CHAPTER 3 - COMPONENT MATERIALS

7. GENERAL. The applicant is responsible for ensuring the integrity of all materials used in the system. This Chapter describes the material characteristics which have been found important in auxiliary fuel systems. Information and documents concerning material properties and environmental testing requirements can be obtained by contacting the American Society for Testing and Materials (ASTM).

8. ENVIRONMENTAL PROPERTIES EVALUATION.

a. Normal Environment Properties.

(1) Fuel Resistance. Fuel resistance deficiencies have produced problems in the past.

(i) One problem is the presence of fuel or fuel vapor in air pressurizing systems for auxiliary fuel tanks. Pressurizing components which normally are exposed to air will also, during normal static conditions, be exposed to fuel vapor, especially when the airplane is exposed to solar heating while parked for some period of time. Expansion and vaporization of fuel in the tanks can cause vapor migration through a part of the pressurizing system. A failure of a pressurizing system component can also inadvertently cause exposure to fuel. Seals and diaphragms in components which make up this system should be fuel resistant.

(ii) Another aspect which should be evaluated is the prolonged effects of fuel exposure. Some materials, certain plastics in particular, which exhibit short term fuel resistance have, over a prolonged period, deteriorated under the influence of fuel or fuel vapor.

(iii) New innovative material applications, such as composites, and new bonding adhesives should be thoroughly tested to determine the long term effects of fuel and fuel vapor exposure. The use of composite materials is discussed in more detail in Chapter 3, paragraph 9 of this AC. Surface treatments, coatings and sealants intended to reduce weathering and corrosion and seal structural areas should also be substantiated to ensure fuel and fuel vapor resistance, where applicable.

(iv) If a component is life limited, the limits due to fuel environmental conditions should be defined, particularly for nonmetallic items.

(2) Fuel Additive Compatibility. An evaluation should be made of the effects of additives, approved for the airplane, on the components of the auxiliary fuel system. The applicant should substantiate, by suitable methods, that the use of approved additives will not deteriorate these components or restrict the use of specific additives by suitable warning placards on the airplane and notices in the limitations section of the AFM.

(3) Ozone Resistance. High concentrations of ozone may be encountered by airplanes at cruise altitudes. Some materials, particularly certain rubber and plastic compounds, are susceptible to ozone deterioration and should not be used in auxiliary fuel systems. In some cases the combined ozone and fuel environment can produce rapid weathering and disintegration of the material. The effects of ozone should be evaluated with respect to the particular auxiliary fuel system design in question. Ozone compatibility should be substantiated using approved methods and specifications.

(4) Corrosion and Micro-Organism Resistance. Corrosion in auxiliary fuel systems is primarily due to entrained water in the fuel and the acids produced by the associated microbial contamination. Thus corrosion protection is especially important for tanks, sumps and equipment located in sump areas. Metal tanks and components should be made of materials resistant to corrosion or otherwise suitably protected. Metal combinations (dissimilar materials) which are subject to electrolytic corrosion problems should be avoided. Magnesium, copper, cadmium, and brass should not be used in auxiliary fuel systems as these metals are very active chemically. The combination of graphite layers of composite construction attached directly to aluminum will result in intergranular corrosion and should be avoided. Materials used for bladder cells, seals and composite tanks and fittings should be resistant to microbial contamination. Bladder cells must conform to Technical Standard Order (TSO) C80 or otherwise be shown suitable for the intended application.

(5) Temperature Range Suitability. Materials and components used in the auxiliary fuel system must have suitable properties and must perform their intended function throughout the approved airplane operating envelope. In some instances, they may be exposed to temperatures as low as -65^{o} F. or lower and as high as 250^{o} F., or even higher. Some rubber and plastic materials, for example, have excellent flexure properties at room temperature, but become unacceptably brittle at low temperatures.

b. Extreme Environment Properties. Extreme environment properties are those properties a material or combination of materials should have under certain conditions which are not encountered during the routine operating life of the materials. Examples are conditions which may be imposed by component failure or crash environments. An evaluation of the extreme environment properties should account for the following:

(1) Flexibility and Resilience. The properties of flexibility and resilience must to a certain degree be considered as a part of the normal environmental condition for flexible liners, flex connections and other components; however, these properties become of critical importance under crash conditions. Flexure and resilience must be considered to ensure fuel containment under these conditions. It may be necessary to demonstrate by test that certain fuel lines and shrouds are sufficiently resilient or ductile to withstand survivable crash load impact without fuel leakage. Materials and parts for rubber fuel lines should provide resilience and flexibility and conform to TSO-C53 or otherwise be shown suitable for the intended application.

(2) Heat-Strength Characteristics. The high temperature strength properties of materials used in the auxiliary fuel system should be considered for those components which may be subjected to sources of heat due to the failure of some component in another adjacent compartment or adjacent system. In addition, these configurations should be capable of sustaining the critical flight and landing loads and thus the integrity of the system under these conditions.

(3) Fire Resistance and Crash Fire Propagation Characteristics. Auxiliary fuel systems are frequently installed in cargo compartments. By definition, if the tank and component secondary barriers are capable of withstanding a cargo compartment fire such that the safety of the airplane is maintained then the secondary barrier materials are acceptable. These fire resistant characteristics should be equivalent to the liner materials of the compartment in which they are located. For Class B through Class E cargo or baggage compartments the materials must, at least, meet the requirements of §§ 25.853(b) and 25.855(a-1). The system should also be evaluated with respect to materials from the standpoint of toxic gas release under fire conditions. No materials should be used which act as a fuel for fires. Avoid the use of magnesium or flammable resins, sealants and coatings.

