The Historic Jetliners Group

Boeing 707
Fuel System Tutorial

By Harerton Dourado

Introduction

My name is Harerton Dourado. I'm from Brazil. I've been a 707 fan for years and I was fortunate enough to fly on those birds three times in my life. I try to gather as much info on the 707 as I can so the HJG staff asked me to write this tutorial. With George Carty's masterpiece panel we can now have the chance to seat on the flight engineer seat and see the flight from a different point of view. In FS as we don't usually have a copilot, not to mention a flight engineer, the pilot has to do the job of 3 people. In order to facilitate things I'll try to explain how to work and manage the 707 fuel system.

I want to thank HJG for all the support in the preparation of this tutorial and also for presenting their aircraft models, liveries, panels and soundpacks to the FS community. They are pure art!

I also would like to thank Capt. Paulo Marcelo Soares from TAM Brazilian Airlines for the technical support and suggestions. He's also a 707 admirer and had the opportunity to fly the Lufthansa 707 simulator in the left seat. Flight simulation can't get any real than that!

To make things as real as possible I'll make use of some images taken from an old 707 manual. But I have to make it clear that this tutorial is FOR FLIGHT SIMULATION ONLY! I am not a real 707 pilot, in fact I'm only a MS Flight Simulator pilot. So you'd better not try to fly your grandfather's 707 based on this text! And of course, neither HJG nor I are responsible for what you'll do with this tutorial and how you'll use it.

Ok, so much said. There's a lot to be learned. So relax and read on.

Fuel loading

The first thing we have to know is how much fuel we'll need for our flight. There are several flight planning software out there and some of them already have profiles for the several 707 models. When you generate the flight plan you get info on the amount of fuel needed to accomplish the flight. But if don't have such software or are not lucky to have a real 707 manual you can use the following data as a rough guide when planning your flights:

Type	***Range full payload (NM)***	***Range full mixed class (NM)***	***Range without payload (NM)***
707-120	2465	3310	4040
707-220	2050	Data not available	4010
707-320	4155	5180	5750
707-420	4225	5270	5850
707-120B	2640	3545	4325
707-320B	4275	5385	6040
707-320C	2800	Data not available	6000
720	2120	2465	3110
720B	2085	3300	3910

(Obs: If you happen to know the missing data on the -220, -320C and also on the -138, -138B, -700 and 367-80, please let me know!)

The keyword is balance. Once we know how much fuel we'll need we have to distribute it on the several tanks. The 707 have 4 main tanks, 2 reserve tanks and a central tank. The priority is to first fill the main tanks. If you've not guessed yet, half the fuel will go to the left tanks and the other half to the right tanks (rememeber: balance).

Now take a look at the following table. It is obtained from two different *aircraft.cfg* files of HJG 707. It shows the capacity in gallons of the several tanks.

Model	*Main 1*	*Main 2*	*Main 3*	*Main 4*	*Reserve 1*	*Reserve 2*	central
707-120	2062	2275	2275	2062	434	434	7306
707-320C	2323	4069	4069	2323	439	439	10193

Let's take the 707-320C as an example. Suppose we need 6000 gallons of fuel for our flight. If you look at the table you'll see 4 main tanks. Those tanks are directly linked to the engines, each one supplying fuel for a specific engine. So without much guessing, we will feed each tank with 1500 gallons. This way, each engine will have the same amount of fuel and the fuel weight will be distributed equally on each side of the plane, thus maintaining balance.

Ok, but what if we need more fuel? This is simple: just put the same amount of fuel on each main tank. When all the main tanks are completely full, load the remaining fuel to the reserve tanks. There are two reserve tanks, one linked to no. 1 main tank and the other to no. 4 main tank. Only when the reserve tanks are completely full you will start loading the central tank. Pretty simple isn't it?

The Fuel system

Now comes the fun part. For many flightsimmers the look of the HJG flight engineer (FE) panel on the 707 or 720 might be a little scaring. There are many buttons and gauges which may lead you to think this panel is hard to master. Well don't give up. Although there are indeed a lot of instruments on the FE panel it is perfectly possible for anyone to understand how they work. Just keep reading.

First of all, spend some time looking at the fuel section on the FE panel. It's shown on figure 1. It's basically located on the lowest half of the panel, towards the left side. You'll notice 9 gauges, a lot of switches and a red line linking them (well, on the real panel it's painted in white). This line is a basic representation of how fuel flow from the tanks to the engines. Notice the engine representation above 4 of the gauges. Just follow the line and you'll understand the fuel system. I'll try to describe it with some detail.

