely with plane manufacturers and airlines in the preparation of these manuals to ensure they are well written in a language easy to understand in the field, and also in compliance with individual airline policies as well as FAA requirements.

11. Error tolerant design that recognizes the possibility of human error in the operation, inspection, maintenance and replacement of the SHN fuel system.

12. Margins of safety that allow for undefined, unforeseeable and adverse flight conditions.

OBJECTIVE #1

THE FIRE TRIANGLE

For a fire/explosion to occur three conditions must be present:

1. Combustible material: in this case, fuel fumes.
2. Oxygen (O_2): in the fuel tank.
3. Ignition: which can come from a hot motor bearing, a lightning strike, a spark due to the buildup of static electricity, a dropped metal tool striking another piece of metal, or due to autoignition because of rising temperatures in the fuel tank as the plane is on the ground.

Combustible Materials

The SHN fuel system continuously removes combustible gas fumes from the fuel tanks. It does this by scooping CO_2 and other gases exiting the jet engines and using these flows, which are then pressurized, chilled and filtered of all contaminants, through the use of air cycle units, water separators/heat exchangers, contaminant filters, expansion orifices, mixing valves and aquastats to remove all fuel fumes from the tanks. SHN outflow valves are calibrated to maintain 2.7 pressure differential (usually the same as cabin differential). Outflow valves are also installed in the vent surge tanks. During ground operations exhausts of ground power units (GPU) or auxiliary power units (APU) operate air cycle machines.

Fuel temperature in fuel tanks is controlled within appropriate ranges by the use of aquastats in the fuel tanks, sensing fuel temperatures and modulating the mixing valves to maintain desired temperature levels. Docket 1999-6411 notes on p. 5, "...Vapors from Jet A fuel (the typical commercial turbo jet engine fuel) at temperatures below approximately 100°F are too lean to be flammable at sea level. At higher altitudes the fuel vapors become flammable at temperatures above approximately 45°F (at 40,000 feet altitude). However, regulatory authorities and aviation industry have always presumed that a flammable fuel air mixture exists in fuel tanks at all times and have adopted the philosophy that the best way to ensure airplane fuel tank safety is to preclude ignition sources within fuel tanks." It should be noted that on a typical day (at operating altitudes) outside temperatures are usually a minus 55°C plus or minus IS. Therefore, since the SHN system controls fuel temperature, at no time will fuel approach temperatures that support combustion. This philosophy considers only one side of the "FIRE TRIANGLE," ignition. The SHN fuel system, by controlling fuel temperature, takes ignition and therefore combustibility of fuel and fumes out of technical possibility.

Oxygen

A significant feature of the SHN fuel system is that it continually purges fuel tanks of all fumes, using inert gases filtered of all contaminants so that the level of O_2 never reaches a volume where combustion can be supported.

Ignition

The most significant feature of the SHN fuel system compared to present fuel systems in use and the source of the inherent design flaw, is the removal of all ignition sources from the fuel tanks. By design, two SHN in-line axial flow boost pumps are mounted in series in the main fuel line from fuel tanks to the jet engine driven pumps. All SHN in-line boost pumps are designed, constructed and installed to be impact proof The downstream pump serves as a standby pump in event of a main pump failure, and in normal operation operates as a fuel flow generator. In the unlikely event the main pump malfunctions triggering a drop in fuel pressure, the standby pump automatically starts, and without interruption continues supplying fuel at the required pressure.

All SHN in-line boost pumps are a/c operated, using permanent armatures with field coils positioned external to the carbon fiber housing and made a part of the air frame structure. One lamination of the carbon fiber housing contains a copper mesh screen to provide shielding from static pickup by avionic equipment, as well as a bonding connect.

