CF-105

Refueling and Defueling

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CF-105

REFUELING AND DEFUELING

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SUMMARY

INTRODUCTION

This report deals with the refueling and defueling requirements for the CF-105 aircraft.

PURPOSE

The purpose was to determine the following:

(a) The time required to carry out the various operations necessary to refuel the aircraft within the specified ten (10) minute turn around period.

(b) The time required to carry out the various operations necessary to refuel four aircraft within the specified fifteen (15) minute turn around period.

(c) The required rate of fuel flow and pressure, for refueling the CF-105 within the specified ten (10) minute turn around period.

(d) The number of service personnel required to refuel the aircraft within the specified ten (10) minute turn around period, and to refuel four aircraft within the specified 15 minute turn around period.

CONCLUSIONS

(a) With the requirement for a ten (10) minute turn around, adequate time is available for the actual pumping of fuel to the normal design mission fuel load, using existing RCAF tenders and pumping equipment. However, to meet the requirement for a turn around of four aircraft in 15 minutes, specified in AIR-7-4, issue 3, the time and motion study included in this report has been based on a turn around time of 7½ minutes per aircraft. Time spent on actual pumping of fuel to a normal design mission fuel load is 4.05 minutes.

This time results in a required flow rate of 250 imp. gallons per minute, per hose, therefore a total flow rate of 500 imp. gallons per minute into the aircraft.

From Fig. 1, it is seen that the aircraft system pressure loss for a rate of 250 imp. gallons per minute is 11 p.s.i. gauge, therefore, existing RCAF pumping equipment, capable of delivering 50 p.s.i. gauge at each nozzle exit, is adequate to meet the requirements.

SUMMARY

CONCLUSIONS (cont'd)

(b) It is recommended that a refueling team consist of four men, allocated as follows:

(1) One man on the ground, to open access doors and operate the master refueling controls. He will also assist in handling hoses. He should be nominally, the refueling crew-chief, and as such, responsible for directing the other members of the crew, checking aircraft fuel contents gauges, and making the entry in the L-14 at the completion of the operation.

(2) One man on the ground to operate the tender pumping equipment. He is responsible for ensuring that the required amount of fuel is pumped aboard the aircraft.

(3) One man at each main wheel well, responsible for opening and closing access doors, removing and replacing adaptor covers, handling refueling nozzles and carrying out pre-refueling checks.

(c) It is considered that the requirement for a man in the aircraft cockpit, to operate the master power switch, and read the aircraft fuel quantity gauges, can be met by having the member of the aircraft towing crew, carry out these functions and relay the information, pertaining to the quantity of fuel left in the aircraft, to the man located at the refueling tender controls.

(d) To meet the requirement of the 15 minute turn around time for four aircraft, it will be seen that two crews of four men each are required.

1. INTRODUCTION

This report deals with the pressure refueling and defueling requirements for the Avro CF-105 aircraft.

The design objective is to provide a refueling system which will comply with the requirement for a ten minute turn-around period, specified in amendment to be issued to AIR-7-4 issue 3; and for the additional requirement for the turn-around of four aircraft at one base in fifteen minutes, stipulated in AFHQ letter S1038-105 (ACE) 9 December 1954, and noted in the Minutes of the 25th Meeting of the Co-ordinating Committee, 18 January 1956.

The following extracts from AIR-7-4 issue 3; AFHQ letter S1038-105 (ACE) 9 December 1954; and the Minutes of the 25th Meeting of the Co-ordinating Committee are include to describe the refueling requirement -

AIR-7-4 issue 3

Para. 4.7.2.1

"Turn-around is a first line maintenance operation required to return the aircraft to an operationally serviceable condition after landing, and shall include replenishment of all consumable stores and liquids, as well as between flight inspections. Replenishment of fuel shall be to the normal design mission fuel load, as detailed in para. 3.6.1.1."

