The Fuel System, and most everything else, is described in B-17 MANUALS published by the Army. These are available on-line in Col. Chris Elhardt’s dropbox at https://www.dropbox.com/sh/t7p2snciy3exd/AADthZvRKPjrtNB-9bd0Mfqha?dl=0

Note that these Manuals were published in 1943 and TR was built in 1945 with modifications since, so there are differences. Notable among those regarding the fuel system are that TR does not have operational Tokyo tanks, does not have bomb bay fuel tanks and the engine priming system is different. Also TR’s fuel quantity and fuel flow gauges are not operational.

B17s were built with FOUR independent fuel systems – one for each engine. The significance is that failure in one system has no effect upon the other three systems. All of the four systems are virtually identical.

Flow diagrams of the fuel system are as follows (the only significant difference is the two connected tanks for Engines #2 & #3).
Each fuel system has the following components:

**Fuel Tank**  One tank for each engine #1 & #4 with each at 425 gal capacity,  Two tanks for each engine #2 & #3 with each at 212 gal capacity for total 425 gal capacity per engine. (The two tanks are piped together to function a ONE tank).  Every tank has vent line to the bottom of the wing.

**Boost Pump.**  Electric motor driven centrifugal pump operated (on / off) by the pilot.  When ON, the pump boosts the fuel pressure up from 0 to 10 psi.  Design of the pump allows fuel to pass through even when the pump is OFF.

The Boost Pump is the ‘back-up’ fuel pump.

**Fuel Shut Off Valve.**  This valve shuts off all fuel to the engine.  Used only for emergency situations.  Valve is operated (CLOSED) by the pilot.  The valve requires electric power to close.  By design the valve fails OPEN (i.e. failure of the solenoid or with loss of electrical power – then the valve will be OPEN).

Strainer  This separates particulate matter and water from the fuel.

Fuel Pump  Pump is engine driven (i.e. only operates when the engine is running - no pilot control).  Pump internals include a regulator (relief valve).  The regulator maintains a steady pressure to the carburetor.  The fuel flow rate may vary but the pressure output from this pump is held constant.  Also the internals of this pump also allows flow from the boost pump to pass through and on to the carburetor when this pump is not operating.  Output pressure from the pump when operating is between 14 to 19 PSI.  The pressure setting can be adjusted by the maintenance crew.  TR’s setting is 18 PSI.

This Fuel Pump is the ‘primary’ fuel pump.

Carburetor  This mixes fuel with air and feeds into the engine supercharger housing.  The carburetor has mixture and throttle controls operated by the pilot.  Internals include automatic altitude and temperature compensation mechanisms.

Priming Valve  This is only used during engine start.  Fuel from the boost pump feeds through this valve and into the engine supercharger housing.  Valve is operated (open / close) by the pilot.

Transmitter / Fuel Pressure Gauge  The transmitter converts fuel pressure (PSI) to an electrical signal which is then read on the pressure gauge (gauge located on the co-pilot instrument panel).  The fuel pressure measured is the inlet pressure to the Carburetor from the Fuel Pump.  [On the instrument panel there are actually two gages, each with two indication needles – thus showing the fuel pressure for four engines]

Fuel System Operating Scenarios:  (Note: the Fuel Tank and Strainer are not operated components and the Fuel Shut-off Valve is for emergency only, so not included in the following normal ‘operating’ scenarios)

Before Engine Starting
Boost Pump  -------------------------  ON
Fuel Pump  _________________  Not pumping (engine driven)
Carburetor  _________________  Auto Rich
Priming Valve  _______________  ON - until fuel comes out the over fill drain, then OFF
Transmitter / Pressure Gauge  __  Reading boost pump pressure (10 PSI)

Started Engine & Taxi
Boost Pump  -------------------------  OFF
Fuel Pump  _________________  Pumping (engine driven)
Carburetor  _________________  Mixture as req’d by pilot
Priming Valve _______________     OFF
Transmitter / Pressure Gauge __          Reading Fuel Pump set pressure (18 PSI)

Take Off
Boost Pump ------------------------    ON
Fuel Pump ______________________    Pumping (engine driven)
Carburetor ________________________    Auto Rich
Priming Valve _______________    OFF
Transmitter / Pressure Gauge __     Reading Fuel Pump set pressure (18 PSI)
(Note: a pressure reading not in the ‘green’ on the gauge is a NO-GO for take off)

Cruise:
Boost Pump ------------------------    OFF
Fuel Pump ______________________    Pumping (engine driven)
Carburetor ________________________    Auto Lean
Priming Valve _______________    OFF
Transmitter / Pressure Gauge __    Reading Fuel Pump set pressure (18 PSI)