The capacitance type fuel quantity measuring devices presently in use along with their associated wiring are eliminated. These present in-use devices and their associated wiring are removed from inside the fuel tanks and replaced with SHN fuel level measuring instruments. There will be multiple SHN fuel level measuring instruments in the top of each fuel tank. The actual number depending on tank size and configuration. Most often there will be a minimum of five fuel level sensors, one in each quarter and one in the center. An average of the multiple readings provides very accurate measures of fuel levels regardless of an aircraft's attitude. The SHN fuel measuring units use a concept that has a long history of measurement reliability and accuracy. Importantly, these units weigh only a fraction of the present capacitance type fuel measuring devices. The SHN fuel system requires no wiring inside any fuel tank thereby eliminating the major source of ignition inside fuel tanks.

Since the SHN fuel system has no wiring in any fuel tank there are no electrically operated boost pumps and fuel measuring devices in any tanks. The SHN fuel system not only eliminates the ignition problem but also reduces weight, increases fuel measurement accuracy, and reduces the costs associated with inspection, maintenance and replacement.

The SHN fuel system removes combustible materials, oxygen and ignition sources from the present fuel systems thereby eliminating all 3 sides of the "Fire Triangle."

OBJECTIVE #2

PURPOSE OF SHN FUEL SYSTEM

We commend the Federal Aviation Administration for their determination to resolve the "Fire Triangle" problem in large commercial aircraft, which will result in the saving of many, many lives over the years. For SHN Aeronautical Technologies the process of finding an answer to this problem actually began within a few days after the catastrophic accident of TWA Fl 800. Two principals of SHN Aeronautical Technologies concluded that an explosion of that magnitude could have only resulted from a center wing tank explosion. That was the beginning of creating the SHN fuel system. This proposal is the result of our efforts from that day. We strongly believe this system resolves the "Fire Triangle" issue.

We have read Docket 1994-6411 many times and appreciate FAA's focus on all three legs of the "Fire Triangle." Our study of the Docket led to the creation of twelve objectives, when taken in total do four things:

1. First and foremost, resolve the "Fire Triangle" problem.
2. Create a very reliable, fail-safe fuel system.
3. Incorporate FAA's concerns for a fuel system that is economical in terms of initial costs of components relative to present systems in use, and also in redesign, retrofitting and long term operating costs that include inspection, maintenance, repair and replacement. Indirect long term costs, such as legal and insurance, will also be significantly reduced because of the reliability and fail-safe design of the SHN fuel system.

4. Recognize that the SHN fuel system is just one of many sub systems, in which all are interconnected to make up, holistically, an airplane that carries passengers safely.

All of the objectives are fully discussed often referencing the schematic drawing of the SHN fuel system. (See Figure 1) Our purpose mimics those of the FAA., design a fuel system that has little or no opportunity to explode, therefore saving many lives. SHN Aeronautical Technologies has worked towards that goal and we believe that goal has been achieved.

OBJECTIVE #3

BASIS FOR STC

After several meetings with FAA officials in Atlanta, Georgia, we were advised to apply for an STC for the SHN fuel system. The process has begun. A positive response by FAA to our proposal will spur our efforts to attain an STC.

Preliminary evaluations of the SHN fuel system by independent authorities confirm that the SHN fuel system concept is valid and has the potential to save many lives. No doubt the transition to a more effective fuel system will be time consuming and costly during the retrofitting phase. But eliminating this design flaw is long overdue and in the long run will not only save lines, it will be less costly operationally and reduce indirect costs. SHN Aeronautical Technologies has taken the first steps in putting this problem behind us.

OBJECTIVE #4

CATASTROPHIC FAILURE CONDITIONS WILL NOT OCCUR DURING LIFE OF FLEETS USING SHN FUEL SYSTEMS

The probability of failure in an SHN fuel system is very remote. The strategic partners that supply the various components have a history of quality that has led us to employ them to help create a fail-safe fuel system that not only meets SHN standards but meets the requirements of FAA's new policy of fuel system safety as specified in Docket 1999-6411.

