# IV. ARMY AIRCRAFT ENGINES AND FUEL SYSTEMS

The potential differences in fuel properties relative to current JP-4 properties have been identified, and the impact that these properties can have on the performance and durability of engines and fuel system components have been discussed. The purpose of this chapter is to identify the engines and fuel system components used in Army aircraft, discuss the interface between the components and the fuel, and identify specific potential problems. In general this discussion will address materials compatibility since this is the most significant area of impact with most components.

Materials compatibility can be reduced to elastomer compatibility if one makes the assumption that the synthetic and alternate fuel will meet the same restrictions on corrosion that JP-4 does. This is a reasonable assumption since there is no desire to allow corrosiveness in a fuel whereas there is pressure to increase the aromatic content of JP-5. The sensitivities of elastomers to fuel properties, namely aromatic content, were discussed earlier in this report. It is sufficient here to say that higher aromatic concentrations cause Buna N to swell considerably; while this is generally not a problem in static seals it can be a problem in dynamic applications and perhaps flexing diaphragms. Quite often the compatibility depends on the specific application and whether or not the distress is acceptable or within design limits.

## A. Army Aircraft

The U.S. Army has a variety of jet engine aircraft. Table 13 lists the aircraft considered in this program. This list identifies the airframes, engines, auxiliary power units, and their manufacturers. Most of the U.S. Army's aircraft are helicopters that are powered by five different types of engines. Some of the larger helicopters have airborne

Table 13. Army Aircraft, Engines, and APU's

| Airframe | | | Engine | | Auxiliary Power Unit | |
|---|---|---|---|---|---|---|
| Model | Name | Manufacturer | Model | Manufacturer | Model | Manufacturer |
| H-1 | Cobra | Bell | T53 | Lycoming | -- | -- |
| H-6 | Cayuse | Hughes | T63 | Allison | -- | -- |
| H47 | Chinook | Vertol | T55 | Lycoming | T62T-2A1 | Turbomach |
| H54 | Skycrane | Sikorsky | T73 | PWA USA | T62T-16A1 | Turbomach |
| H-58 | Kiowa | Bell | T63 | Allison | -- | -- |
| H-60 | Black Hawk | Sikorsky | T700 | G.E. | T62T-40-1 | Turbomach |
| H-64 | Apache | Hughes | T700 | G.E. | GTCP36-55H | AiResearch |
| C-12 | Huron | Beech | T74 | PWA Canada | -- | -- |
| OV-1 | Mohawk | Grumman | T53 | Lycoming | -- | -- |
| U-21 | UTE | Beech | T74 | PWA Canada | -- | -- |
| UV-18 | Twin Otter | DeHavilland | T74 | PWA Canada | -- | -- |

auxiliary power units. These units usually provide starting capability, electric power, and, in some cases, hydraulic power. All of the fixed-wing aircraft are powered with either T53 or T74 turboprop engines. The effects of reduced fuel hydrogen content on low-cycle thermal fatigue life was discussed earlier in the report as were the impact of viscosity and volatility on cold day ignition. These are the major areas of impact of potential fuel variation on engine performance and durability.

## B. Army Aircraft Fuel Systems

There are two basic types of fuel systems used in Army aircraft:

- Pressurized versus suction
- Crashworthy versus non-crashworthy

The first refers to the method of fuel delivery from the fuel cells to the engine. The second is a design criteria for components to improve helicopter crash safety. Other complexities depend upon the aircraft mission requirements, the number of engines used, fuel crossfeed capabilities, fueling/defueling capabilities, and other airframe design requirements.

An extensive survey was conducted with the assistance of AVRADCOM personnel to identify the fuel system components. The detailed component lists are provided as appendices to this report as follows:

| Appendix | Contents |
|---|---|
| A | Airframe Fuel System Components |
| B | Engine Fuel System Components |
| C | APU Fuel System Components |

1. H-1 Fuel System

The Army has a variety of different models of the H-1 helicopter, as noted below:

| Aircraft Type | Engine Used | Popular Name |
|---|---|---|
| UH-1B | T53-L-11D | Huey/Iroquois |
| UH-1C | T53-L-11D | Huey/Iroquois |
| UH-1D | T53-L-11D | Huey/Iroquois |
| UH-1H | T53-L-13B | Huey/Iroquois |
| UH-1Q | T53-L-13B | Huey/Iroquois |
| UH-1M | T53-L-13B | Huey/Iroquois |
| EH-1H | T53-L-13B | Huey/Iroquois |
| AH-1G | T53-L-13B | Cobra |
| TH-1G | T53-L-13B | Cobra |
| AH-1S | T53-L-703 | Cobra |
| AH-1Q | T53-L-13B | Cobra |