9. COMPOSITES (§§ 25.601, 25.603, 25.609, 25.613, 25.615, 25.619, 25.571, 25.581). The suitability and durability of materials used for nonmetallic auxiliary fuel tanks must be established by tests. Advisory Circular 20-107, Composite Aircraft Structure, should be reviewed for applicability when composite materials are used. The following elements should be considered in establishing material properties and substantiating the nonmetallic auxiliary fuel tank structure by tests:

a. Aging of the laminate in the operating environment, including wear, due to temperature, pressure, cavitation, moisture content changes, etc.

b. Chemical reactions with fuel vapor, cleaning liquids, solvents, salt water vapor and any other contaminates such as fungus in the tank.

c. Static electrical charge, bonding or lightning strike.

d. Any other elements characteristic of or unique to the type of nonmetallic material, method of processing and design applications.

e. A manufacturing process to ensure repeatability of material properties.

f. Inspection techniques for manufacturing and for continued airworthiness.

g. Statistically based material strength properties for critical tank structure. Strength, detail design and fabrication must minimize the probability of fatigue failure. Chapter 9 of MIL-HDBK-5D, Metallic Materials and Elements for Aerospace Vehicle Structures, and MIL-HDBK-17, Plastics for Flight Vehicles, contain procedures for establishing such properties.

h. Composite repair procedures defined by the applicant and approved by the FAA.

CHAPTER 4 - AUXILIARY FUEL SYSTEM PERFORMANCE

10. GENERAL. The designer should evaluate the auxiliary fuel system performance for all normal operating conditions of the airplane. This will, as a minimum, require a FAA witnessed functional ground and flight test program. Some of the performance criteria discussed in this section can be sufficiently evaluated by analytical methods, and substantiation reports submitted to the applicable FAA aircraft certification office for approval. As noted earlier, installations that involve changes in primary structure, aerodynamics, or mass distribution may require additional extensive substantiation that is beyond the scope of this AC. The following criteria should be considered by the applicant in generating test plans and substantiation reports for certification of the system.

11. NORMAL OPERATION EVALUATION.

a. Refueling and Transfer Performance.

(1) Refueling and Transfer Flow Rates and Pressures (§§ 25.951, 25.955, 25.957, 25.961, 25.991 and 25.979).

(i) The auxiliary refueling system should be analyzed to determine that the flow rates and pressures are acceptable. Fueling flow rates should also be demonstrated and verified by ground tests. The tank vent system capacity should be verified for the required operations and to ensure that over pressurization of the tanks, including the existing airplane main tanks when applicable, does not occur. Verification is also required that the pressure fueling automatic shutoff means does not produce unacceptable surge pressures which may damage the system or fueling equipment or rupture fueling lines. This verification can be accomplished by ground or laboratory refueling tests using fast response pressure transducers and recorders or submittal of previously accepted similar tests and service history data.

(ii) Transfer rates should be determined for all flight conditions in which transfer will be permitted to ensure that the receiving tank will be neither overfilled nor depleted before transfer is completed. It should be shown that transfer does not present any hazard, such as unwanted fuel migration, during such flight conditions. Any restrictions on transfer, such as duration or flight operating condition, must be outlined in the limitations section of the AFM. It should be assumed that the transfer system might be left on inadvertently; therefore, it should also be shown that transfer under conditions not permitted by the AFM would not present any hazard.

(iii) Compliance with the hot weather operational performance requirements of § 25.961 must be shown for auxiliary feed systems that feed directly to the engine. This is normally accomplished by conducting a hot fuel test; however, it may, in some instances, be sufficient to show that the system is similar to a previously approved system or to submit an analysis that is supplemented with component test data.

(iv) For auxiliary fuel systems that depend on bleed air for fuel transfer the airplane engine is, in effect, a transfer pump, and fail-safe requirements for pump transfer apply. This means that there must be an alternate means of providing fuel transfer in event of an engine inflight shutdown in accordance with § 25.901(c). This is usually provided by extracting bleed air for auxiliary tank transfer downstream of the pneumatic cross-over point. It is suggested that the applicant consult the airplane type certificate holder concerning the proper location of bleed air extraction points.

(2) Fuel Tank Capacities (Usable Fuel, Sump Capacity, Undrainable Fuel, and Expansion Space) (§§ 25.959, 25.969, and 25.971).

(i) For direct feed auxiliary fuel systems, the unusable fuel requirements of § 25.959, apply. For transfer type auxiliary fuel systems, the unusable fuel is the quantity of fuel remaining after transfer under the most critical steady state airplane flight attitude and altitude conditions permitted by the AFM.

(ii) Sump capacity is a part of the unusable fuel and as previously noted, is defined by § 25.971(a).

(iii) The undrainable fuel quantity should be measured, usually during the initial filling of the auxiliary tanks as a part of FAA witnessed ground tests. The undrainable fuel quantity is the fuel remaining in the system after all fuel possible has been sump drained from the system. It is not usually necessary to completely fill the tanks to determine the undrainable fuel, as the undrainable fuel is fuel trapped between stringers, at low points in fuel fittings, etc. Usually measuring the quantity of fuel necessary to fill all trapping cavities in the system is all that is necessary.

(iv) The maximum tank fueling capacity must take into consideration the expansion space requirements of § 25.969, Fuel Tank Expansion Space. The expansion space volume is the space available for fuel thermal expansion within the tank itself and does not include vent line volume. Basically, the expansion space is the volume from the tank full level to the level where fuel will just begin to enter the vent line.