Landing
Boost Pump ------------------------    ON (when on ‘final’)
Fuel Pump ______________________    Pumping (engine driven)
Carburetor ________________________    Auto Rich
Priming Valve _______________    OFF
Transmitter / Pressure Gauge __    Reading Fuel Pump set pressure (18 PSI)

Engine Shut-down
Boost Pump ------------------------    OFF
Fuel Pump ______________________    Pumping slows to a stop (engine driven)
Carburetor ________________________    Auto Cut-off
Priming Valve _______________    OFF
Transmitter / Pressure Gauge __    Pressure falls to zero

Some operation notes:

During engine start, the open Primer Valve puts fuel into the supercharger housing. Too much fuel and it comes out the ‘over fill drain’. This is conveyed to the pilot by the ground crew’s “thumb-up / thumb-down” signal.

The Fuel Pressure Gauge is the most boring gauge on the instrument panel - beyond starting and shutting down the engine, it doesn’t move (in normal conditions). Take-off, landing, climb, or descend – the gauge stays the same. That’s a good thing. The gauge is monitoring the health of the fuel system, and steady is AOK.

Engine shut down is caused by the pilot setting the mixture control to Auto Cut-off which stops fuel flow into the Carburetor. The engine dies from starvation. This means the Carburetor, supercharger housing and the engine cylinders all become void of fuel.
mixture (call it ‘dry’). This is why the Boost Pump and Primer Valve are needed to re-start the engine. They ‘re-wet’ the carburetor and supercharger housing prior to cranking the engine.

The Boost Pump is also ON during the critical times of take-off and landing. It is a back up (redundancy) for the Fuel Pump. Also the Boost Pump’s added pressure to the fuel pump avoids possible vapor lock while in the warmer atmosphere close to the ground. The aircraft could successfully take-off and land with the Boost Pump OFF; however that is not safe practice.

Turning the Boost Pump ON or OFF once the engine is running will have no effect of the Pressure Gauge reading.

**Maintenance / Repair of Fuel System components:**

(Note: All FE maintenance / repair is done subject to the overview and approval of an A & P).

There are components in the fuel systems that are “black boxes”: A black box is a component that requires a certified shop to disassemble for repair. From an FE’s vantage point, these components either work or they don’t. If they don’t work, the fix is to replace them with another that does.

Maintenance on the controls, interconnecting hoses and adjustments for these components however can be done by an FE supervised by an A & P.

Black boxes in the fuel system are: Boost Pump, Fuel shut off Valve, Fuel Pump, Carburetor with Priming Valve, and Transmitter / Fuel Gauge.

**Fuel Leaks:**

Leaks happen.

In flight, a leak can permeate the airplane with the odor of gasoline. FE, and crew, to identify the leak source if possible. The pilot has options: fly with the leak as-is, or close the Fuel shut off Valve (this will shut down an engine), or make a no Boost Pump landing (suspecting the leak is just downstream of the boost pump and turning the pump on would only make the leak worse), and/or elect to not operate any electric motors that are aft of the suspected leak area (avoiding sparks). With the last option, the FE will be hand cranking the landing gear and maybe even the flaps.

On the ground, leaks drip and/or show up as blue stains on the sheet metal (the stains usually start at the sheet metal seams and flow aft). Use the Boost Pump if necessary to pressure up the system to better expose the leak location. Also the interior construction of the wing is of a honeycomb nature so pockets of leaked gasoline could have accumulated – to be checked.
FE’s fix leaks.

**Fueling TR**

FEs fuel TR.

There are FOUR in independent fuel systems, so effectively the airplane is fueled four times at each fuel stop.

Gauging the fuel quantity in a tank is done with a calibrated dip stick. The procedure is to immerse the stick all the way to the bottom of the tank, remove and then read the calibration at the ‘wet line’. (Note Engines #2 & #3 each have two tanks that function as one. The dipstick is calibrated for the tank closest to the fuselage and reads the sum quantity of both tanks).

There are two concerns with the dipstick: FIRST, the outboard tanks are shaped differently than the inboard tanks (i.e. both inboard tanks acting together) therefore the dipstick has two calibrations – one on each side of the dipstick. One side is for Engines #1 & #4, the other is for Engines #2 & #3. Be very certain the correct calibration side is used on the correct tank. Getting this backwards will result in a 125 gallon reading error (plus or minus depending) – not good. SECOND, pulling the dipstick out and then reading the ‘wet line’ is tricky. The gasoline remaining on the stick evaporates very quickly causing the ‘wet line’ to drop rapidly. A procedure to mitigate this is to pull the stick out of the tank only enough to see the ‘wet line’ and then quickly place a finger at that location. Pull the stick out the rest of the way and then read the finger location. It is best to repeat the dipstick procedure to minimize errors.

