

Palletized Air to Air Refueling Kit for Medium and Light Military Transport Aircraft

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ABSTRACT

Air to Air refueling (AAR) operations are typically performed with dedicated tanker A/C. Most existing tankers are derived from civil airliners like the A330MRTT from Airbus Military or from military transport A/C with permanent modifications for the tanker role. For being able to refuel in flight some type of receivers like medium and light turboprops, helicopters and certain UAVs, the tanker aircraft should be able to fly at low speeds. For that role medium/small size turboprop military transport aircraft, like the C295 from Airbus Military are ideally suited.

This paper proposes a new palletized AAR kit for conversion of a transport A/C into a tanker. The kit includes all the needed air refueling systems, and can be installed on an existing military transport aircraft with rear cargo door ramp without big permanent modifications to the base platform.

The kit can also integrate an autonomous electrical system for powering the power-hungry refueling systems with no power demand to the base A/C. It includes power storage and supply to the pumps and refueling systems as well as energy recovery from the refueling systems.

With this kit the conversion of a military transport aircraft into a tanker aircraft or viceversa becomes a matter of hours, as opposed to permanent or semi-permanent conversions existing on the actual tanker fleet in operation.

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INTRODUCTION

In military aerial operations, tankers are considered "force multipliers," because they convey considerable tactical advantages. Primarily, aerial refueling increases the operating range of attack, fighter and transport aircraft, and allows patrol and special mission aircraft to remain airborne longer, thereby reducing the numbers of aircraft necessary to accomplish a given mission. Aerial refueling can also mitigate basing issues which might otherwise place limitations on combat payload. Combat and transport aircraft operating from airfields with shorter runways must limit their takeoff weight, which could mean a choice between range (fuel) and combat payload (munitions). Aerial refueling, however, eliminates many of these basing difficulties because a mission aircraft can take-off with a full payload and refuel immediately.

Overview of Up-to-Date Tankers and Capabilities

Most current tanker A/C actually in operation are based on large transport A/C or commercial aircraft adapted to the tanker role. According to the size of the original platform, they are designed for over 20,000 kg fuel offload capability in a search of maximizing the fuel load capability. This is the case for the Hercules KC-130J and for the A400M, as well as other Russian designs like the Ilyushin Il-78 MP (NATO reporting name Midas) based on military transports, or the A330MRTT or KC767 based on commercial aircraft.

However for some missions that require the transfer of much lower fuel quantities the operation of that large A/C can be very inefficient due to their high cost per flight hour. In addition, there are some countries that cannot afford the high acquisition costs of those large platforms, but still have the need of flight refueling capabilities for some of their operations.

On the other extreme, the buddy-refuelling technique typically allows flight refueling of a fighter A/C from another fighter A/C, but in those cases the fuel offload capability is very limited, usually to less than 2,000 kg.

Table 1 shows a brief overview of typical missions within the capabilities of the most known up-to-date tanker currently in operation:

Table 1. Typical AAR missions of actual up-to-date tankers in operation

	Fuel offload	Range
Airbus Military A310MRTT	24,000 kg	2,500 nm
Airbus Military A330MRTT	50,000 kg	1,000 nm
Airbus Military A400M	20,000 kg	3450 nm
	30,000kg	2450 nm
Lockheed Martin KC-130J	25,650 kg + 10,980 kg with aux tank	500 nmi
	20,412 kg	1,000 nmi
Boeing KC767	18,000 kg	1,200 nmi
Ilyushin Il-78 MP	57,720 kg	3,942 nmi
	85,720 kg with hold tanks	



Figure 1. C295 being refueled form an A400M.

It is apparent that there exist a gap in the tanker market for medium size tanker A/C with very low operating costs and fuel offload capabilities in the range of 5,000 to 15,000 kg. This tanker size would allow in flight refueling of light & medium-sized transport A/C, military helicopters and certain UAVs more efficiently than current tankers. Target receivers for these missions could be transports like the C295 (that can accept up to 6,000 kg of fuel), the C27J (up to 10,000 kg of fuel), an EC725 helicopter (up to 2,000 kg of fuel) and others.