(v) Figure 5 shows how the expansion space would be defined for three different vent configurations. The expansion space volume must be subtracted from the total volume of fuel at the level at which fuel will just begin to enter the vent line, and does not include the "compression" space above the vent opening. The expansion space should be derived for the airplane in its normal ground attitude. Expansion space capacity is verified during the airplane ground fueling tests conducted as a part of the test program.

(vi) Ground and flight tests of the installed system must be conducted in accordance with § 25.979 with the airplane in the correct ground and flight attitudes to verify that the expansion space requirements are maintained for pressure fueling to the maximum automatic fuel shutoff level, verify tank(s) pressures during failure of the auto shutoff and also provide the correct values for usable and unusable system fuel.

(3) Pressure Relief (Water Hammer and Thermal Expansion) (§§ 25.995 and 25.1189(h)). The designer should evaluate the pressure fueling and transfer or direct feed system operation to ensure that no damaging fuel line pressures will occur during flow shutoff or due to thermal expansion effects. Normally, sufficient flex line length and the use of "slow" shutoff valves or valves with thermal relief features will negate this problem. In some cases relief valves or other means may need to be incorporated in the system.

(4) Vent System Anti-Siphoning (§ 25.975). The auxiliary tank vent system should be arranged so that no hazardous quantities of fuel can migrate from one tank to another tank or discharged overboard during any normal flight attitudes.

b. Operating Limits (§§ 25.1503 through 25.1533). Assuming that the airspeed, c.g., maximum takeoff weight and maximum landing weight limitations will not be changed as a result of the auxiliary fuel system installation, the applicant's alternatives will be tradeoffs between payload weight and auxiliary fuel system weight at maximum capacity loading. Using these criteria, the applicant should review the requirements of Part 25 Subpart G, Operating Limitations and Information, to ensure that the auxiliary fuel system design does not degrade the airplane performance and other requirements stated in this subpart. If the c.g., airspeed, maximum takeoff or landing weight limits are increased, recertification efforts beyond the scope of this AC will be required.

(1) Operating Airplane Flight Envelope. The installation of the auxiliary fuel system should not restrict the operating flight envelope of the airplane, or a major recertification effort may be required. This does not mean that the auxiliary fuel system must function (transfer fuel) at all existing extremes of the airplane flight envelope. Envelope limitations on the transfer of auxiliary tank fuel must, however, be stated in the AFM. Using the above criteria the applicant should ensure that the auxiliary fuel system will not be adversely affected by exposure to the temperatures, pressures, altitude variation, and flight loads encountered in all regions of the airplane flight envelope. Specific examples of the above are discussed in Chapter 3 of this AC, in particular sections 8a(3) and 8a(5).

(2) System Electrical Power Requirements (§§ 25.1351, 25.1357).

(i) If additional equipment which consumes electrical power is installed in an airplane, the revised total electrical loads should not exceed the generator or alternator output ratings and limits prescribed for the airplane, or the ratings of any airplane bus(es). To ensure that the design meets the criteria, the applicant should provide the following:

(A) Power requirements for each of the equipment items which will be installed.

(B) Wiring diagrams for the equipment installation.

(C) An updated, electrical load analysis for the airplane including the auxiliary fuel system.

(ii) An appropriate circuit protective device (circuit breaker or fuse) should be installed as close as possible to the electrical power-source bus. Good engineering practices for selection of circuit breakers would consider the following:

(A) The minimum rating commercially-available airplane circuit breaker size which will power the normal (i.e. intended) load without nuisance trips, there by minimizing deliverable power to possible fault loads.

(B) Integral three-phase circuit breakers to protect three-phase loads.

(C) The selected circuit protective device must be consistent with the airplane electrical system protection and must protect the smallest wiring in the circuit.

(3) System Pneumatic Requirements (If Applicable) (§§ 25.981 and 25.965). If pneumatic pressure is used to transfer the fuel, it should be demonstrated that safe air supply temperatures and pressures are maintained under all normal and failure conditions of the pneumatic system. Air supply temperature, verified by test, should never exceed a safe margin below the lowest expected autoignition temperature of the fuel during fuel transfer. Safeguards should be provided, such as pressure regulators or relief valves, to ensure that over pressurization of the tanks will not occur in event of a pressure regulation failure in the pneumatic system. Cockpit pressure gauges indicating actual transfer pressure may also be required to ensure correct and adequate pressure levels.

(4) Fuel Quantity System Calibrations and Limitations (§ 25.1337(b)). Part 25 requires that fuel quantity gages read zero when the fuel remaining in the tank is equal to the unusable fuel supply. In this respect fuel quantity systems are calibrated for usable fuel wet, i.e., with a specific fuel of known density to substantiate that the fuel measurement system, as installed in the airplane, indicates zero in a level flight attitude. The applicant may want to increase the unusable fuel to the zero limit of the gage in some cases where the gage can not be calibrated down to the actual unusable tank fuel level, in lieu of replacing the gage. The calibration also encompasses additional readings of the fuel quantity gage which are compared against a standard, usually the readings taken from a fueling system having a calibrated accuracy of 0.5 percent. With the exception of the zero reading, all other calibration errors should be defined so that the acceptability for the particular auxiliary fuel system under review can be determined.

12. FAIL SAFE AND EMERGENCY OPERATION EVALUATION (§§ 25.952 and 25.901(c)). It is the applicant's responsibility, as a part of the certification compliance program, to analyze and submit a report(s) on the auxiliary fuel system component failure modes and consequences of these failures. It must be shown that the resulting consequence of any single detectable failure or combination of undetectable failures will not jeopardize the safety of the airplane. The fail safe criteria as defined in Appendix 1, Definitions, should be used as a guide in all design and failure mode analyses.

a. System Failure Modes.