Fueling of TR is managed, and reported to the pilot, by use of the “FUEL / Engine OIL / LOAD WORKSHEET.” This form is used for every pre-flight inspection AND every time fuel is added. The WORKSHEETS are to be sequentially numbered and retained in a binder in the airplane.

The ‘FUEL’ portion of the Worksheet is shown below (with EXAMPLE entries):
Use of the WORKSHEET:

The Pilot will determine the amount of fuel required to operate between the current and the next fueling location, and gives that number (gallons) to the FE. This is the number to be placed in the 'blue' box on the WORKSHEET. Divide that by four and enter result in the four boxes under the ‘Pre-Depart” header. – this is the fuel quantity the pilot wants for each engine.

Dipstick the tanks and enter the readings under the ‘Pre-Flight’ header.

Side Note: All four tanks depart with the same amount of fuel. All four engines are identical. Therefore, in a perfect word, all four tanks always would have the same amount of fuel remaining at the nest fueling stop. This rarely happens for multiple reasons, but the post flight tanks should all have about the same amount of fuel. A big difference in post flight fuel is a ‘Red Flag’ – the FE needs to understand why that difference occurred before proceeding. How much is a big difference? Fifty gallons is a reasonable number. Fifty gallons is about an hours flying time for one engine.

The difference between each tanks ‘Pre-Depart’ quantity (what you need) and the ‘Pre-Flight’ quantity (what you have) is the amount to be added to each tank (enter under the “FUEL Added” header).
Add up the four ‘FUEL Added’ quantities and enter the SUM in the ‘Total Gal.’ row.

*Side Note:* The SUM of the ‘FUEL Added’ quantities is the amount of fuel to be ordered from the FBO. In doing that, make sure the FBO sends the fuel truck with at least that much fuel onboard. Not doing so means the truck could arrive short. A short truck very likely will unload whatever, run off for more fuel and then return to complete the delivery. During fueling the airplane is completely shut down except for fueling. No one is allowed inside TR. The public is held back 50’. Tours are shut down (a revenue source). Interim maintenance is shut down. Having the fuel truck extend the downtime with multiple deliveries is not good operations.

At the next fuel stop and before re-fueling, dipstick the tanks again and enter the readings under the ‘Post-Flight’ header. The difference between each tanks ‘Post Flight quantity (the amount remaining) and the ‘Pre-Depart’ quantity is the amount of fuel consumed by each engine (enter under the “FUEL Consumed” header). From the Pre and Post Hobbs meter readings, determine the Flight Hours. Divide each engine’s Fuel Consumed by the Flight Hrs to get the GPH (gallons per hour).

*Side Note:* The GPH information is reviewed over a number of previous flights to identify engine performance trends. The GPH numbers will vary depending on the type of flying (lots of revenue rides vs. long transit flights – for example). The pilots can use this in their pre-flight required fuel estimations. Each tank at pre-depart will have the same amount of fuel load (for weight and balance reasons) but the RANGE of the aircraft is set by the GPH of the least efficient engine – not the average.

Also the ‘Post Flight’ fuel quantities on the current Fuel Card are (or should be) the ‘Pre-Flight” quantities on the next Fuel Card.

**The Fuel Truck:**

The fuel truck arrives, connects a ground wire to TR’s tow bar eye on the landing gear (or an engine exhaust pipe) and reels out a hose. The hose is never long enough to fuel all four tanks from one truck position. The truck fuels one wing, then rolls up, repositions to the other wing, re-connects and fuels some more.

Position the truck in front of the wing and run the hose up between the engines. We use a small rug placed on the leading edge of the wing, between the engines, to prevent the hose from chaffing TR’s paint.

Good practice is to fuel the inboard engine first (the inboard has two connected tanks and doing this allows the two tanks time to equalize while the outboard is being filled).

The fuel truck has a meter which records the TOTAL amount of fuel dispensed. TR is fueled into four tanks meaning the fueling is to stopped then moved to the next tank –
three times. The FE determines the gallon count for each stop and works with the truck driver to make that happen. The gallon count for each stop is the sub-TOTAL as the fueling moves from one tank to the next.

A static electric spark is a possibility while fueling – not a good thing. To prevent this, the three components of the filling operation are to be grounded together. The three components are the Fuel Truck, the Airplane and YOU. The fuel truck will be grounded to TR’s landing gear with a wire (hooked up by the truck driver). The hose (handled by the FE) completes the circuit and needs to be touching TR whenever fueling. Do this by inserting the hose nozzle into the tank filler neck and then lean the nozzle over to where it firmly touches the metal of the filler neck. The FE then keeps a hand on the metal of the hose nozzle throughout fueling. All three are then are electrically neutral.