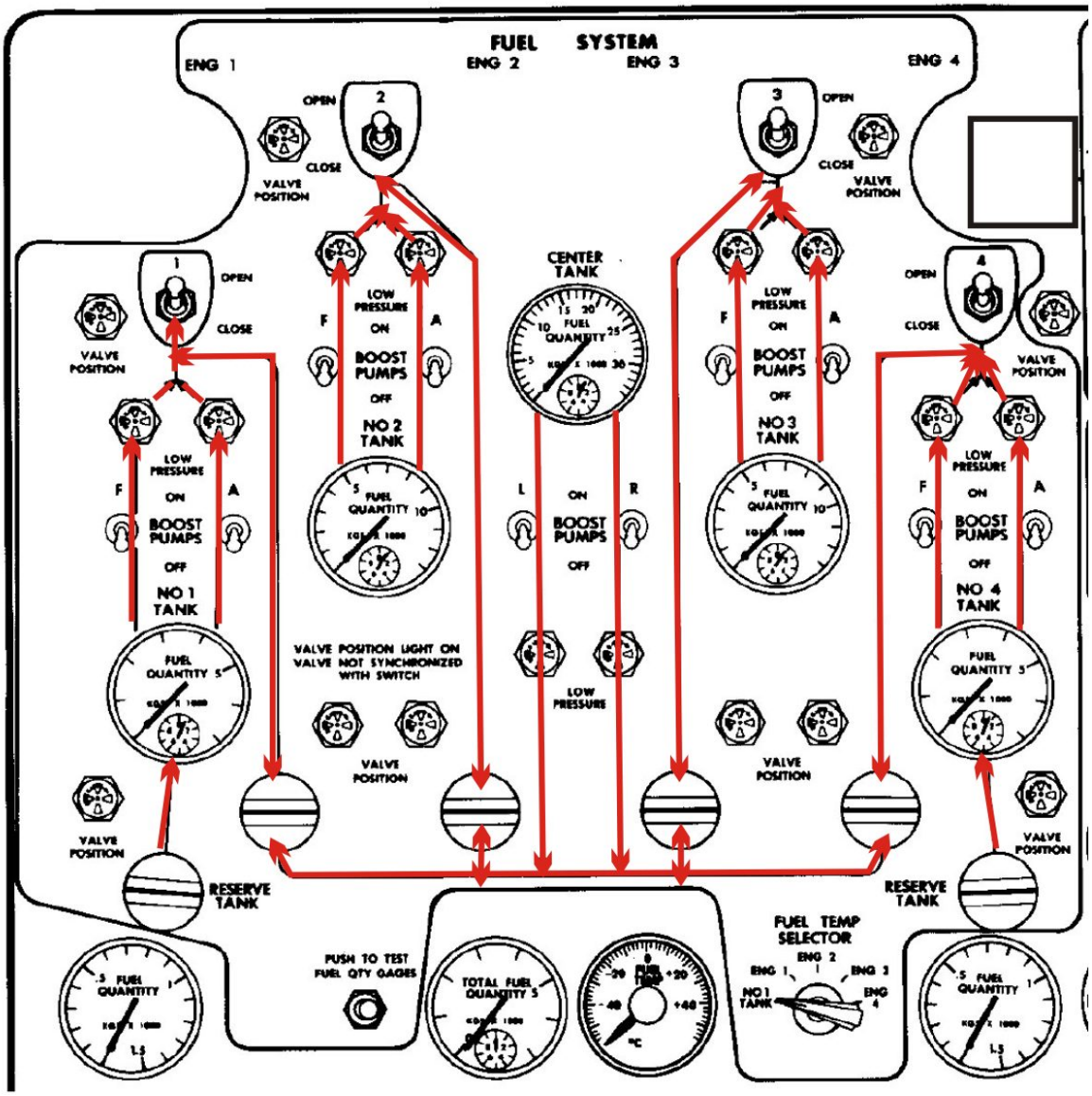


Figure 1: 707 fuel panel

Basic fuel flow is from each main tank to the corresponding engine. Reserve tanks 1 and 4 supply main tanks 1 and 4 respectively. The central tank can supply any engine.