(1) Component Failure Modes.

(i) The applicant will analyze the effects of malfunction or failure of each piece of equipment installed in the auxiliary fuel system and ensure that no malfunction will result in a hazard to the airplane. The analysis will include the effects of failure for all modes of component failure and all modes of auxiliary fuel system operation, such as, pressure fueling and defueling, fuel transfer or engine feed, and emergency fuel jettisoning. The effects of both detectable and undetectable failures shall be analyzed.

(ii) Wherever possible the configuration should incorporate means to detect component failures in the system. An example of such detecting means is the momentary "on" position detecting circuit incorporated in electric motor operated fuel shutoff valves. Valves with this feature are available as off-the-shelf items.

(2) Component Failure Indication.

(i) As discussed in the previous section, failure indication should be incorporated wherever possible to preclude situations of undetectable failure which can jeopardize airplane safety. Failure indication can be provided in a number of ways. The best from a recognition standpoint is indication which is immediate and draws attention. The momentary "on" position, or in-transit light for a motor operated shutoff valve, a low fuel state warning light, and an audible warning and light indicating fire or overheat are all examples of this type of indication. Continuous monitoring indicators such as pressure gauges, fuel quantity indicators, and temperature gauges can also provide failure indication. However, these devices are not as effective because they rely heavily on human judgment and alertness. Where crew workloads are heavy, such indications may go unnoticed for long periods or until the failure produces a critical flight incident.

(ii) Periodic inspection, such as the preflight inspection for fuel dripping from the auxiliary fuel system shroud drain (indication of fuel system leakage) is an essential function, but does not preclude the chance of failure occurring during long duration flights. Thus, assuming other means of detecting leakage are not incorporated, design precautions (for example, placing electrical wiring in conduits where it is routed through shroud spaces) may be necessary to preclude the chances that another failure will affect the safety of the airplane.

(3) Special Considerations for Auxiliary Fuel Systems Used for C.G. Control. On occasion, an applicant has elected to offset an airplane's c.g. shift by retaining fuel in an auxiliary tank for use late in the flight profile. Normally, auxiliary system fuel is used after takeoff and early in flight. This allows a somewhat simpler system having reduced redundancy compared to that of the main fuel tank system for the airplane. If the auxiliary fuel system should fail to transfer, the flight can return to the point of departure. However, for an auxiliary fuel system used for c.g. control, as where fuel is consumed late in flight, it may not be possible for the airplane to return to the original point of departure in the event of a fuel transfer malfunction. For this reason the system should have fail-safe transfer capability similar, in part, to the main tank fuel system. The safety of this system must stand on its own merits, i.e., a failure or malfunction of the auxiliary system should not prevent continued safe operation of the engines nor require reliance on the basic airplane's reserve fuel to complete the planned flight. Consideration must be given to the amount of vibration, wing flexure loads transferred to connections, support brackets, locking devices, etc., and the consequences of failure on the ability to maintain critical transfer flow rate. Therefore, the configuration should provide appropriate fail-safe features to assure that auxiliary fuel is always available in the event of a malfunction. Examples of some of the fail safe features which have been incorporated in a c.g. managed system in the past are shown in Figure 6 and include:

(i) Verification that in event of a significant failure of a feed line, the shroud would act as a redundant line to transfer the required fuel.

(ii) Incorporation of dual transfer pumps, line check valves and additional line support brackets. The added brackets ensured that if the feed line couplings inside the tank failed and separated, sufficient line alignment was maintained to ensure the fuel transfer. The added braces restricted both longitudinal and lateral line movement in event of coupling separation.

(iii) A fuel transfer verification check procedure incorporated in the AFM. This check procedure required that a sufficient quantity of fuel be tranferred early in flight to ensure that the system was functioning properly.

b. Operating Limits (§ 25.1351(d)).

(1) Emergency Electric Power Requirements. Generally there are no auxiliary fuel system electrical components which are required to be on the airplane essential bus circuits. There are however two exceptions which the designer should consider carefully:

(i) Direct engine feed auxiliary systems where the loss of pump electrical power could create an unsafe operating condition, such as an engine flame-out.

(ii) Direct engine feed or transfer auxiliary systems where fuel management is required to maintain proper airplane c.g. control (such as, fuel used late in the flight).

(iii) If, in either of these cases, fail-safe features are used which require the need for emergency electrical power, these needs should be assessed to ensure that sufficient power is available from the airplane essential power system. (See also Chapter 4, paragraph 11b(2).)

(2) Fuel Jettisoning (§ 25.1001).

(i) If the applicant uses a trade-off between auxiliary fuel system weight at maximum fuel capacity and payload weight (and thus there is no change in the airplane maximum takeoff and landing weights) the fuel jettisoning requirements of the airplane will be the same as for the original, unmodified airplane. There will therefore be no need to jettison auxiliary tank fuel. Addition of fuel capacity which increases the maximum take-off weight of the airplane would require recertification efforts which are beyond the scope of this AC. One of these efforts would, however, be to evaluate the need of auxiliary fuel jettisoning.

(ii) Regardless of the need for auxiliary fuel jettisoning, the applicant should ensure by failure mode analysis or demonstration, that main tank fuel jettisoning can still be accomplished without hazard to the modified airplane (see also the discussion in Chapter 1, paragraph 3b).