**Sump the Tanks**

Sump the THREE tanks and the TWO strainers on each wing (TEN total locations) as part of all pre-flight inspections. Check the sample for color (*should be a light BLUE – 100 LL av.gas is BLUE, Jet Fuel is RED to Straw color and wrong*) If the sample is a nice clear liquid, it’s not gas, it’s water. Keep repeating the sump until only BLUE appears. Sometimes part water and part gas will be in the sump sample. The two do not mix and a distinct separation line will be apparent – if so, keep repeating the sump until only BLUE appears. (*The water is likely condensation in the tanks due to day / night temperature differences*).

Sump the THREE tanks on each wing (SIX total locations) after all re-fueling. The FBO’s fuel storage tanks and the fuel trucks all have fuel / water separators, so there shouldn’t be any water in the gas. BUT, don’t believe it – sump the tanks anyway after every fueling to be absolutely sure.

*Side Note: The reason for fueling the inboard engines first is to allow time for the two connected tanks to stabilize allowing any possible water to then settle down to the sumps.*

Also check the odor of the sump samples – aviation fuel smells like gasoline.

The TEN sump valves can leak. A little debris gets under the valve seat during the sump testing and a drip happens. Double check this. Cycle the valves to clear if necessary.

**Tank Filler Caps**

The tank filler caps are on top of the wings. Obviously put the tank filler caps back on after fueling. Insert the cap, rotate until it clicks, tighten the seal wing nut, and then challenge the cap tightness by pulling on the attached ‘D’ ring. Simple enough, except a mistake here is a SERIOUS problem. An improperly seated filler cap is a vent to the top of the wing. The hydraulics are complex but suffice to say that in flight fuel will
stream out of the filler cap at a prodigious rate. The fuel becomes a vortex mixing with the air and will trail back to become as large as the fuselage - a flammable mixture; not good. This won’t appear until the airplane is in flight. There is nothing the flight crew can do to stop it. The only option is to land quickly.

Exercise real caution with the fuel filler caps.

**Fuel Transfer**

TR has a system to transfer fuel from one engine to any other engine. There are two parts to understanding the fuel transfer system – HOW-TO transfer and WHY to transfer.

The HOW-TO is two selector valves and a three position toggle switch all located on the step between the bomb bay and the flight deck. Procedure is to select a tank on one wing with that side’s selector valve, select another tank on the other wing with the other side’s selector valve, then move the toggle switch in the direction (left or right) that flow is wanted. The switch activates a pump which moves about 15 gallons a minute. When done, shut off the pump and close the valves. All this is done by the FE.

WHY to transfer has to do with weight and balance. The only probable scenario calling for fuel transfer is an in-flight engine shut down (*during war time there were probably many*). A shut down engine no longer consumes fuel. That means the wing with the shut down engine will steadily be getting heavier than the other wing - an out of balance situation. Two real world considerations when an engine is shut down: first, the airplane can fly perfectly well on three engines. Second, wherever the airplane is set down is where the problem engine will be fixed (*the plane can fly on three, but it can’t take off without four*). With that, the pilot’s propensity is to fly all the way back to the home base where all the ground support to fix the problem is located – home base is Conroe, TX. The three engine flight could be (and has been) hours long.

A standard procedure for fuel transfer has been adopted. This procedure is valid regardless of which engine is shut down and is regularly repeated in flight which accommodates any flight duration.
Standard Procedure:

One Engine Out - In-Flight Fuel Transfer Procedure

Fuel not consumed by a non-running engine will cause an uneven weight distribution across the wing. The longer the engine outage the more pronounced the out-of-balance becomes. Transferring fuel from the OUT engine to the opposite side MIRROR IMAGE engine reduces the imbalance.

Procedure:

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<tr>
<td>1</td>
<td>Note the TIME of the Engine Outage</td>
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<tr>
<td>2</td>
<td>Transfer fuel at 30 MINUTES after Engine Out.</td>
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<tr>
<td>3</td>
<td>Transfer from the OUT Engine to its opposite-side-mirror-image engine</td>
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<tr>
<td></td>
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4 | Run the Fuel Transfer Pump for ONE MINUTE

5 | Repeat fuel transfer every 30 MINUTES

Note that from actual flight experience, fuel consumption on the remaining running engines increased from a typical 52 GPH to about 65 GPH. This procedure does not add fuel to two of the three running engines, so be aware, the remaining RANGE from the time of the Engine Outage will be reduced by about 25%.
The in-flight procedure will be for the FE to set the transfer valves, then notify the Pilot “Ready for fuel transfer according to the Standard Procedure”. With the Pilot’s approval, transfer the fuel. Upon completion, notify the Pilot “Fuel transfer complete”. Reset the transfer valves to the closed positions between each 30 minute transfer cycle.

*Side Note:* There is no Two Engine Out procedure. Loss of a second engine requires the plane to land immediately.

FE: Lee Brown

Approved:

_____________ Pilot

_____________ A & P