Let's focus on each main tank/engine controls. Below is the number 1 engine fuel line (figure 2).

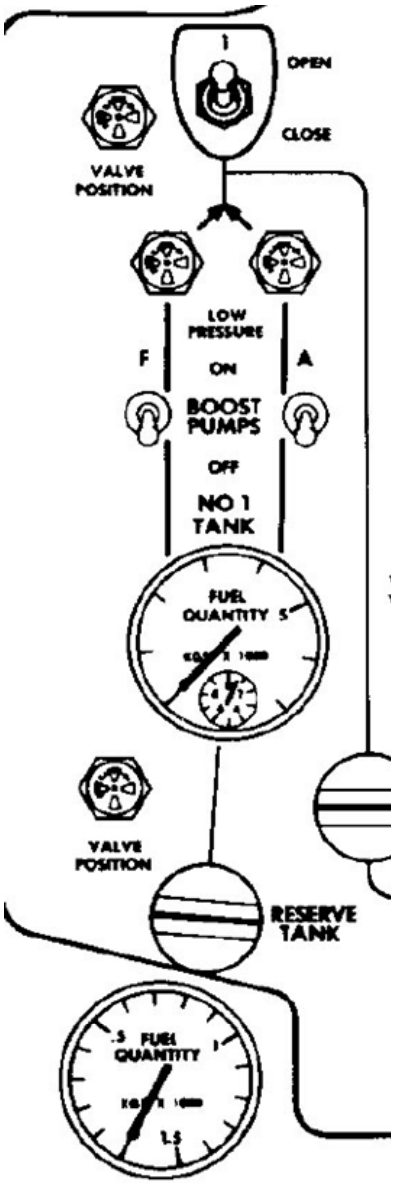


Figure 2: fuel line number 1

The switch inside the engine will cut fuel flow, effectively turning it off.

Following you'll notice two paths. One comes from the main tank and the other comes from the fuel crossfeed manifold.

Following the main tank path, just below the engines you'll see a pair of switches. Those are the boost pump switches. There are two per tank and they serve the purpose of supplying fuel from the corresponding tank to the engine or fuel crossfeed manifold.

Under the switches is a fuel quantity gage, showing remaining usable fuel in the tank.

Following the path, there is the reserve fuel line. As I said before, the outboard tanks are linked to the reserve tanks. To supply fuel from this tank to the main tank, the reserve tank selector must be turned to the vertical position (in figure 2 it is shown on the closed – horizontal – position).

Below the reserve tank selector is a gage showing the remaining usable fuel on the reserve tank.

Basic fuel management include loading the main tanks and turning on the boost pumps (at least one of them for each engine).

The Crossfeed manifold

As I said before, there are times when a large amount of fuel is needed (i.e. on an intercontinental flight) that the central tank must be used. Good practice states that the central tank must be emptied before the main tanks in order to reduce the load on the wings, and to have plenty of fuel remaining for a diversion to an alternate airport early in the trip, in case of the center tank fuel becomes unusable. So there must be a way of distributing fuel from the central tanks to all 4 engines.

Another example: suppose one engine is lost during flight. As the other engines continue to receive fuel from their respective tanks the dead engine won't be receiving any fuel so an imbalance situation is likely to occur, where one side of the plane will be heavier than the other. In this case what's needed is a way of using the fuel from the dead engine tank to supply the other engines.

Here comes the crossfeed manifold. Is function is to allow fuel flow from any tank to any engine. If you look at figure 1, you will notice 4 switches. Those are the fuel crossfeed selectors and they control how the fuel will be distributed. In the following illustrations I'll try to cover the several possibilities.

1. *Main tanks boost pumps:* on*; central tank boost pump:* off*; crossfeed selectors:* closed.

   In this configuration, no fuel will flow in the manifold. Each engine receives fuel from its corresponding main tank. Notice the central tank boost pumps are turned off.

2. *Main tanks boost pumps:* on*; central tank boost pump:* off*; 1, 3 and 4 crossfeed selectors:* closed*; 2 crossfeed selector:* open

   This option is almost identical the previous one and in fact is the default mode of operation when no fuel is used from the central tank. Crossfeed selector number 2 is open to maintain the manifold pressurized and thus ready to be used. This mode is also used in takeoffs and landings.

3. *Main tanks boost pumps 1 and 4:* off*; Main tanks boost pumps 2 and 3:*on*; central tank boost pump:* on*; 1, 2, 3 and 4 crossfeed selectors:* open.