Figure 5

EXAMPLES OF EXPANSION SPACE DEFINITION

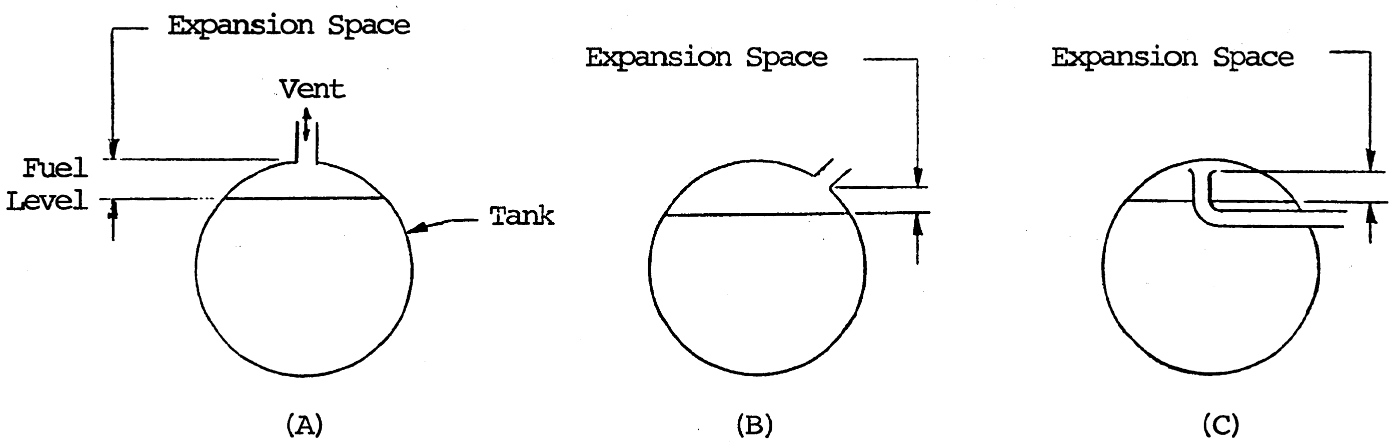
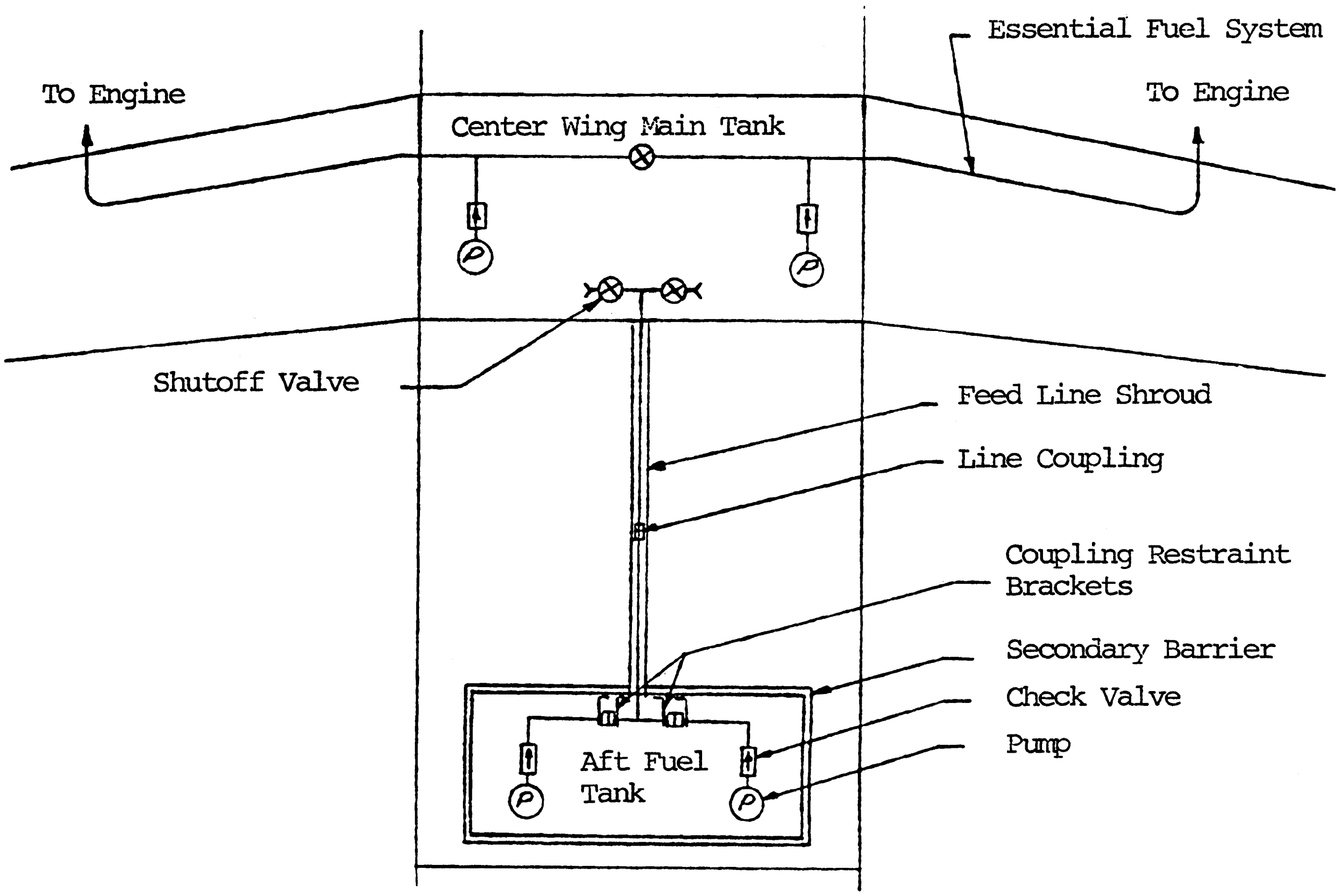


Figure 6

AN EXAMPLE OF AN AUXILIARY FUEL SYSTEM USED FOR C.G. CONTROL



CHAPTER 5 - IMPACT OF SYSTEM ON AIRPLANE OPERATION AND PERFORMANCE.