The Huey and Cobra aircraft have similar fuel systems. Figure 9 illustrates the fuel system schematic for the AH-1G. Fuel is contained in two interconnected fuel cells. An electrically-driven, centrifugal boost pump is provided inside each cell. Fuel is directed to a common manifold valve (containing two check valves and two thermal relief valves) and then to the main fuel shutoff valve. From these, the fuel is directed through a fuel filter to the engine fuel pump/fuel control system. The fuel tanks are vented together. Capacitance-type, fuel-level sensors are used for total fuel quantity and low fuel indication. Sump drain valves are provided at low points in each fuel cell. Aircraft fueling is performed at the left fuel-cell filler cap. The incoming fuel will fill both tanks through a crossover pipe. A swing/flapper type check valve is used in the right tank.

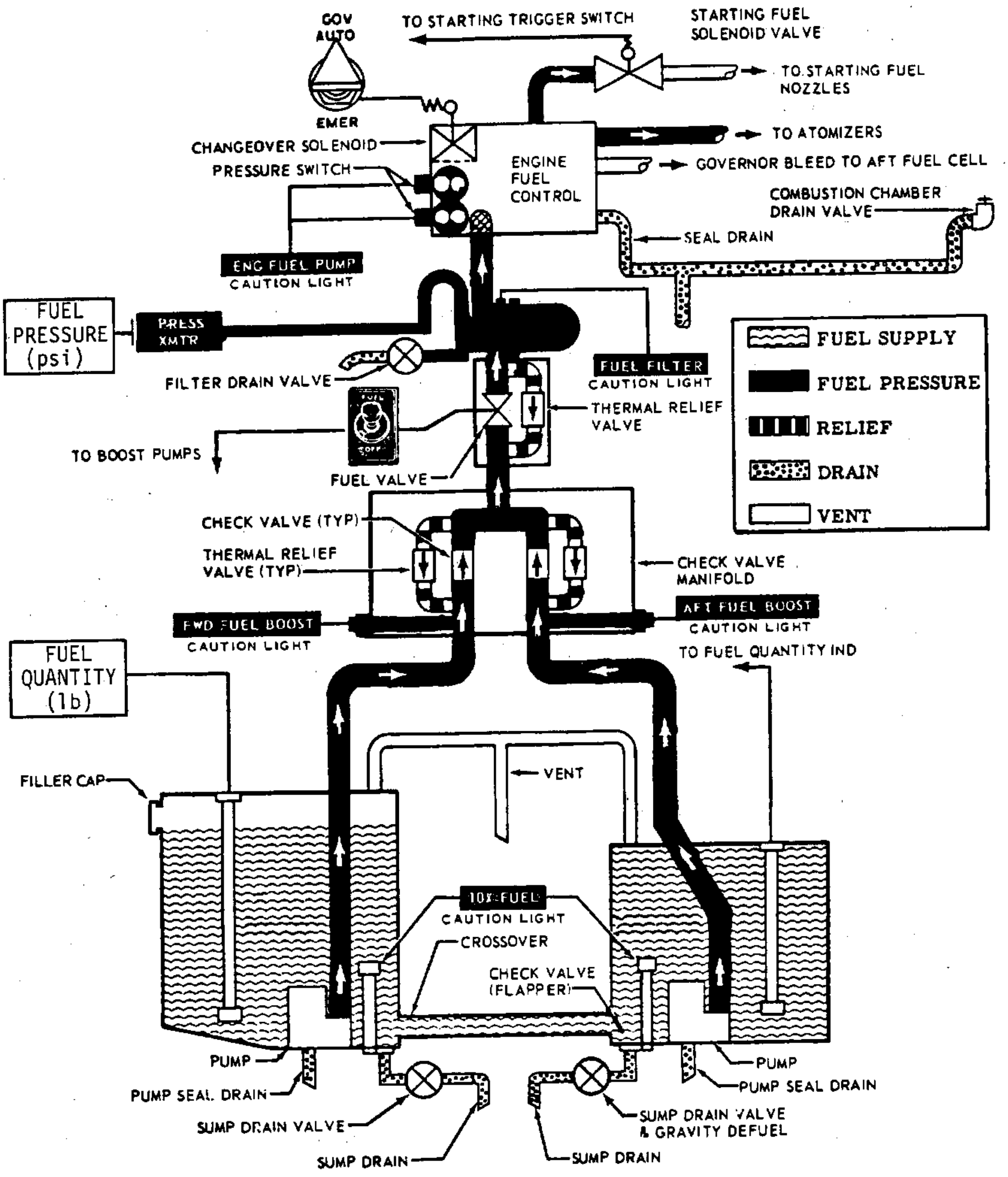


FIGURE 9. AH-1G FUEL SYSTEM SCHEMATIC

The fuel system used in the UH-1 (no figure provided) is somewhat different. The fuel is contained in five fuel cells interconnected to act as a single tank. Three cells are located across the fuselage below the engine deck with a filler cap on the right cell. Two forward cells (located under the cabin floor and gravity fed from the aft cells) are provided with a fuel boost pump. The right pump is electrically operated and the left pump is driven by bleed air from the engine compressor. An ejector pump is also used in the left and right fuel cells. Fuel under pressure is delivered from the boost pumps through separate lines to a check valve manifold located on the front of the engine firewall. The fuel then passes through two check valves in a single outlet manifold to an electrically controlled main fuel shutoff valve. As in the AH-1G fuel system, the fuel then goes to a fuel filter and to the engine. The fuel shutoff valve and each check valve in the manifold have internal bypass valves to relieve thermal expansion of trapped fuel when the system is inoperative. Sump drain valves are provided. The left-hand, center, and right-hand fuel cells are interconnected together and vented to the atmosphere.

2. <u>H-6 Fuel System</u>

The H-6 aircraft is a small, single-engine, observation helicopter designated as the OH-6A.

Figure 10 shows a schematic representation of the fuel system. This crashworthy helicopter has self-sealing hoses and several breakaway fittings. Fuel may be introduced into the aircraft by gravity or through a closed-circuit fuel receiver assembly. Two interconnected self-sealing bladders are used. Fuel is directed from a submerged centrifugal boost pump to a submerged fuel shutoff valve to a fuel outlet valve. The fuel then passes through the other half of the fuel outlet valve (in-line fuel valve) through a self-sealing hose to the engine. Vent valves are