   This is the setup for using the central tank fuel. Notice the main boost pumps 1 and 4 are turned off and the central tank boost pumps are on. This way fuel will be supplied from the central tank to engines 1 and 4. A smaller quantity will also go to engines 2 and 3. This mode is used after takeoff, when a certain amount of fuel from the main tanks has already been used (14,000lb recommended).

4. *Main tanks boost pumps 1 and 4:*on*; Main tanks boost pumps 2 and 3:* off*; central tank boost pump:* on (if central tank is being used)*; 1, 2, 3 and 4 crossfeed selectors:* open.

   Suppose engine 1 is lost. Fuel from the number 1 main tank need to be supplied to the number 2 and 3 engines to maintain lateral balance. Boost pumps from main tank 1 and 4 are turned on and all fuel crossfeed selectors are open. If the central tank is still not empty, its boost pumps will be turned on in order to supply fuel flow to the remaining engines. The flight engineer must be constantly monitor fuel balance turning off boost pumps from number 1 tank when necessary. Every 30 minutes engine number 1 windmilling procedure must be carried.

As real as It Gets…

Now what about some real world procedures? JUST REMEMEBER: USE THEM ONLY IN MS FLIGHT SMULATOR.

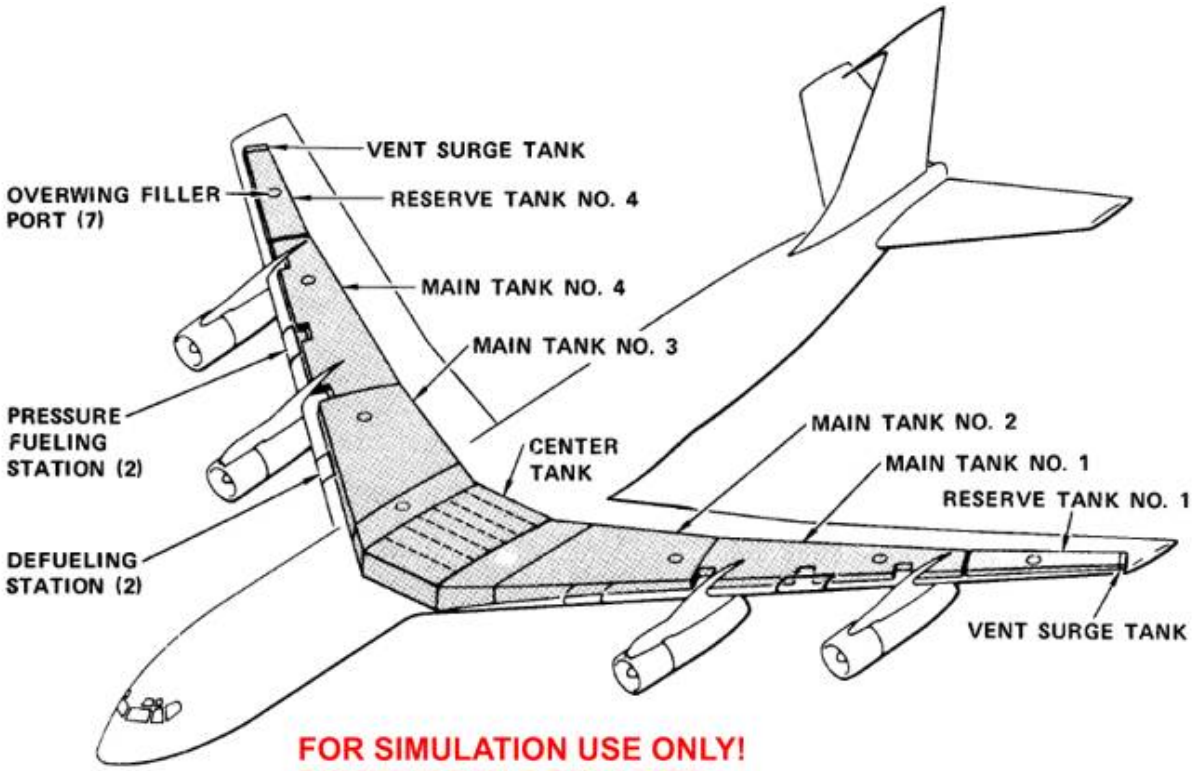
The link: <http://www.airweb.faa.gov/Regulatory_and_Guidance_Library/rgMakeModel.nsf> contains the FAA type certificate data sheets on all FAA homologated aircraft. Each document has lots of information about aircraft performances, limitations and operation.