The SHN fuel system is designed with in-depth redundancy dramatically reducing the opportunity for catastrophic failure conditions to occur. Since all large certificated passenger aircraft have at least two turbo engines, the SHN fuel system, by design, has built-in redundancy in addition to the on-board APU. For example, a Boeing 767 would have it's primary fuel system powered by the exhaust from one engine and the second engine's exhaust could power a standby system in the event the primary system were to malfunction. An added benefit of the SHN fuel system is the components, by design, weigh significantly less than components presently in use, therefore, the addition of a standby fuel system would not add weight to the aircraft.

The on-board APU could also be used as a power source for a standby fuel system as it has sufficient exhaust to operate the SHN fuel system.

OBJECTIVE #5

INSPECTION AND MAINTENANCE: MAJOR FACTORS TO SUCCESS OF SHN FUEL SYSTEM

Fuel system components that contribute to the "Fire Triangle" are inside the fuel tanks making proper inspection and maintenance very difficult. Physical demands made on personnel responsible for these crucial tasks is severe to say the least. As long as this design flaw exists adequate inspection and maintenance will always be suspect. The Docket also makes the same observation: ". . . Visual inspection of fuel tank system components is by far the predominant method of inspection for components such as boost pumps, couplings, wiring, etc. Typically these inspections are internal or external fuel tank structural inspections. These inspections normally do not provide information regarding the continued serviceability of components within the fuel tank system, unless the visual inspection indicates a potential problem area. For example, it would be difficult, if not impossible, to detect certain degraded fuel system conditions, such as worn wiring routed through conduit to fuel pumps, corrosion to bonding wire interfaces, etc., without dedicated intrusive inspections that are much more extensive than those normally conducted." (p. 25)

To bring attention to the situation the FAA established the Fuel Tank Harmonization Working Group (FTHWG) in January 1998 with the task of evaluating fuel tank flammability and to make recommendations. The multistakeholder working group submitted their report six months later (Docket No. FAA- 1998-4183) and made several recommendations, including the following: (1) amend section 25.981, requiring all new type design airplanes to limit the time transport airplane fuel tanks could operate with flammable vapors in the vapor space of fuel tanks to less than seven percent of expected fleet operating time; or (2) provide the means to prevent ignition of vapors within fuel tanks such that any ignition of vapors within fuel tanks would not preclude the continued safe flight and landing.

Unlike wing tanks, center wing fuel tanks are often adjacent to heat generating equipment creating an overheat situation. The Committee recommended that this overheat condition should be limited, on average, to 30 percent or less of the fleet operating time. They further recommended controlling heat transfer into and out of fuel tanks, maintaining fuel temperatures below dangerous levels. As FAA notes on p. 3 1 in Docket 1999-6411, ". . . the major issue is one of minimizing flammable vapors in fuel tanks." This is exactly what the SHN fuel system does: maintains fuel temperatures within safety ranges both in flight and on the ground during the refueling process; and, more importantly, constantly purges fume vapors from fuel tanks. With vapors being a major culprit of the most recent center wing tank explosions SHN Aeronautical Technologies made the vapor issue a major focal point in the design of our fuel system.

Follow up studies by independent expert groups of TWA Fl 800, as well as FAA's own survey of the accident, revealed many instances of conditions that could have contributed to ignition inside the center wing tank. To a significant degree these conditions pointed to inadequate inspection, maintenance and replacement procedures. Such findings confirm our own observations of the difficulties associated with effective inspection, maintenance and replacement due to the inherent design flaw: the combination of electrical components, combustible materials (fuel vapors) and oxygen all inside the fuel tanks. Combine this with the difficulty, found by both the independent study team and FAA, of less than timely, effective inspection, maintenance and replacement, conditions were ripe for an accident. There is a serious design flaw. The SHN fuel system eliminates the flaw and therefore the “Fire Triangle.”

The SHN fuel system resolves the design flaw by removing all electrical components located inside the fuel tanks. By design, fuel boost pumps, quantity measuring devices, wiring and other associated components are positioned external to fuel tanks. This design feature not only negates the major cause of fuel tank explosions, but these components are now easily accessible to inspectors and maintenance personnel. Accessibility enhances effectiveness and efficiency.