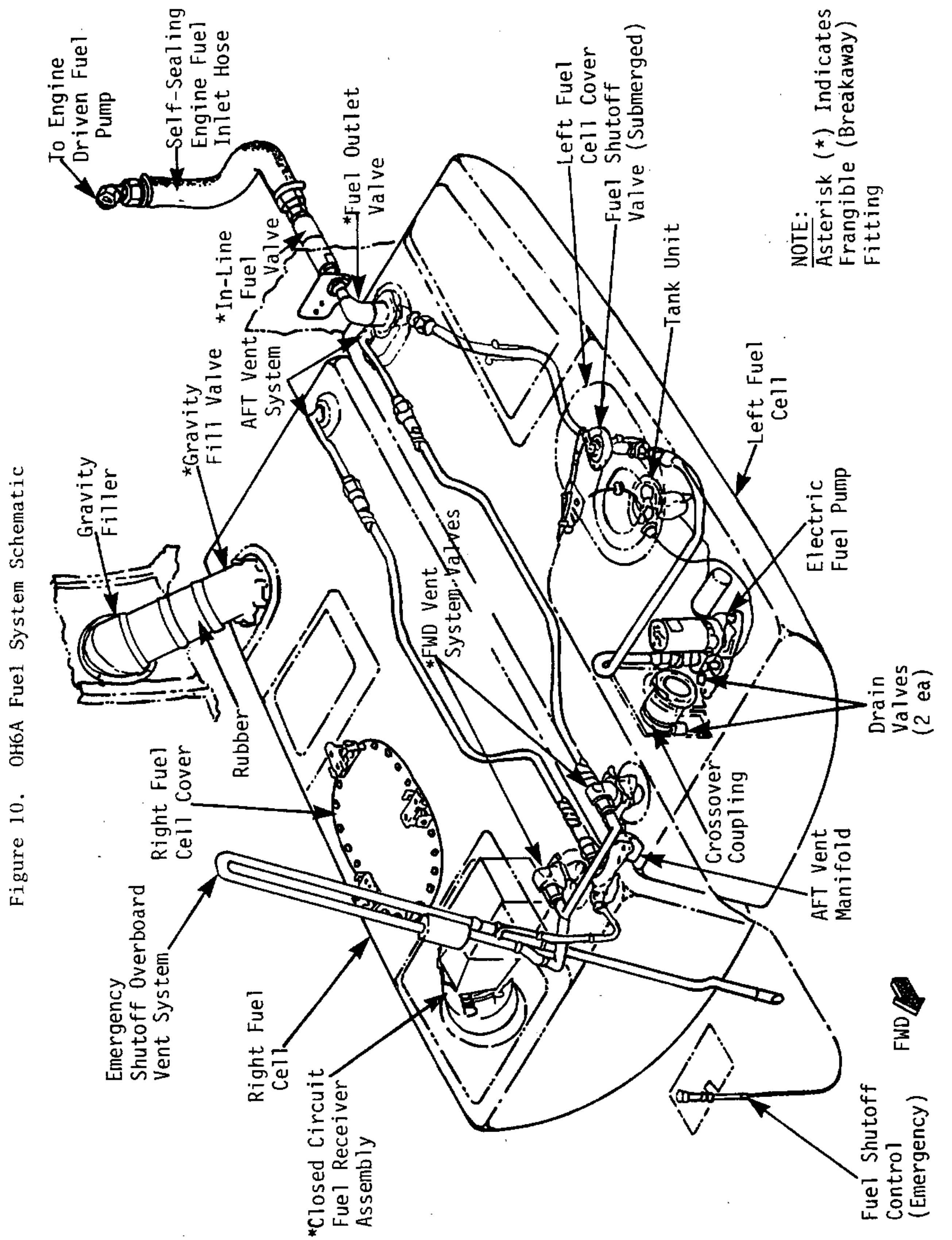


FIGURE 10. OH6A FUEL SYSTEM SCHEMATIC

located forward and aft of the fuel cells and are interconnected to an emergency shutoff overboard vent system. The fuel shutoff valve (mentioned earlier) is actuated from the cockpit by a control cable. The level of the fuel is sensed by a float-lever-electrical system rather than the usual capacitance types. This is the simpliest fuel system used in any of the Army's fixed- or rotary-wing aircraft.

3. H-47 Fuel System

The following models of the H-47 cargo helicopter are used by the Army:

| Aircraft Type | Engine Used | Popular Name |
|---|---|---|
| CH-47A | T55-L-7C | Chinook |
| CH-47B | T55-L-7C | Chinook |
| CH-47C | T55-L-11/11A /ASA/11D/712 | Chinook |
| CH-47D | T55-L-712 | Chinook |

This twin-engine aircraft has basically the same type of fuel system for all of the models noted above (no figure provided). The aircraft uses a total of six bladder-type fuel cells that are fueled by six independent gravity filler caps. The CH-47D model is being modified to have a closed-circuit fuel receiver for single point fueling. The six fuel tanks are distributed throughout the aircraft, with two auxiliary tanks forward, two main tanks, and two more auxiliary tanks aft. The fuel system has complete crossfeed capabilities for supply fuel to either or both engines from any fuel tank. Each fuel tank has a submerged boost pump with a check valve to ensure proper fuel flow direction. Each of the main fuel tanks has a thermal-relief check valve and other appropriate check valves along with three fuel-level measuring probes. Pressure switches are also provided at the discharge of each of the boost pumps. Each tank has two drain valves located at low points in the fuel cells. Other drain valves are located throughout the system plumbing. A fuel control panel (located in the cockpit) provides fuel quantity indication for the fuel tanks and pump control for normal engine fueling and crossfeed control. The main fuel system also has a connection for a ferry fuel tank which can be carried inside the helicopter.