There you'll find a certificate for the 707-100B/138B and 200, a certificate for the 707-300/400/300B/300C and 300B-ADV and a certificate for the 720/720B models. Each certificate has a section on fuel usage and loading. I highly recommend you download and read them.

Now as bonus, figure 3, 4 and 5 contains some info on fuel loading, usage and management for the 707-320C.

I hope you enjoyed this tutorial. If you have any doubt, feel free to post a question on the HJG forum, on the General Forum section. The link is: < http://tonymadgehjg.proboards98.com/index.cgi >.

"But those who hope in the LORD will renew their strength. They will soar on wings like eagles" Isaiah 40:31



USABLE FUEL QUANTITIES (PRESSURE OR OVERWING)					
	NO. R1 or R4 TANK	NO. 1 or 4 TANK	NO. 2 or 3 TANK	CTR TANK	TOTAL
U.S. GAL.	439	2,323	4,069	10,193	23,855
LBS.	2941	15,564	27,262	68,293	159,827
KG.	1,335	7,062	12,370	30,986	72,520

TABLE 1

SP. GR. OF FUEL AT 60°F (15°C) = .803
DENSITY OF FUEL AT 60°F (15°C) = 6.7 LB/U.S. GAL
U.S. GAL x 3.785 = LITERS
U.S. GAL x 6.70 = POUNDS (LB)
U.S. GAL x 3.04 = KILOGRAMS (KG)
U.S. GAL x 0.8327 = IMP. GALLONS

Figure 3: 707-300C fuel tanks capacities

TOTAL FUEL WT – 1000 KG	OUTBOARD MAINS 1 & 4 FUEL WT PER SIDE 1000 KG			INBOARD MAINS 2 & 3 FUEL WT PER SIDE 1000 KG			RESERVE TANKS 1 & 4
	FUEL DENSITY LBS. PER U.S. GAL./KGS PER L.						
	6.1/.73	6.7/.80	7.1/.85	6.1/.73	6.7/.80	7.1/.85	
LESS THAN 18.0 ± .5	FUEL SHOULD BE DISTRIBUTED EQUALLY IN MAINS 1, 2, 3, & 4						EMPTY
18	4.2	4.5	4.5	4.5	4.5	4.5	
20	4.2	4.7	4.9	5.0	5.0	5.0	SEE
22	4.3	4.7	4.9	5.6	5.5	5.5	TABLE
24	4.5	4.7	4.9	6.2	6.0	6.0	BELOW
26	4.8	4.9	5.0	6.9	6.8	6.5	
28	5.1	5.2	5.3	7.7	7.5	7.3	
30	5.4	5.5	5.6	8.4	8.2	8.0	
32	5.6	5.7	5.9	9.2	8.9	8.7	
34	5.9	6.0	6.2	9.9	9.6	9.3	
36	6.2	6.3	6.4	10.6	10.3	10.2	
38	6.4	6.5	6.7	11.2	11.1	10.9	
40	FULL 6426	6.8	7.0	FULL 11257	11.8	11.6	
42	SEE	7.0	7.3	SEE	12.4	12.3	
44	TABLE BELOW FOR CENTER TANK FUEL	FULL 7058	7.5 FULL 7479	TABLE BELOW FOR CENTER TANK FUEL	FULL 12364	13.1 FULL 13102	

TOTAL FUEL WT – 1000 KG	CENTERTANK FUEL – 1000 KG		
	FUEL DENSITY LBS. per U.S. GAL/KGS per L.		
	6.1/.73	6.7/.80	7.2/.85
36	0	0	0
38	.2	0	0
40	2.2	0	0
42	4.2	.5	0
44	6.2	2.5	0
46	8.2	4.5	2.0
48	10.2	6.5	4.0
50	12.2	8.5	6.0
55	17.2	13.5	11.0
60	22.2	18.5	16.0
63	27.2	23.5	21.0
70	FULL 28,199	28.5	26.0
75		FULL 30,972	31.0 FULL 32,821

TOTAL FUEL WT – 1000 KG	RESERVE TANKS 1 & 4 FUEL WT PER SIDE 1000 KG		
	FUEL DENSITY LBS per U.S. GAL/KGS per L.		
	6.1/.73	6.7/.80	7.1/.85
18	.3	0	0
20	.8	.4	.1
22	1.2	.9	.6
24	FULL 1214	1.3	1.1
26		FULL 1334	1.4 FULL 1413

ONLY USE FOR FLIGHT SIMULATION!
DON'T USE IN REAL LIFE!!!