The inspection and maintenance section of the SHN fuel system operations manual can now be “at the side” of inspection and maintenance personnel as they perform these crucial tasks. Present fuel system design, with pumps, wiring and other apparatus inside fuel tanks, makes the physical presence of manuals impractical detracting from effective and efficient inspection and maintenance raising the potential for human error. The SHN fuel system eliminates this problem, leading to improved inspection and maintenance and therefore significantly reducing the potential for human error.

OBJECTIVE # 6

REDUNDANCY OR BACKUP SYSTEMS THAT PROVIDE SYSTEM FUNCTION AFTER MALFUNCTION OR FAILURE

As mentioned in Objective #4, built-in redundancy can be added. In addition to the primary system there are two backup systems. However, this could be considered excessive considering the reliability of the components in the SHN fuel system. We suggest the FAA consider using one engine to power the SHN fuel system and a GPU or APU to provide cooling and filtering of fuel during refueling. In the unlikely event there is a failure of the primary power system, power would be maintained by switching to one of the auxiliary units. If this suggestion is adopted it will result in less equipment cost, less weight, less inspection and maintenance costs and less replacement costs; all without sacrificing safety.

Purging fumes from the fuel tanks, both during flight and on the ground during refueling, eliminates combustible materials and controls temperatures, thereby significantly enhancing safety and negating the potential for an explosion. These fumes are vented through outflow valves in the vent surge tanks. If, perchance, one outflow valves sticks-in a closed position, the remaining outflow valves are of sufficient capacity to accommodate the continued normal purging of fuel fumes.

If both mixing valves were to stick causing an overheat situation, a duct overheat sensor automatically activates a temperature limit shut off valve to the full cold position.

Four outflow valves in the two vent surge tanks precludes any overpressure condition in the fuel tanks.

If the water separator/heat exchanger freezes, a heater in the apparatus is automatically activated to relieve the situation.

There are several ultrasonic fuel level sensors on each tank. The actual number depends on tank size and configuration. We anticipate a minimum of five on each tank. If for some rare reason one of the SHN ultrasonic fuel sensors fails the remaining sensors will provide reliable fuel level measures regardless of plane attitude. In the extreme and very hypothetical case all sensors but one fails the flight crew could still get an accurate fuel reading on straight and level flight.

Failure of the main fuel boost pump causing a drop of pressure in the fuel line automatically activates the standby boost pump.