NEW AAR TANKER KIT FOR MEDIUM SIZE TRANSPORT A/C

Kit Description

A new tanker-kit is proposed for reversible conversion of a standard medium transport A/C into a tanker A/C. The kit is targeted to be installed on the Airbus Military C295 A/C and future versions. This A/C has been proven as one of the most efficient (lower specific fuel consumption, lower operating cost) transport A/C of its category.

The kit consists of a set of standard military pallets (HCU-6E 108"×88") that integrate all the components required for the tanker role. The C295 A/C can fit 4 pallets on the cargo area and one additional pallet over the cargo ramp. All the pallets are clamped to the existing A/C loading points on the same way as standard cargo pallets (see Figure 2), without any particular A/C modification.

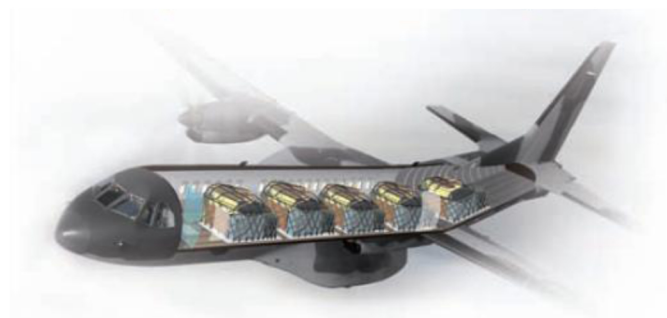


Figure 2. C295 cargo pallet locations.

An overall scheme of the kit is shown in Appendix 1.

Up to four pallets located on the cabin cargo area will accommodate the fuel tanks according to the mission requirements. Each tank accepts up to 2,000 kg of fuel for offloading. Each tank integrates all the needed safety features, anti-sloshing elements, flow control and shut-off valves, filling valves, as well as digital transducers for fuel quantity and fuel temperature. Fuel tanks are independent of the A/C fuel system to minimize operational hazards. The tanks will be interconnected through flexible pipes.

Another pallet installed over the cargo ramp integrates all the fuel offloading components, including the pumping group, the hose reel drum and drive system, the hose and drogue storage tunnel, the receiver guiding lights and the kit control system.

The pumping group is basically composed of two parallel fuel pumps driven by variable speed AC electrical motors, motor servodrives for precise pump speed control, fuel accumulators at the pump inlet and at the outlet for limitation of fuel surges, fuel bypass valve for hose depressurization, and fuel pressure, flow and temperature digital sensors. Fuel pumps will be connected to the fuel tanks through flexible pipes. Both pumps running simultaneously can deliver over

200 gpm fuel flowrate at a regulated pressure of 50 psig at the hose end.

A Ground Refuelling point with regulated pressure is also provided for fuel offload on ground to supply ground vehicles, helicopters, aircraft, or for other uses.

In the base kit option the pump motor servodrives are powered by the existing A/C 115 VAC (wild frequency) electrical system. Internally they convert the AC aircraft power to the required motor AC voltage and frequency to control pump speed to achieve the required delivery pressure at the receiver coupling. The servodrives receive the required speed commands from the Kit Control Unit, close the speed and current loops, and send back their actual status and main parameters for system monitoring. As the pumps only operate in one direction of rotation and their speed is smoothly increased and decreased there is no need for dissipation of regenerated energy within the servodrive.

Both pumps are operated in coordination with independent speed control to compensate asymmetries. The kit will be able to operate with a single pump in case of a first failure for providing high mission reliability.

The fuel supply to the pumps is assured by coordinated commands to the fuel control valves integrated with the fuel tanks. These valves allow the control of the fuel amount extracted from each tank to keep the A/C center of gravity within safe margins while the fuel is offloaded.