13. ENGINE OIL SYSTEM CAPACITY (§ 25.1011). The applicant should ensure that the additional fuel capacity of the auxiliary fuel system, thus the added flight duration, does not cause depletion of the engine oil supply under maximum oil consumption conditions and engine out operation. Adequacy of the engine oil capacity must be shown as a part of the compliance for certification of the auxiliary fuel system.

14. MAIN FUEL SYSTEM CAPACITY AND FLOW REGULATION. The applicant should show that there is no condition in which a receiving tank could be over filled from the auxiliary tank fuel. If necessary, means should be provided in tanks supplied with auxiliary fuel to regulate the fuel level in those tanks. Also, there should be no condition in which a receiving tank could be depleted during auxiliary tank transfer. In some cases, auxiliary tank fuel transfer cannot be initiated until the receiving tank fuel has been used down to a certain quantity. This limitation must be clearly stated in the AFM. The applicant must include in the AFM all limitations on the use of auxiliary tank fuel and any warnings necessary in the operation of the system. Limitations and procedures should be evaluated with regard to practicality and pilot workload.

15. RADIO FREQUENCY INTERFERENCE. The applicant should ensure that the system will not cause objectionable radio frequency interference and not be adversely affected by radio frequency interference from other airplane systems.

16. AIRPLANE CENTER OF GRAVITY CONTROL.

a. Since auxiliary fuel tanks are usually installed after initial certification of the airplane and are not part of the basic fuel system, the weight and location of the installation may introduce complex procedures in c.g. control. Several modes of auxiliary fuel transfer may be used, requiring c.g. control for each. If a failure can trap fuel in an auxiliary fuel system, there must be a means provided to feed the engines and stay within the c.g. limits for the remainder of the flight (to reach the airport of destination or an alternate airport). Instructions necessary to maintain the airplane within the established c.g. limits are required by the operating regulations and by § 25.1583(c).

b. An auxiliary fuel system installed aft of the main gear may affect the airplane ground handling operations. Especially for airplanes which have not normally been ground handling limit critical, special cautions and placards may be required in both cargo and refueling station areas. It may be necessary in some cases to institute refuel sequence controls to prevent tipping of the the airplane. Since removal of interiors or other equipment could also aggravate ground aft c.g. problems, maintenance manual supplements should include appropriate procedures and cautions (see Chapter 6, paragraph 20, also).

c. A means of controlling the center of gravity can be attained by providing c.g. limit charts with associated limits on airplane gross weight, configuration, zero fuel weight, and fuel schedules in the limitations section of the AFM. In addition, fuel transfer procedures should be provided for all modes of transfer along with instructions for c.g. control if fuel transfer is not available. If the airplane is loaded within the zero fuel limits of the charts and fuel is used per the approved transfer schedules, the airplane should remain within the allowable center of gravity limits. See Appendix 1 for definition of zero fuel weight.

CHAPTER 6 - USER INSTRUCTIONAL REQUIREMENTS.

17. AIRPLANE PLACARDS AND INSTRUMENT MARKING EVALUATION.

a. Location of Placards, Markings, Gauges, Switches, etc. (§ 25.1557(a) and (b)).

(1) Cockpit and fueling station placards, markings, annunciator lights, gauges, switches and controls for the auxiliary fuel system should be located in suitable areas with sufficient illumination to assure they are easily readable during day and night operations. The switches and controls must be easily accessible to the ground or flightcrews as required by the applicable regulations.

(2) Special placards, located in the cargo compartment, or adjacent to the auxiliary fuel tank installation may be necessary to inform or caution the ground crew about certain aspects of the installation. These placards may, for example, state certain cargo compartment loading limits or restrictions, flexible cargo barrier tensioning requirements or cautionary flammable fluid requirements as required. Also suitable markings on the airplane exterior surface are required, identifying drain access doors, masts, etc.

b. Instrument, Instrument Identification, Lighting and Calibration §§ 25.1305, 25.1337, 25.1381, 25.1541, 25.1543, 25.1553, 25.1555 and 25.1583).

(1) A fuel quantity indicator should be installed for each independent auxiliary fuel tank which provides indication to the flightcrew of the quantity,in gallons or equivalent units, of usable fuel in each tank during flight (see also Chapter 4, paragraph 11b(4)). Indicators should be as accurate and compatible with the existing airplane fuel quantity indicators as possible and calibrated using the same units of volume (metric or English).

(2) Instrument and switch markings should be easily readable with instrument lights.

(3) Each instrument, indicator and switch must have markings/placards which permit the crew to easily identify it. Markings and placards shall be displayed in conspicuous places and shall be such that they cannot be easily erased, disfigured or obscured.

(4) If the instrument markings are on the cover glass of the instrument, there must be means to maintain the correct alignment of the glass cover with the face of the dial.

(5) Each fuel tank selector control, if used, must be marked to indicate the position corresponding to each tank.