OBJECTIVE #7

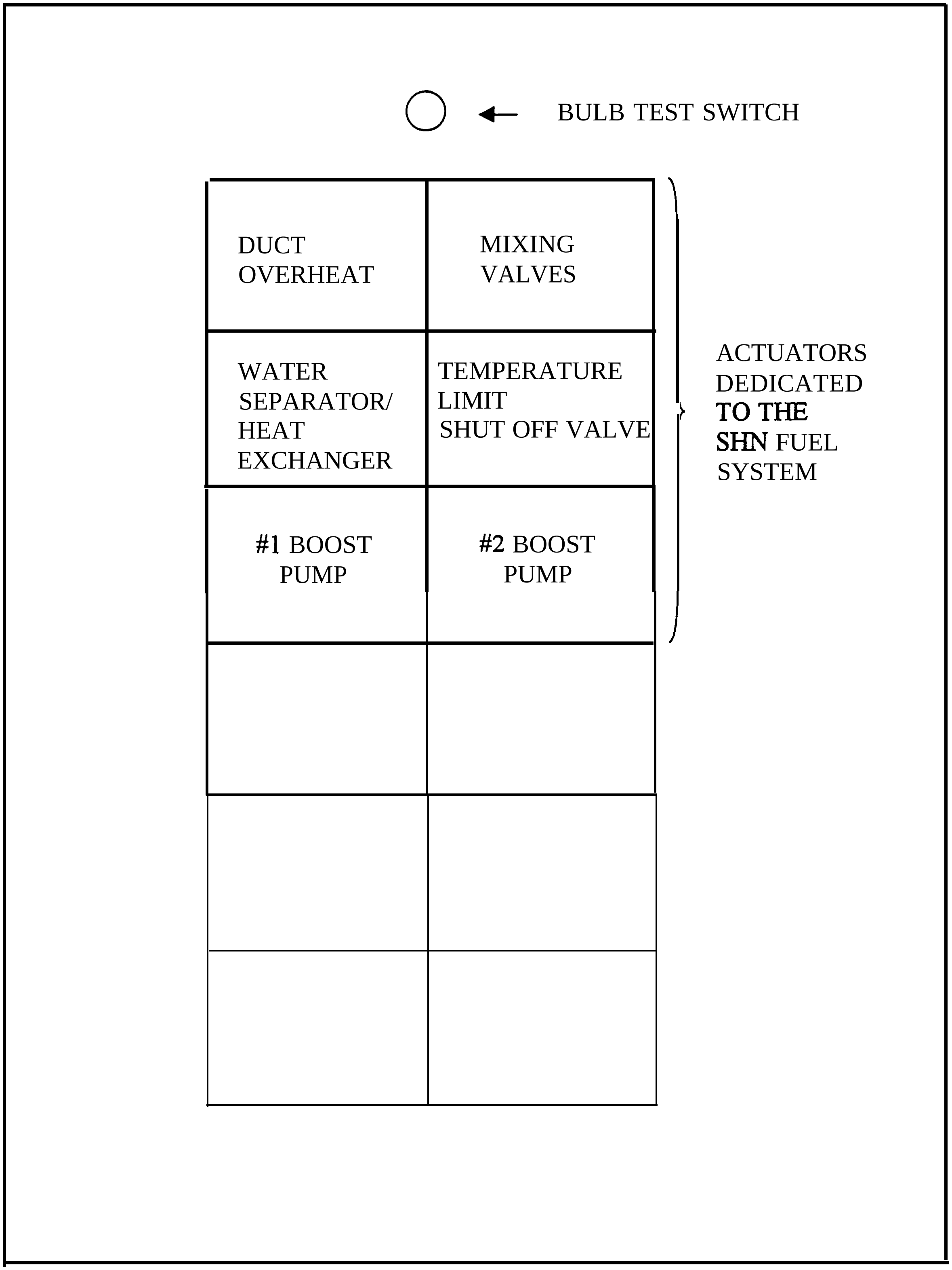
DETECTION OF FAILURES OR FAILURE INDICATIONS

SHN fuel system components are manufactured to our strict specifications of the highest grades of materials and when combined with proper inspection, maintenance and replacement will prove to be rugged, reliable and in most cases exceeding FAA requirements. But malfunctions and failures do occur. Some failures will require action by the flight crew. The majority will be corrected automatically, by design.

There are a set of light indicator switches/reset actuators dedicated to the SHN fuel system built into the annunciator panel. (See Figure 2) This set of actuators assists flight crews to determine the operational efficacy of their fuel systems. If an actuator is red a crew is required to take immediate and appropriate action. An amber actuator indicates a precautionary status and a flight crew would examine the situation to ensure that a backup or redundancy system has been activated or is in an operative standby mode. For example, with a main fuel boost pump failure, its actuator light would turn red and the standby number two boost pump would be activated automatically. That actuator light switch would turn green. A flight crew, knowing that their plane was operating using the standby fuel boost pump, would have to decide whether to continue the flight to its destination or make an “emergency” stop for a quick change replacement. This decision may well be dictated by the operating procedures of each airline. Certainly, plane location relative to destination and alternative airports with appropriate supplies at the time of the main fuel boost pump failure will be major factors in the decision.

The SHN fuel system is designed to allow for quick change of components, such as fuel boost pumps, enhancing flight safety and operational efficiency.