Para. 4.7.2.2

"Turn-around shall not exceed five minutes" (to be amended to read ten minutes)

Para. 6.4.6

"Complete pressure refueling of the internal fuel system to the combat radius of action fuel load detailed in para. 3.6.1.1 shall be accomplished within the five minute turn-around time of para. 4.7.2.2" (to be amended to read ten minute turn-around time)

Para. 3.6.1.1

"Combat radius of action - The combat radius of action at normal gross weight shall not be less than 200 nautical miles."

1. INTRODUCTION (cont'd)

Extract from AFHQ letter S1038-105 (ACE) 9 December 1954

> "Re Para. 2(c) - Although it is desirable to have each aircraft turned around in five minutes, this may not be physically possible when several aircraft land within any five minute time period. In this situation, an arbitrary figure of four aircraft in fifteen minutes is acceptable."

Extract from Minutes of the 25th Meeting of the Co-ordinating Committee, 18 January 1956

> "S/L Armstrong said that DOR have confirmed that the turn-around time required for the CF-105 has been increased from five minutes to ten minutes. RCAF specification AIR-7-4 will be amended to increase the turn-around time to ten minutes. This does not relax the requirement for turning around four CF-105 aircraft at one base in fifteen minutes."

2. AIRCRAFT FUEL SYSTEM GENERAL

For a complete description of this system refer to Avro report F.1. - Fuel System. The fuel is contained in fourteen (14) fuel tanks, the aft fuselage and six left hand wing tanks forming the left hand system, and the forward fuselage and six right hand wing tanks forming the right hand system.

Both fuselage tanks are of bladder type construction, and all wing tanks are of integral construction.

One of the fuel tanks (#5) in each wing is used as a collector tank, and contains an engine driven fuel booster pump, which normally supplies fuel to its respective engine. Fuel transfer from the wing tanks and fuselage tanks to the collector tanks is accomplished by an air pressurization system (derived from engine air bleed), which regulates the tank pressure to 25 p.s.i. absolute in the wing tanks, and 10 p.s.i. differential in the fuselage tanks. A five way flow proportioner located in each main wheel well, meters the flow of fuel from each system to the respective collector tank, in such a manner that all tanks empty at a rate proportional to their respective capacities. This ensures that the effect of fuel transfer on the A/C C.G. is kept to a minimum. To ensure that fuel flow from the fuselage tanks to the collector tanks is proportional to their capacities, an electrically driven transfer pump, coupled with a fuel pressure regulator is installed in the transfer line from each fuselage tank to its respective collector tank. The fuel pressure regulator regulates the outlet pressure to 25 p.s.i. absolute, which matches the delivery pressure from all wing tanks.

2. AIRCRAFT FUEL SYSTEM GENERAL (cont'd)

Downstream of the booster pumps, fuel passes through an oil to fuel heat exchanger, and at the exit from the heat exchanger the two systems are cross connected through a motor operated gate valve normally kept in the closed position. The fuel then flows to each engines fuel connection through an electrically operated shut-off valve (low pressure cock), which is provided for the purpose of isolating the engine for servicing, or for emergency fuel shut-off.

A single connection is made to each engine, within the engine compartment.

3. FUEL TRANSFER SYSTEM

The fuel transfer system operates as follows:-

Pressurized fuel in the tanks is picked up through fuel-no-air valves situated in the extreme corners of each tank. In each sub-system the fuel flows directly from these valves, via appropriate piping, to the sub-system flow proportioner, located in the main wheel well in the wing. This unit, which meters fuel from the tributary tanks so that they all empty in the same elapsed time, delivers from its' five chambers into a common pipe leading directly into the sub-system collector tank.

4. REFUELING AND DEFUELING SYSTEM - GENERAL

The aircraft is refueled and defueled through two standard $2\frac{1}{2}$ inch pressure refueling adaptors, located one in each wheel well, adjacent to its respective system fuel flow proportioner. In each system, fuel is conducted from this point to the downstream side of the proportioner, flow being prevented from entering the collector tanks via the normal transfer pipe by a mechanically operated shut-off valve which is closed by the action of opening the refueling adaptor access door.

The aircraft may be partially or fully refueled, to suit the requirement of the combat mission.