Figure 4: 707-300C fuel loading

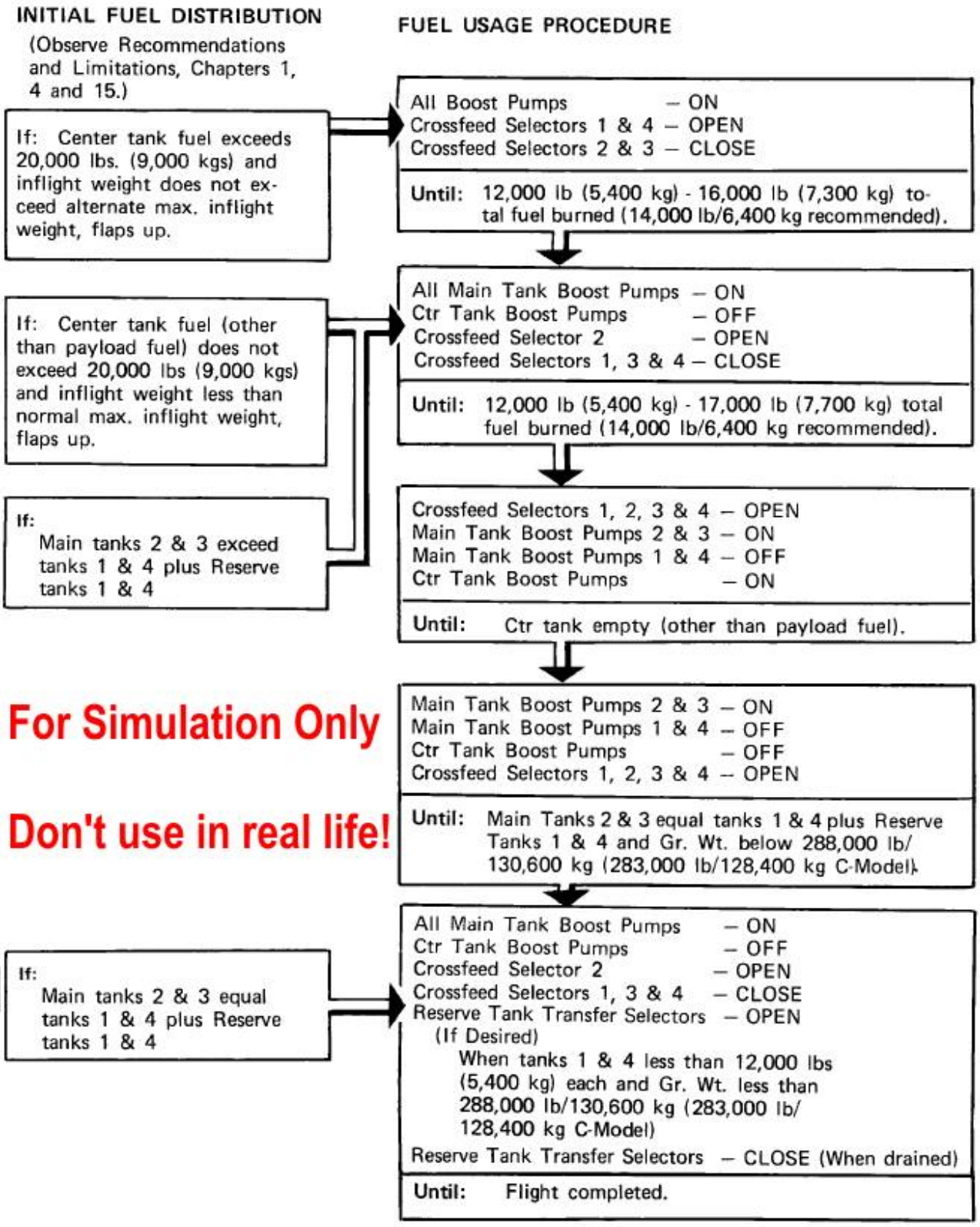


Figure 5: 707-300C Fuel management