FIGURE 2. ANNUNCIATOR PANEL WITH SHN FUEL SYSTEM LIGHT INDICATOR SWITCH AND RESET ACTUATORS



OBJECTIVE # 8

FUNCTIONAL VERIFICATION OF THE CAPABILITY TO TEST OR CHECK COMPONENT'S CONDITION

The annunicator panel permits a flight crew to check the operational efficacy of the major components of the SHN fuel system. For example, to check the function of the annunciator readout panel the bulb test switch is pressed. This will light all lights on the annunciator panel. Pushing each of the annunciator lights in turn checks the circuits to that particular component.

Pressing a fuel boost pump test switch, which simulates a drop in fuel pressure, checks a fuel boost pump's operational condition. The crew would watch for a momentary drop in fuel pressure and a reading on the fuel system panel that the standby fuel boost pump is in operating condition. For example, boost pump #1 actuator will become red and boost pump #2 actuator will turn green.

Test the ultrasonic fuel level sensor units by turning off each unit switch, one at a time, and check that all units read the same. A multiple unit fuel metering system provides a very accurate measure in any attitude with ample redundancy because any three units can adequately compensate for plane attitude,

OBJECTIVE # 9

PROVEN RELIABILITY AND INTEGRITY THAT MULTIPLE COMPONENT OR SYSTEM FAILURES WILL NOT OCCUR ON THE SAME FLIGHT

SHN fuel system components are manufactured to standards that improve the safety factor of each unit. For example, our in-line fuel boost pumps are axial flow that incorporate permanent magnet armatures with field coils as part of the structure, mounted to the exterior of the pump barrel. This design feature enhances safety of the fuel system because no electrical conductors come in contact with the fuel.

In the event a failure occurs that would shut down the fuel system (such as an engine failure), a complete independent standby system, powered by the exhaust of the on board APU is available.

In event of failure of one of the standby systems, such as one of the in-line boost pumps, the aircraft will still fly normally because of the SHN built-in redundancy system (which in this example includes a stand-by pump as well as engine driven pumps).

The turbine side of the air cycle machine has a shield consisting of an upgraded, proven, lightweight rugged material (kevlar) to protect surrounding apparatus in the unlikely event of a turbine failure.

Since the aircraft will continue to fly safely with many components of the SHN fuel system inoperative, the best procedure is to shut down the malfunctioning component and use the back up unit.

Built in redundancy is automatically activated in the case of most malfunctions or failures. However, flight crew knowledge and accepted practices, explained in the SHN operation manual and in aerial operating procedure manuals is the key to ensure a safe flight.

OBJECTIVE #10

FLIGHT CREW PROCEDURES DESIGNED TO ASSURE CONTINUED SAFE FLIGHT IN THE EVENT OF FUEL SYSTEM FAILURE

In event of a complete primary fuel system failure a pilot would switch to the standby system which is powered by the exhaust of another jet engine or the on-board APU. To start an APU a flight crew would refer to the operations manual checklist.

Check lists are modified to each particular model aircraft. Manuals, checklists, and instructions for operating fuel systems, including the functions and use of fuel panel annuciators, are developed in cooperation with all organizations adopting SHN fuel systems for their fleets.

The SHN fuel system has been automated as far as practical. In most cases, the system will take care of itself Switching to a secondary system and or the repositioning of valves to alternative operating positions are accomplished automatically, as when a pressure or heat sensor senses the need for an adjustment.

A SHN fuel system annunciator panel includes override switches, providing the pilot with final control. From a practical point of view we have reviewed every possible situation, with Murphy's law firmly in mind.

OBJECTIVE #11

ERROR TOLERANT DESIGN THAT CONSIDERS PROBABLE HUMAN ERROR IN THE OPERATION, MAINTENANCE AND FABRICATION OF THE AIRPLANE

Only components that have proven track records of reliability and a history of practical maintenance and economy are used in the SHN fuel system. Aircraft will continue to fly safely with the loss of any or all of the primary components of the SHN fuel system.