A separate fuel boost pump, a manual shutoff valve, and a solenoid-operated shutoff valve are also provided for fuel supply to the auxiliary power unit.

4. H-54 Fuel System

The fuel system of the twin-engined UH-54 utility helicopter (no figure provided) has forward, aft, and auxiliary fuel tanks. Two boost pumps are used in each of the forward and the aft fuel tanks. The auxiliary fuel tank has two fuel transfer pumps capable of transferring fuel to the forward or aft tanks. A crossfeed valve is provided along with appropriate engine fuel shutoff valves and an auxiliary-power-unit fuel shutoff valve. The aircraft is fueled through three closed-circuit fuel receivers (one per tank). Appropriate drain valves are also provided at low points in the tanks.

5. H-58 Fuel System

Two models of the H-58 helicopter are used:

| Aircraft Type | Engine Used | Popular Name | Fuel System |
|---|---|---|---|
| OH-58A | T63-A-700 | Kiowa | Noncrashworthy |
| OH-58C | T63-A-720 | Kiowa | Crashworthy |

This small single-engine observation helicopter has a single L-shaped fuel cell located beneath and in back of the pilot's seat. Only the lower half of the fuel cell is constructed of self-sealing material on the non-crashworthy OH-58A aircraft. In the crashworthy OH-58C aircraft, the entire fuel cell is self-sealing, with self-sealing hoses and breakaway fittings.

The fuel system (no figure provided) uses gravity fueling to fill the fuel cell. A submerged boost pump is used to supply the fuel through a breakaway valve to a shutoff valve. A pressure sensor is provided to indicate fuel pressure. The fuel is then directed through a filter to the engine. A tank vent is provided along with a sump drain-defuel valve. Capacitance-type fuel-level sensors monitor the fuel quantity. A fuel low-level switch is also used to indicate that twenty minutes of fuel remains in the tank.