18. AIRPLANE FLIGHT MANUAL (AFM) (§§ 25.1581 through 25.1587).

a. Auxiliary fuel tanks installed after initial certification of the airplane require an FAA-approved AFM supplement or an appendix to the existing basic AFM to provide appropriate operating information, procedures and limitations. Generally, an appendix to an AFM is appropriate when written by the manufacturer of the basic airplane, and a supplement is appropriate when the applicant for an auxiliary fuel tank installation is other than the manufacturer.

b. The applicant is responsible for preparing the AFM supplement or appendix which will be incorporated into the basic AFM. The operating procedures and limitations will be evaluated by the FAA flight test crew as part of the flight test evaluations prescribed by the Type Inspection Authorization (TIA). Crew workload also will be evaluated to determine whether it is still acceptable with the addition of an auxiliary fuel system. Crew workload should be considered early in the design of the system, with FAA participation, to ensure that all considerations are properly coordinated.

c. Sufficient information and data should be provided in the AFM to assure that the flightcrew will be able to understand and operate the system during normal, abnormal, and emergency operations of the airplane.

d. Abnormal procedures are those that are not normal procedures and also are not emergency procedures. They include procedures for foreseeable failure situations in which the use of special systems, or the use of regular systems, may be expected to maintain an acceptable level of airworthiness. Immediate action is not usually required. Since most auxiliary fuel systems are add-on systems, which are not included in the flight training syllabus of the airplane, the AFM supplement or appendix must be complete in providing the required information. To assure completeness of the AFM supplement (or appendix) the following discussion and format are provided as a guide for the type of information that should be considered.

(1) Limitations.

(i) Weight Limitations. Maximum zero fuel weight changes and weight and center of gravity limits should be specified. It should be emphasized that when fuel is loaded into fuselage auxiliary tanks, the maximum zero fuel weight must be reduced by the weight of the added fuel.

(ii) Fuel Loading Limitations. The maximum allowable fuel in each auxiliary tank should be specified. Loading limitations may be required to maintain weight/c.g. within limits, i.e., certain main fuel tanks may be required to be loaded before the auxiliary tanks and the auxiliary tanks may be required to be loaded in a particular sequence depending on the design of the system.

(iii) Fuel Management Limitations.

(A) Specific fuel usage procedures may be required to maintain the weight and balance of the airplane within limits. Additionally, flight planning limitations may be required if a single failure can trap fuel in the auxiliary fuel system; the main fuel system must still provide sufficient fuel to the engines for the remainder of the flight, i.e., to reach the airport of destination or to an alternate airport.

(B) A specific sequence of transferring auxiliary fuel may be required as a result of fuel flow rates.

(C) If auxiliary fuel is used for ballast, a placard indicating the amount of ballast fuel is required in the cockpit.

(iv) Operating Limitations.

(A) Maneuvering limitations should be specified.

(B) Tank pressurization or transfer of fuel during takeoff and landing are usually prohibited because of the crashworthiness fire hazard.

(C) Transfer of fuel during climb or descent may be prohibited because of usable fuel considerations.

(v) Miscellaneous Limitations. Cargo and floor loading restrictions may be required due to the auxiliary fuel tank installation.

(2) Emergency Procedures.

(i) Ditching. If applicable, procedures must be provided regarding transfer of fuel from auxiliary fuel tanks and placement of controls and switches prior to ditching.

(ii) No Fuel Transfer. Should fuel not transfer and become trapped in the auxiliary tanks, procedures should be included to regain transfer capability. If transfer is still not available, management procedures should specify how to maintain weight/c.g. within limits.

(iii) Engine Inoperative. In the event of an engine failure, auxiliary fuel systems which use engine bleed air for fuel transfer may lose transfer capability. In order to restore transfer, procedures must be included which define the steps required for obtaining bleed air from the remaining operating engine(s). These procedures should also define engine operating restrictions, if required, which apply during transfer following engine-out conditions. Continued use of bleed air for fuel transfer may be affected by the engine-out enroute climb performance requirements of Part 25.

(3) Normal Procedures/Abnormal Procedures.

(i) Fuel Loading. Instructions necessary to enable loading of the airplane within the established limits of weight and center of gravity, and to maintain the loading within these limits in flight must be provided.

(ii) External Preflight Check. Detailed procedures should be specified.

(iii) Cockpit Preflight Check. Detailed procedures should be specified.

(iv) Fuel Management and Transfer Procedures.

(A) Detailed procedures should be specified for each fuel transfer schedule approved and should include normal fuel transfer rates for use.

(B) Flow Check. Procedures to determine that auxiliary fuel transfer is available should be specified, where required.

(C) Fuel Jettison. (If installed). Procedures should be established to dump fuel, if desired, listing airspeed, altitude, and configuration.

(v) Usable Fuel. Maximum usable fuel should be specified.

(vi) Unusable Fuel. The unusable fuel should be specified.

(4) Performance. Any change in airplane performance should be provided. For instance, if engine bleed air is used to pressurize the auxiliary fuel system, its effects should be accounted for.

(5) Auxiliary Fuel System Description. A detailed description and functional arrangement schematic should be provided. This information may be provided in an unapproved section of the AFM supplement (or appendix) or may be included in the approved SECTION 3, NORMAL PROCEDURES. A suggested outline includes the following:

(i) Fuel Transfer System.

(ii) Control Panel.

(iii) Refueling System.

(iv) Electrical System.

(v) Schematics.

19. WEIGHT AND BALANCE MANUAL INFORMATION. Weight and loading distribution information including loading instructions must be presented either in the AFM

supplement or in a separate weight and balance control and loading document which will be referenced in the AFM. Reference § 25.1583(c).