For example, in-line axial flow fuel boost pumps are designed with ample space between impeller vanes so that adequate fuel flow through both main and standby pumps continues in the event of failure of either or both. In a 767 more than ten thousand pounds, or twenty two and one half cubic feet of fuel per hour, can continue to flow in the event of failure of either or both boost pumps. In the unlikely event that both pumps fail engine driven fuel pumps can supply the necessary fuel for a safe flight to an appropriate destination.

It is impossible to install SHN boost pumps backwards. The intake end of the pumps have left hand threads while the pressure, or outlet end, have right hand threads. In addition, a color-coding system with arrows indicating direction of flow are imprinted on the housing with a circuit diagram of the wiring on the barrel of the pumps.

SHN fuel system operations manuals not only provides direction for installation of fuel boost pumps and other components, they also provide procedures for inspection, maintenance, replacement and trouble shooting considering a variety of scenarios. For example, since SHN boost pumps are a/c pumps, inspection and maintenance procedures are significantly simplified over boost pumps presently in use. All components and installed units are labeled with date of installation and scheduled date of next inspection including the date/hours when replacement is due.

OBJECTIVE # 12

MARGINS OF SAFETY THAT ALLOW FOR UNDEFINED, UNFORSEEABLE AND ADVERSE FLIGHT CONDITIONS.

SHN fuel systems are designed to withstand greater stress and adversity than the aircraft in which they are installed. No aircraft operations are compromised because of the installation of our system. Table VI provides several illustrations of the impact of selected adverse flight conditions on the SHN fuel system and flight safety.

TABLE VI. IMPACT' OF SELECTED ADVERSE FLIGHT CONDITIONS ON THE SHN FUEL SYSTEM AND FLIGHT SAFETY

Flight Conditions	**Effect on SHN fuel system**	**Effect on Safety of Flight**
Clear air turbulence	None	Normal
Lightning strike	All components well bonded	Normal
Icing	Water separator heater is activated automatically	Normal
Excessive negative "G" forces	None, unless water separator heater turns on extended inverted flight	Do not exceed published aircraft limitations
Excessive positive "G" forces	None. (Do not exceed published limits.)	Stay within published limits
Engine fire	None or catastrophic	Isolate fuel system

SUMMARY

At the NBAA conference in Atlanta in 1999, we spent many hours examining fuel systems on display. We are convinced, that, after comparing these systems with the SHN fuel system, ours is better designed, more fail-safe, with superior built-in redundancy. Ruggedness, the historic reliability of the various components and the design of the SHN fuel system leaves no doubt in our minds of the superiority of the SHN fuel system in its ability to negate all three sides of the "Fire Triangle."

Throughout this response we have referred to the reliability of the components used in the SHN fuel system. At the heart of our fuel system are the air cycle machine and the outflow valves. For example, a similar air cycle machine on a UPS 767 was changed out at 78,000 hours. No inspection was required. Our outflows valves operate 24 months before a required inspection.

In summary the SHN fuel system eliminates the "Fire Triangle," is rugged, reliable, accurate, lightweight, simple to inspect, maintain and replace. The SHN fuel system is both effective and efficient, meeting all the requirements contained in Docket 1999-6411.

APPENDIX

SUPPORTING INFORMATION AND TABLES

TABLE I. U.S. AIR CARRIERS, LARGE AIR CARRIERS, ENPLANEMENTS: HISTORICAL (1990- 1996) AND FORECAST (1997-2008)

Emplanements (Millions)	**Historical**			**Forecast**		
	1900	**1995**	**1996**	**1997**	**1998**	**2008**
Domestic	424.1	496.3	523.6	546.2	569.4	827.1
International	41.3	48.6	50.3	53.1	56.1	98.5
Svstem	**465.4**	**544.9**	**573.9**	**599.3**	**625.5**	**925.6**
Percent Increase	◄——	**23.31**	——►	◄——	**54.44**	——►
	◄——		**98.88**			——►

Source: <www.api.faa.gov/forcast/fol-297. htm> Table 1-2 (14 February 2000)