During partial refueling, the fuel is pumped from the adaptors to the proportioning units which, functioning in a reverse order to their operation during fuel transfer, meter the fuel to each tank according to its respective capacity.

4. REFUELING AND DEFUELING SYSTEM - GENERAL (cont'd)

During full refueling, the fuel pumped from the adaptors by-passes the proportioning unit and flows directly to all tanks until they are filled to capacity.

The air contained in the tanks is discharged through the relief valves in the pressurization system, during the refueling operation. These relief valves are fully opened electrically by the operation of the refueling selector switch.

In addition, the operation of the refueling selector switch closes the pressurization system regulator valves, to prevent pressurizing the fuel system, in the event that the ground air conditioning unit is in operation during refueling.

Special provision was originally made in the aircraft for emergency refueling, to cater for the case of the aircraft landing at an emergency air-strip where pressure refueling equipment might not be available.

For this condition, the aircraft was to be refueled through a filler cap located in the top access door to the rear fuselage tank. An electric motor driven pump was located in this tank to pump the fuel back into the pressure refueling circuit for distribution to all tanks at a rate of up to 50 imp. gallons per minute. However, Avro's proposal to delete this emergency refueling provision, for a saving of approximately 12½ lbs. weight, was accepted by the RCAF at the Co-ordinating Committee meeting on April 20th, 1955. It was decided to refuel the CF-105 under the stated emergency conditions by using the existing RCAF refueling tender, but equipped with a special adaptor instead of the refueling nozzle and that refueling would be carried out through the standard pressure refueling adaptors in the wheel wells of the aircraft. Such emergency refueling would of course be carried out at a much slower rate than normal pressure refueling for this aircraft.

5. AIRCRAFT REFUELING CONTROLS

Each tank contains a servo-operated fuel shut-off valve which controls the admission of fuel to that tank, and an associated fuel level sensing valve. Since the normal fuel transfer system piping is used for refueling, the fuel shut-off valve in each tank is located in the fuel transfer piping which serves each particular tank. The fuel level sensing valve is located at the highest point in each tank, and is connected to its associated shut-off valve by two servo bleed lines.

5. AIRCRAFT REFUELING CONTROLS (cont'd)

During refueling, fuel pressure applied at the refueling adaptors will be felt up to the shut-off valves forcing them open against a slight spring pressure. To cut off admission of fuel, the shut-off valves may be actuated in two ways.

During full refueling, the fuel level rising in the tanks to the full level, will cause floats in the fuel level sensing valves to rise, cutting off the flow of fuel through the servo lines from the shut-off valve. This fuel will then be trapped behind the valve actuating piston in the shut-off valve, forcing the valve closed and cutting off admission fuel.

During partial refueling, operation of the refueling switch in the main wheel well to the "Off" position will energize a solenoid in the tank level sensing valve which will move the pilot valve to cut off the flow of servo fuel from the shut-off valve, forcing the shut-off valve to close. When the switch is operated to the "On" position, the fuel trapped in the servo line will be dumped, allowing the shut-off valve to open.

A master refueling panel is located on the underside of the fuselage, immediately forward of the dive brakes. This panel contains a master refueling switch and a selector switch for "Partial Refuel", "Full Refuel" and "Defuel". Operation of the master switch provides electrical power to the system. This switch must be turned "off" at the termination of the refueling operation. To ensure that this is done, a guard on the switch prevents the closing of the refueling panel access door unless the switch is in the "Off" position.

The function of the selector switch is to actuate the motor operated slide valve in the wing flow proportioner. When "partial refuel" is selected, the valve is closed, directing fuel through the flow proportioner. When "full refuel" is selected, the valve is opened allowing the fuel to by-pass the proportioner, and flow directly to the tanks.

The master refueling panel also contains the fuel differential pressure indicator check lights. These lights are operated by a pressure switch located at each booster pump. They sense and signal that the output pressure of each booster pump is adequate, and are checked at regular intervals by means of running-up the engines on the ground to idling r.p.m.

6. AIRCRAFT PRESSURE REFUELING SYSTEM

6.1 Tank Capacity

(a) For the specified normal combat mission with a radius of action of 200 nautical miles, the fuel required (at present) is 2026 imp. gallons.