6. H-60 Fuel System

The UH-60A is the Army's newest utility helicopter. Two T700-GE-700 jet engines are used for propulsion along with an airborne T62 auxiliary power unit. Figure 11 illustrates the fuel system schematic for the UH-60A helicopter. This crashworthy fuel system utilizes two self-sealing fuel cells that are supported by fiberglass liners. A 3-inch layer of purple (fire-explosion suppression) foam is used adjacent to the outside of the fuel cell liners. Foam is not used inside the fuel cells. The foam (made by the Foam Division of Scott Paper Company) is used to prevent explosions by acting as a void filler around the outside of the fuel cells.

As noted in Figure 11, the aircraft can be fueled by gravity and pressurized closed-circuit fueling methods. A suction-type fuel system is used in flight. The fuel system serving engine 1 and the left fuel cell is identical to the other half of the fuel system serving engine 2 and the right fuel cell. An electric pump (located outside of the fuel

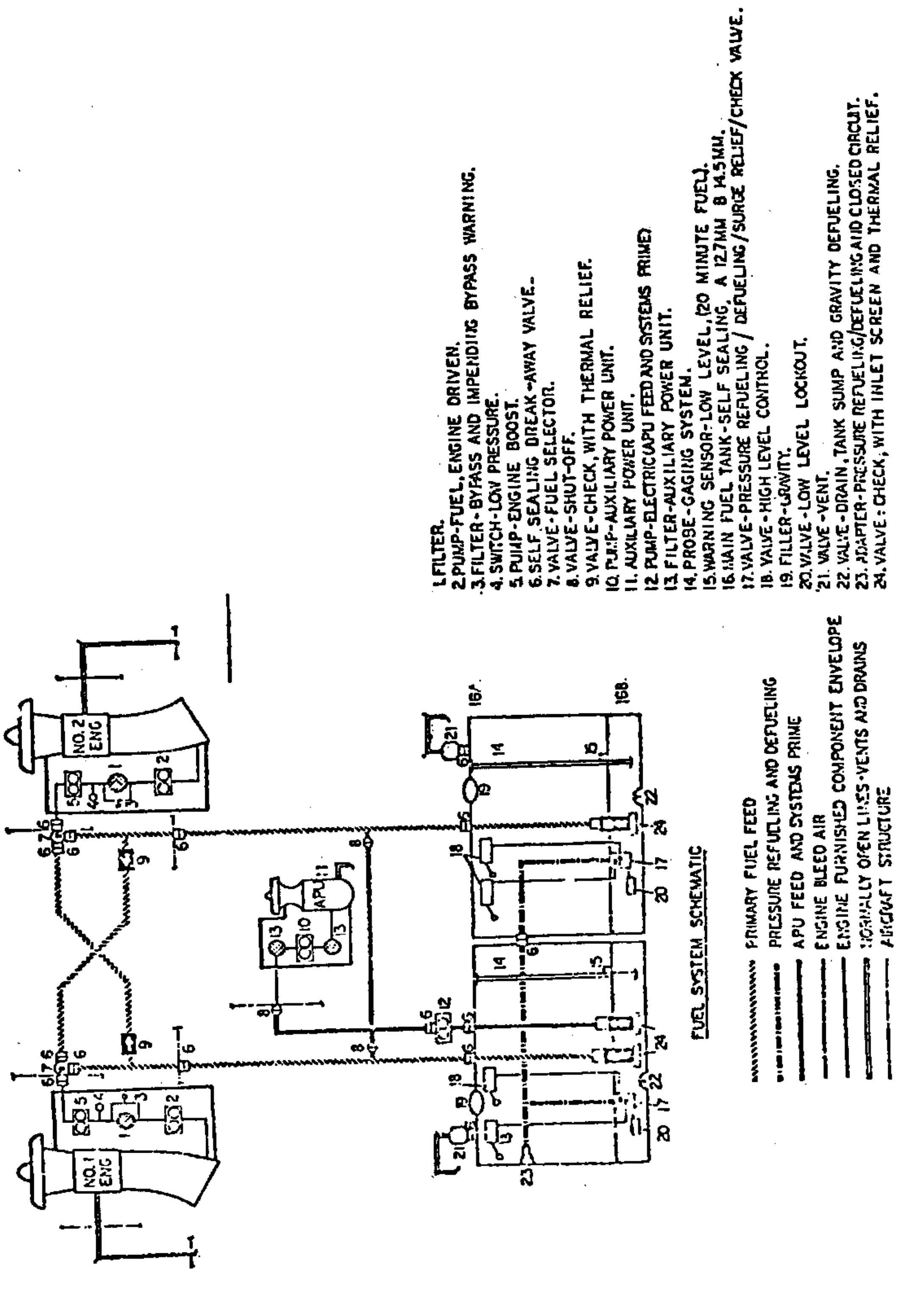


FIGURE 11. UH-60A FUEL SYSTEM SCHEMATIC

bladder) primes all of the fuel lines providing fuel up to the engine boost pump and the APU pump. Once the engine is started, the engine-operated boost pump provides the necessary suction to draw the fuel from the fuel tank. Complete crossfeed capabilities are provided to supply fuel to either engine from either tank. Fifteen breakaway self-sealing valves are used throughout the fuel system while six check valves are used to control the direction of the fuel flow. The fuel level in each tank is monitored by a capacitance probe. High-level float control valves are provided to shut the fuel off during fueling operations. Appropriate vent and fuel tank drain valves are used.