TABLE II. TOTAL TURBOJET AIRCRAFT REPORTED IN OPERATION BY AIR CARRIERS: 1987-1996

Year	Number of Turbojets	Accumulated Percentage Increase
1987	3,575	
1988	3,915	-9.5
1989	3,942	10.3
1990	4,148	16.0
1991	4,167	16.6
1992	4,446	24.4
1993	4,584	28.2
1994	4,636	29.7
1995	4,834	35.2
1996	4,922	37.7

Source: <www.api.faa.gov/forcast/fortab.htm> Table 5.1 (15 February 2000)

TABLE III. HOURS FLOWN PER LARGE CERTIFICATED CARRIERS: 1987-1996

Year	Revenue Aircraft Departures	Revenue Aircraft Hours Flown	Hours Flown Per Flight
1987	308,484	1,075,187	3.485
1988	353,892	1,258,489	3.556
1989	392,028	1,446,188	3.687
1990	419,472	1,556,575	3.711
1991	418,146	1,644,475	3.933
1992	439,046	1,825,202	4.157
1993	460,518	1,933,046	4.198
1994	481,781	1,973,473	4.096
1995	504,572	2,019,103	4.002
1996	525,268	2,108,695	4.015

Source: <www.api.faa.gov/forcast/fortab.htm> Table 6.4 (15 February 2000)

TABLE IV. HOURS FLOWN BY LARGE CERTIFICATED U.S. COMMERCIAL AIR CARRIERS: HISTORICAL (1991-1996) AND FORECAST (1997-2008)

Year	Number of Aircraft	Airborne Hours	Average Airborne Hours Per Aircraft
Historical			
1991	4,244	10,554	2.487
1992	4,202	10,728	2.553
1993	4,254	11,206	2.634
1994	4,421	11,538	2.610
1995	4,605	12,020	2.610
1996	4,775	12,343	2.585
Forecast			
1997	4,916	12,690	2.581
1998	5,069	13,042	2.573
1999	5,197	13,375	2.579
2000	5,314	13,802	2.597
2001	5,560	14,443	2.598
2002	5,796	15,101	2.605
2003	6,027	16,778	2.618
2004	6,281	16,518	2.630
2005	6,508	17,198	2.643
2006	6,762	17,948	2.654
2007	6,987	18,617	2.665
2008	7,226	19,335	2.676

Source: <www.api.faa.gov/forcast/foac1697.htm> Table 16 and 17 (16 February 2000)

TABLE V. U.S. COMMERCIAL AIR CARRIERS: SCHEDULED PASSENGER TRAFFIC: 1991 THROUGH 2008

Year	Revenue Passenger Enplanements (Millions)			Revenue Passenger Miles (Billions)		
	Domestic	International	Total	Domestic	International	Total
Historical						
1991	413.3	39.7	453.1	333.6	113.5	447.1
1992	430.3	42.6	472.9	346.7	128.5	475.2
1993	434.0	45.2	479.2	348.6	134.8	483.4
1994	472.1	46.3	518.4	371.4	138.6	510.0
1995	496.3	48.6	544.8	392.5	144.3	536.9
1996E	523.6	50.3	573.9	418.6	151.1	569.6
Forecast						
1997	546.2	53.1	599.3	439.5	159.4	598.9
1998	569.4	56.1	625.5	459.3	168.3	627.6
1999	591.0	59.2	650.2	477.9	177.9	655.8
2000	613.5	62.6	676.1	497.3	188.2	685.5
2001	636.8	66.5	703.3	517.5	200.2	717.7
2002	661.1	70.8	731.9	538.5	213.3	751.8
2003	686.2	75.5	761.7	560.4	227.0	787.4
2004	712.3	79.8	792.1	583.1	240.1	823.2
2005	739.4	84.2	823.6	606.8	253.8	860.6
2006	767.6	88.9	856.5	631.4	267.8	899.2
2007	796.8	93.6	890.4	657.0	282.5	939.5
2008	827.1	98.5	925.6	683.7	297.6	981.3

Source: <www.api. faa.gov/forcast/foac1297. htm> (16 February 2000)