20. MAINTENANCE MANUAL (§ 25.1529). The inspections, tests, repairs and related intervals upon which compliance with the applicable certification basis is based should be included in a maintenance manual supplement supplied by the applicant. The manual should also contain complete servicing information for the auxiliary tanks and systems. If the applicant proposes to have a system where a tank(s) may be removed or made inoperable for maintenance purposes and the remainder of the system remains airworthy (as where more than one tank configuration is an approved configuration) or where the entire system is classified as removable, complete maintenance instructions should also be provided detailing the methods of system modification or removal, resealing and restoring the compartments, and other considerations necessary to make the airplane airworthy. The applicant should refer to Part 25, Appendix H, Instructions for Continued Airworthiness, when providing maintenance instructions.

APPENDIX 1

1. DEFINITIONS. The following definitions are applicable as used in the text of this AC.

a. Auxiliary Fuel System. An auxiliary fuel system is a system installed within the airplane which makes additional fuel available for increasing the flight range of that airplane. The term "auxiliary" means that this system is secondary to and backed by the airplane's essential fuel system, i.e., that the functions of the essential fuel system are immediately available and operative without immediate supervision by the flightcrew in the event of failure or inadvertent depletion of fuel in the auxiliary fuel system (reference § 25.955(b)(2)). In essence, an airplane equipped with an auxiliary fuel system is capable of safe flight even when the auxiliary fuel system is not used, i.e., where its fuel storage capacity is not required for short range flight.

b. Essential Fuel System. An essential fuel system is a system installed within an engine powered airplane which is required for safe operation of the airplane. Its primary function is to provide an independent, uninterrupted flow of fuel to each airplane engine. Essential (or main) fuel tanks are those tanks which normally supply fuel directly to the engine in at least one operating mode and are necessary to satisfy the independent feed requirements of the airplane (reference § 25.953). These tanks also contain the reserve fuel necessary for all flight diversions and other contingenices.

c. Fail-Safe.

(1) The FAA fail-safe design concept is a design methodology where the effect of failures and failure combinations must be considered in defining a safe design. The following basic rules involving failure events apply:

(i) In any system or subsystem a single failure of any element or connection during any one flight (brake release through ground deceleration to stop) must be assumed without consideration as to its probability of failing. This single failure event must not prevent the continued safe flight and landing of the airplane.

(ii) Additional independent failure events during any one flight following the first single failure must also be considered when the probability of occurrence is likely (i.e., those combinations of failures not shown to be extremely improbable). If a critical failure event cannot readily be detected, it must be counted as a latent existing failure in addition to the first failure. The probability of these combined failures includes the probability of occurrence of the first failure event.

(2) The following design principles and techniques are generally utilized to prevent single failures and likely combinations of failures from jeopardizing the continued safe flight and landing of the airplane:

(i) Redundancy or back up systems that provide system function after the first failure, i.e., two or more engines, two or more hydraulic systems, dual flight controls, etc.

(ii) Isolation of systems and components, both physically and functionally, so that failure of one element will not cause failure of the other. This is sometimes referred to as system independence.

(iii) Detection of failures or failure indication.

(iv) Functional verification, i.e., the capability for testing or checking the condition of the components.

(v) Proven reliability and integrity to assure that multiple component or system failures will not occur in the same flight.

(vi) Damage tolerance that limits the safety impact or effect of the failure.

(vii) Designed failure path that controls and directs the failure event by design to limit the safety impact.

(viii) Flightcrew procedures following the failure event designed to assure continued safe flight by specific crew actions.

(3) The FAA fail-safe design concept utilizes all of the above eight design principles in whatever combination is required to produce a fail-safe design. The employment of only one of the above principles is seldom adequate; generally two or more are used in the design to satisfy the fail-safe design concept, i.e., assure that catastrophic failures will be extremely improbable.

d. Fuselage Break Points. Fuselage break points are points along the fuselage where accident data has shown the fuselage shell structure has failed. It can be a partial failure in which the structure across the break remains attached or a complete failure resulting in two separate pieces. These are generally attributable to two types of conditions:

(1) Cutouts and stress concentrations.

(2) Points of maximum load, either point loads by the landing gear or maximum bending moments, such as, at the juncture of the wing and body.

e. Passenger/Cargo Compartments. All compartments specifically designed to provide a suitable life support environment for people and animals during all operating modes of the airplane. These areas may or may not be pressurized.

These areas include, but are not limited to, the cockpit, passenger compartments, galleys, and all classes of cargo and baggage compartments.

f. Zero Fuel Weight. Typically, transport category airplanes are designed to carry the fuel supply in the wings. In addition to any other advantages, locating the fuel in the wings relieves wing bending stresses and allows a higher maximum weight than would be possible with the same quantity of fuel located within the fuselage. For such airplanes, zero fuel weight is established as a limit to ensure that maximum wing bending stresses are not exceeded by replacing fuel in the wings with an equal weight of payload carried in the fuselage. When an auxiliary fuel tank is installed within the fuselage, the existing zero fuel weight limit is no longer directly applicable because the fuel contained in that tank does not relieve wing bending stresses. It is, therefore, necessary to reduce the zero fuel weight limit by the maximum usable fuel capacity of the auxiliary tank. Alternatively, the zero fuel weight limit may be redefined as the maximum zero wing fuel weight limit. Any fuel contained in the auxiliary tank would then be treated as payload from a weight and balance standpoint. Regardless of which procedure is used, the AFM must clearly state the limit and its meaning.

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