The UH-60A also has the capability of accepting a range extension kit. Figure 12 shows the fuel system schematic for the auxiliary fuel system and its connection to the main fuel tanks. Two self-sealing auxiliary fuel tanks are used with breakaway, self-sealing couplings. A positive-displacement vane pump is used with each auxiliary fuel tanks to lift and transfer the fuel through a check valve. A motor-operated transfer valve is used to allow the fuel to flow to the main fuel tanks. An emergency motor-operated dump valve is also provided. Both of the fuel tanks are filled by gravity. Empty tank sensors and appropriate vent valves are provided for each tank.

7. H-64 Fuel System

The YAH-64 is the Army's newest preproduction attack helicopter called the Apache. This aircraft is also powered by two T700-GE-700 engines and has an airborne GTP36-55H auxiliary power unit.

The crashworthy fuel system (no figure provided) has forward and aft self-sealing fuel cells. Fuel may be introduced by gravity or pressure fueling. An air-driven boost pump is used to direct the fuel to the engine. Fuel is transferred from the forward cell to the aft cell by

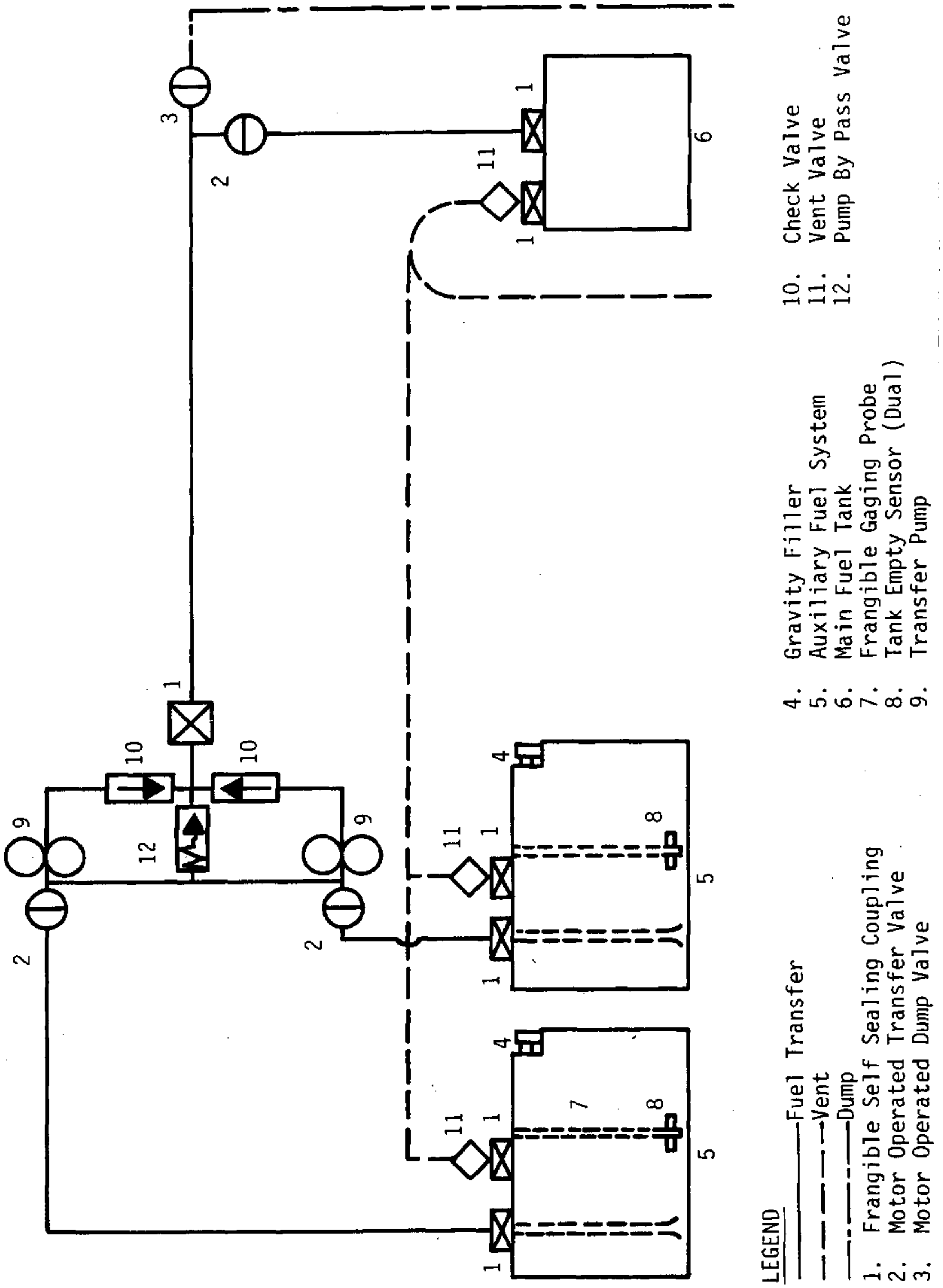


FIGURE 12. UH-60A RANGE EXTENSION KIT FUEL SYSTEM SCHEMATIC

means of an external air-driven transfer pump. An external aluminum fuel tank is also available for mounting on the aircraft pylon. Breakaway valves are used throughout the fuel system along with fuel vent valves, a fuel transfer valve, and engine fuel shutoff valves.

## 8. C-12 Fuel System

The C-12 aircraft is one of the four fixed-wing aircraft used by the Army. These commercially-purchased aircraft are powered by two PT6 PWA turboprop engines (T74 is the military designation for the same engine).

Figure 13 illustrates one half of the fuel system used in the C-12 aircraft. Each wing has four nonselfsealing bladders interconnected to each other and to a wet wing tank. Fuel from these tanks is gravity fed to a feeder tank (called a nacelle tank). Fuel from the feeder tank is pumped to the engine by a jet-type transfer pump. A crossfeed valve is used to interconnect to the other engine and the other half of the fuel system. Check valves and suction relief valves are used throughout the system along with drain valves and vent float valves. Most of the fuel system components used in the C-12 aircraft are the same as the ones used in the U-21 fixed-wing aircraft.

## 9. OV-1 Fuel System

There is a total of about 200 OV-1 fixed-wing aircraft in the Army inventory. The twin-engine aircraft is powered by two Lycoming T53 engines of the models noted below:

| Aircraft | Engines |
|---|---|
| OV-1B | T53-L-7A |
| OV-1C | T53-L-7A/15 |
| OV-1D | T53-L-701A |
| RV-1D | T53-L-701A |