(b) The maximum internal fuel capacity is 2544 imp. gallons at present.

(c) The external fuel capacity is 500 imp. gallons, contained in an external tank slung below the fuselage.

6.2 Design Data for Refueling

The fuel piping system has been designed to a working pressure of 60 p.s.i.g., plus surges, and will be proof tested to a pressure of 120 p.s.i.g.

The fuel tank shut-off valves have been designed to operate up to and including a flow rate of 500 imp. gallons per minute. The rate of closing of the valve is dependent upon the flow rate of the fuel, but a time of five (5) seconds has been specified by Avro, as the maximum time for the valve to close. This provides a damping effect on the pressure build up or surge in the fuel line at the shut-off valve. Therefore the specified flow rate for refueling the aircraft may be maintained up to the last five seconds of the refueling time, after which there will be a gradual decrease of flow rate.

During "Partial refueling", when the required amount of fuel has been loaded, the fuel tank shut-off valves are closed by the operation of the "On"-"Off" switch on the refueling test panel in each main wheel well.

During "Full refueling", when each tank is filled, the level sensing valve causes the tank shut-off valve to close.

Both the tank shut-off valves and the level sensing valves are designed as double units. In an emergency, if one half of the unit is unserviceable, the other half will operate independently to shut off the supply of fuel to the tank. As a further safety measure, the "Pre-refueling test" on the tank shut-off valves, will always be carried out before refueling.

6.2 Design Data for Refueling (cont'd)

In the extreme case, where both units of the tank shut-off valve and fuel level sensing valve fail, and all remaining tanks are filled, it would be possible to fracture the tank with the resultant flow of fuel.

Aircraft fuel system pressure losses have been plotted against fuel flow rates in Fig. 1. This pressure loss is the (left hand or right hand) total loss calculated for one nozzle, adaptor, piping and fuel system units for one system between the exit of the fuel tender hose and the aircraft fuel tanks.

The requirement for a tender nozzle pressure of 50 p.s.i. and a flow rate of 250 imp. gallons per minute per hose is established in Section 8 of this report.

From Fig. 1 it will be noted that the aircraft system pressure loss for a flow rate of 250 imp. gallons per minute is 11 p.s.i.g.

Fig. 1 also shows that the maximum allowable flow rate that aircraft piping system could handle, would be 560 gallons per minute with 50 p.s.i. at the end of the hose. At 600 gallons per minute, the pressure loss would be 57 p.s.i., and it would be necessary to increase the pump pressure to overcome this additional pressure loss.

The nozzle to be used on the refueling tender shall comply with Specification MIL-N-5877A; which requires that the nozzle be capable of handling a flow rate of 500 imp. gallons per minute with the equivalent of a total pressure loss (nozzle & adaptor) of not more than 11 p.s.i. for J.P.4 fuel at temperatures of 60°-90°F.

7. REFUELING TENDER

The relaxation of the turn around time to ten (10) minutes will enable existing RCAF refueling tenders to be used.

These tenders are capable of deliverying 250 imp. gallons per minute per hose at a maximum nozzle pressure of 50 p.s.i.

The capacity of the tender, which is 3200 imp. gallons will require the topping up of the tender after each refueling operation.

8. TIME AND MOTION FOR 10 MINUTE TURN-AROUND

8.1 Purpose and Conditions

An investigation has been carried out to determine:

(a) The time required to carry out the various operations necessary to refuel the aircraft within the specified 10 minute turn-around period.

(b) The required rate of flow for refueling the CF-105 within this 10 minute turn-around period.

(c) Number of service personnel required to refuel the aircraft within this 10 minute turn-around period.

Fig. 2 is a schedule of refueling operations, time consumed, and number of men required.

8.2 Refueling Procedure

Refueling operations shown on Fig. 2 are here described in more detail.

8.2.1 Partial Refuel with pre-refuel check on Tank shut-off valves:

(a) Turn Master Refueling Switch on at the Master Refueling panel on the bottom of the fuselage. The green indicator lights on the subsidiary refueling panels in the wheel wells will illuminate, indicating that the individual shut-off valve in each tank is closed.