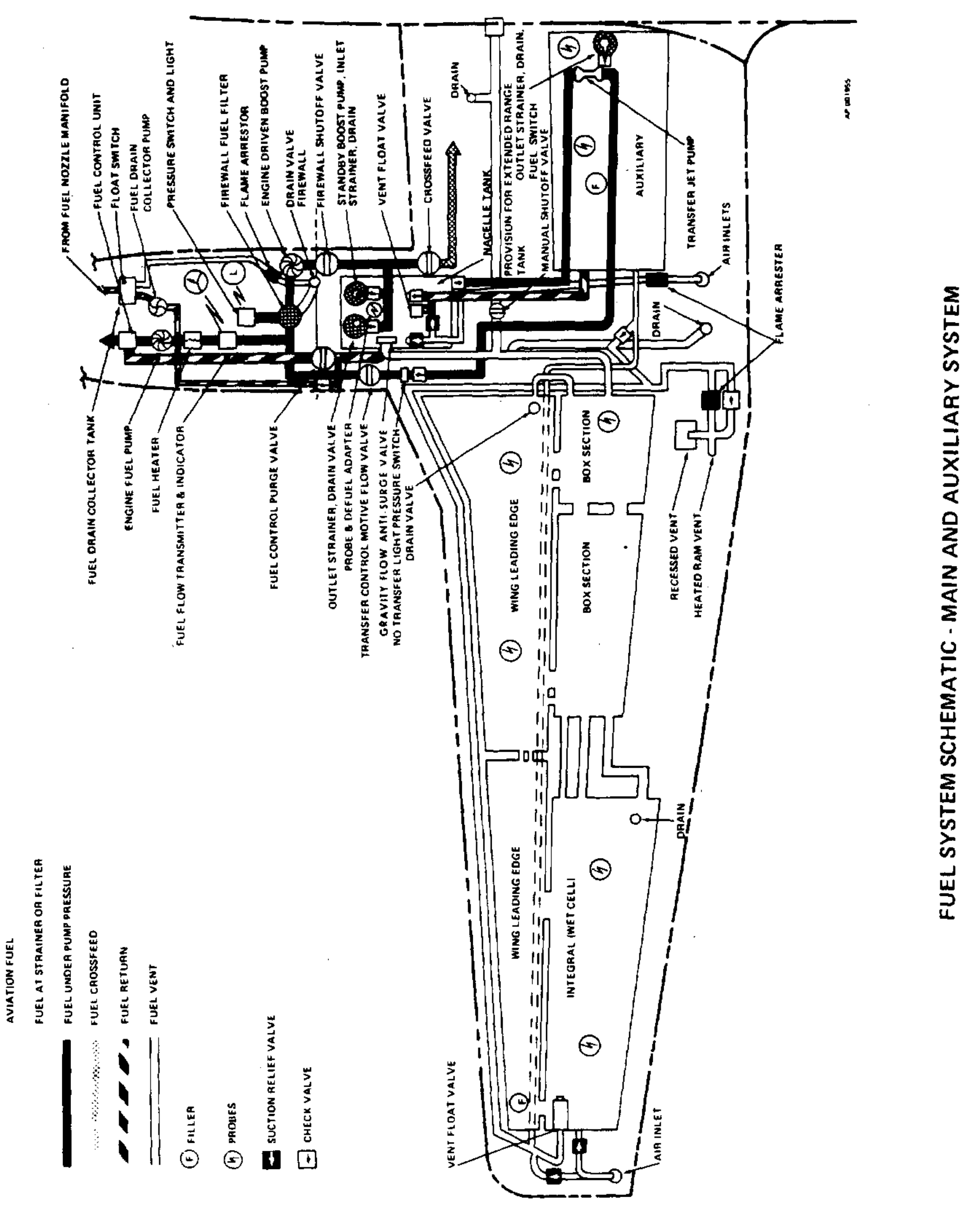


FIGURE 13. C-12 FUEL SYSTEM SCHEMATIC

The OV-1 aircraft is qualified to operate on JP-4, JP-5, JP-8, Avgas, unleaded gas, and leaded fuels. A maximum operation time of 50 hours is allowed for operation using leaded fuel; extended operation with leaded fuels can cause damage to the turbine blades.

The OV-1 fuel system (no figure provided) has one self-sealing, 350-gallon, main fuel tank and two 150-gallon aluminum drop tanks. Vane pumps are used to transfer fuel from the drop tanks to the main fuel tank. The aircraft is generally fueled/defueled through the single-point nozzle (pressure fueling), but gravity fueling capability is also provided.

During a typical pressure-fueling operation, the fuel is directed through the pressure-fueling adapter to the main fuel tank and through a pilot float valve to a solenoid-operated shutoff valve (both of which are located inside the tank). The pilot valve has dual floats. As the fuel rises in the tank the pilot float valve senses the fuel level. Once the fuel reaches the maximum level, the pilot float valve shuts off, creating a pressure difference which actuates the solenoid shutoff valve and stops the fueling operation.

Fuel is directed to the engines by two submerged dual-impeller boost pumps (one forward and one aft in the main fuel tank). An ejector pump is also used as a backup for the forward boost pump. Several check valves (swing- and ball-type) are used to maintain the correct fuel flow direction. Three motorized gate valves are used in this system: 1) between the pressure-refueling and the main fuel tank, 2) between the left engine and the main fuel tank, and 3) between the right engine and main fuel tank. The gate valves for the right and left engines are actuated every time the engine is started.

The main fuel tank has an access port with a cover assembly. This oval access port uses a large Neoprene gasket to seal the port to the cover. The gasket is exposed to fuel vapors and some fuel sloshing which aggravates the Neoprene material causing it to swell.

10. U-21 Fuel System

The Army has about 150 U-21 fixed-wing aircraft powered by two Pratt and Whitney T74-CP-700/702 turboprop engines. The different Army aircraft types and engine models are noted below:

| Aircraft | Engine |
|---|---|
| U-21A/D/F/G/H | T74-CP700 |
| RU-21A/D/H/E | T74-CP700 |
| RU-21B/C | T74-CP702 |

Figure 14 illustrates the fuel system used for the RU/U-21 aircraft. A total of 370 gallons of usable fuel is stored in several nonself-sealing fuel cells. Each wing has four interconnected fuel cells. The fuel from these cells is directed to a feed tank by gravity and pumped by a transfer pump to another fuel cell (nacelle tank). Fuel from the nacelle tank is pumped by a boost pump to the engine. A complete duplicate system is used for the other wing-to-engine fuel system. Crossfeed capabilities are provided to transfer fuel to either engine. Since the fuel system uses a large number of fuel cells and has crossfeed capability, a large number of check valves are used.

11. UV-18 Fuel System

The Army has less than five of the UV-18A fixed-wing aircraft, each powered by two T74 engines. No additional information was obtained.