(b) Select "Partial Refuel" with the selector switch on the Master Refueling panel. This selection energizes solenoids at the 25 p.s.i. (abs.) regulators (ea 2) and the 10 p.s.i. (diff.) regulator (ea 1) in the pressurization system, to permit pneumatic operation of the regulators to the closed position and prevent pressurization air going to the tanks in the event that the ground pressure rig is in operation.

It also energizes solenoids at each of the 25 p.s.i. (abs.) relief valves (ea 2) and the 10 p.s.i. (diff.) relief valve in the pressurization system, operating them to the fully open position, in order that the fuel tanks have complete venting of air during refueling.

The by-pass valves in the flow proportioners are maintained in the closed position during partial refueling.

(c) In each wheel well, open an access panel, remove the cap from the pressure refueling adaptor, and attach the refueling nozzle to the adaptor.

(d) Start the refueling pumps, and proceed with the pre-refueling check on the tank shut-off valves. As soon as the fuel reaches the valves, the pressure build up will open the valves, and the indicator lights on the subsidiary refueling panels in the wheel wells should go out. Operate the switch on the subsidiary panel to the "Off" position, closing the shut-off valves. The pressure build up will operate a by-pass at the refueling pump, and the fuel will then be by-passed within the refueler. With the closing of the valves, the indicator lights on the subsidiary panel will come on, indicating the closed position. Operate switch to the "On" position, to open the valves, and proceed with refueling. The indicator lights on the subsidiary panel will go out.

(e) The refueling operation is controlled by the fuel tender operator. The quantity of fuel remaining in each tank system of the aircraft is noted by a member of the towing crew in the cockpit, who transmits it to the operator. By means of a chart conveniently located on the tender, on which fuel remaining is plotted against fuel required, the operator will determine exactly how much fuel has to be pumped into the aircraft for the "partial refuel" case.

The cockpit fuel capacity gauges are calibrated in pounds, and the flow meter on the fuel tender normally records fuel delivery in imperial gallons. The chart mentioned above, will present fuel required in imperial gallons, unless a meter, calibrated in pounds, is provided on the fuel tender. The fuel tender operator starts the refueling operation by starting the tender pumps. When the fuel tender meters indicate that the required amount of fuel has been delivered, the operator shuts off the fuel tender pumps, and the aircraft fuel tank shut-off valves are closed by operating the "On"-"Off" switches on the subsidiary refueling panels. The green indicator lights will come on.

(f) Remove the nozzles from the adaptors, replace the caps on the adaptors, and close access doors.

(g) Turn off the master refueling switch. The tank shut-off valve indicator lights will go out when the master switch is selected to "Off".

8.2.2 Full Refueling Operation

This operation is the same as "Partial Refuel" except:-

(a) "Full Refuel" is selected by means of the selector switch on the master refueling panel. This selection actuates the by-pass valves in the flow proportioning units to the "Open" position.

(b) The fuel level sensing units in the tanks will operate the tank shut-off valves to the closed position automatically when the tanks are filled. The lights on the refueling panel will come on when the shut-off valves close, indicating that the tanks are full.

9. DEFUELING

9.1 Method

The aircraft is defueled through the pressure refueling adaptors. The refueling tender nozzles are connected to each refueling adaptor, the air connections are made from the ground air conditioning unit, in order to maintain the tank pressure. With the exception of the collector tanks, the pressurized air causes the fuel to flow from the tanks through the normal fuel transfer lines to the flow proportioning units. Since the shut-off valves in the transfer lines to the collector tanks are closed, the fuel flows through the pressure refueling adaptor and hose to the refueling tender, under pump suction from the refueling tender.

The collector tank is defueled through the shut-off valve in that tank, which, unlike the shut-off valves in the remainder of the system, opens under negative pressure to permit reverse flow.

Manually operated shut-off valves in the transfer lines from the flow proportioners to the collector tanks are actuated to the closed position through mechanical linkage, when the access doors to the pressure refueling adaptors are opened.

9.2 Time to Defuel

Calculations to determine the defueling rate of flow have been carried out, with the following result -

9.2.1 Normal Defueling

It has been calculated that normal defueling of an aircraft with full internal tanks may be carried out in approximately 8½ minutes. This assumes that ground power unit and ground air conditioning unit are connected, and normal fuel system pressure is available before the defueling operation is commenced.

9.2.2 Defueling without Pressurization

The aircraft may be defueled if necessary, when fuel system pressurization is not available. It has been calculated that a time of approximately 11 minutes will be required to defuel an aircraft with full internal tanks under these conditions.

10. CONCLUSIONS

(a) With the requirement for a ten (10) minute turn-around, adequate time is available for the actual pumping of fuel to the normal design mission fuel load, using existing RCAF tenders and pumping equipment. However, to meet the requirement for a turn-around of four (4) aircraft in fifteen minutes, specified in AIR-7-4 issue, the time motion study included in this report has been based on a turn-around time of 7½ minutes per aircraft. Time spent on actual pumping of fuel to a normal design mission fuel load is 4.05 minutes.

From Fig. 1 it is seen that the aircraft system pressure loss for a rate of 250 imp. gallons per minute is 11 p.s.i. gauge.

Therefore it is believed that existing RCAF pumping equipment, capable of delivering 50 p.s.i. gauge at each nozzle exit, is adequate to meet requirements.

(b) It is recommended that a refueling team consist of four (4) men, allocated as follows:-

(1) One man on the ground, to open access door and operate master refueling controls. He will also assist in handling hoses. He should be the nominal refueling crew-chief, and as such responsible for directing the other members of the

crew, checking aircraft fuel contents gauges and making the entry in the L.14 at the completion of the operation.

(2) One man on the ground to operate the tender pumping equipment. He is responsible for ensuring that the required amount of fuel is pumped aboard the aircraft.

(3) One man at each main wheel well. Responsible for opening and closing access doors, removing and replacing adaptor covers, handling refueling nozzles, and carrying out pre-refueling checks.

(c) It is considered that the requirement for a man in the aircraft cockpit, to operate the master power switch, and read the aircraft fuel quantity gauges, can be met by having the member of the aircraft towing crew carry out these functions and relay the information pertaining to the quantity of fuel left in the aircraft, to the man located at the refueling tender controls.

(d) To meet the requirement of the 15 minute turn-around time for four aircraft, it will be seen that two crews of four men each are required.

NO.	OPERATIONS	TIME IN SECONDS: 60	120	180	240
1.	Man "A" opens refuel control access panel - operates master refuel switch and selects partial refuel.	———			
2.	Man "B" stationed at refuel pump controls - obtains information from cockpit refuel remaining in aircraft.	———			
3.	Men "C" & "D" position refuel stands - open access panels and remove adaptor covers.	———			
4.	Man "A" hands refueling hose and nozzles to men "C" & "D" on refueling stands.	———			
5.	Men "C" & "D" attach nozzles to adaptors. Signal man "B" to start pumps on tender.	———			
6.	Men "C" & "D" carry out pre-refuel check on tank shut-off valves.	———			
7.	Refueling time 2026 imp. gallons	———	———	———	4.05 minutes
8.	Man "B" stops refueling operation by shutting off refueling tender pumps.				
9.	Men "C" & "D" operate tank shut-off switches to close tank shut-off valves				
10.	Men "C" & "D" remove nozzles, replace adaptor cap. Close access doors and remove refueling stands.				
11.	Man "A" closes refueling control panel access door, checks aircraft fuel contents gauges, and signs L-14.				

TIME IN SECONDS

180 240 300 360 420 480

minutes

FIGURE 2

TIME & MOTION STUDY -

PARTIAL REFUELING FOR PRIMARY MISSION FUEL LOAD

Total time of 7½ minutes is based on requirement to "Turn-around" (Refuel) 4 aircraft in 15 minutes. Two refueling crews of 4 men each will be used to meet this requirement.

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