The hose drum drive system allows deployment and recovery of the refueling hose. It also takes care of the hose tension during coupling with the receiver A/C. It integrates a brushless DC motor driving the hose drum through a coupling mechanism. The motor is controlled with a motor servodrive that can operate either in speed or in torque modes according to the commands from the Kit Control Unit related to the AAR operating phase. The servodrive has to be able to operate in the four torque-speed quadrants and therefore must internally dissipate the regenerated energy into heat. The servodrive sends its status and control variables back to the Control Unit for system monitoring.



Figure 3. C295 with the AAR kit refueling helicopters

The 2" hose is 90 ft long when fully deployed and ends with a standard MA4 coupling and a low speed aerodynamic drogue.

Signaling lights integrated with the drogue storage tunnel will provide visual information (day and night) to the receiver A/C to ease the refueling operation.

The AAR kit system is operated by a single AAR operator from a dedicated control panel installed on the cargo bay. The operator will visually monitor the refueling operation from the control panel.

The Kit Control Unit manages the overall operation of all the AAR kit. It is connected to the control panel to receive operator commands. Indications of system status and operational data are also shown in dedicated displays at the control panel with the information sent from the Control Unit. It also provides the commands to the tank fuel control valves, ground refueling pressure control valve and to the hose drive system, and receives information from all the sensors and hose drive system. Based on all that it implements the mode control functions, fuel pressure control, hose drum control and fuel flow distribution between the fuel tanks. It also performs system monitoring and failure detection and isolation, as well as maintenance functions. The Control Unit integrates the control computer and the dedicated safety functions, including the activation of a hose jettison mechanism in case of impossibility to recover the hose.

Kit options

The kit will be offered with a base configuration and the possibility to acquire or upgrade in the future to other additional options featuring additional capabilities that improve the operational use of the kit according to the customer needs.

The basic kit configuration is powered from the A/C electrical power system. The C295 A/C is fitted with two wild frequency 115 Vac electrical generators capable of providing 26 KVA of electrical power each, more than needed for the kit operation. The pump motors and the hose drum drive system will be powered from AC power, while the computers, sensors and safety functions will be powered by A/C 28 Vdc sources (not shown in the scheme for simplicity).

The installation of the base tanker kit only requires small modifications to the base A/C, as the kit is fitted into standardized cargo pallets. The modification will consist basically on connection to the A/C electrical system for powering the pumping group, hose drum drive system and control system and the other low power consumers, as well as installation of the operator control panel. The installed A/C generation capability of the C295 widely exceeds the power requirements of the kit.

The base option is shown in part 1 of [Appendix 1](#).

A first option will be to acquire a fully autonomous refueling kit. With this option the kit will be self-powered so that no modification to the base A/C is needed. Electrical power will be drained from 270 Vdc and 28 Vdc Li-ion batteries integrated within the kit (recalled ESS subassembly, that includes also the additional safety preventions for battery integration). The batteries will be sized for ensuring the full completion of a mission with the full fuel offload capability. Power distribution is 270 VDC from the batteries to the servodrives, which operate directly with this supply. This

option allows also the recovering into the batteries of the energy regenerated by the hose drive system during operation, avoiding the need of internal power dissipation within the drum system servodrive. A more detailed analysis of this case is provided in next sections of this document. This option is shown in part 2 of [Appendix 1](#).

As another option it will be offered the possibility of interconnection of the kit fuel tanks to the A/C AAR refueling probe. Although this option will require some additional modifications to the base A/C fuel system for installation of tank interconnection lines and isolation valves, it opens the possibility of new mission types. With this option installed a C295 tanker with a refueling probe could be refueled in flight from a larger tanker (i.e. A330MRTT, A400M, KC130) and refill the kit fuel tanks in flight, and therefore operate as a short range tactical tanker acting as a link between the large tanker flying at a safe area and the receiver A/C (i.e. attack or mission helicopters) acting over the target scenario. This concept will provide enhanced availability and mission effectiveness for the receiver A/C. This option is shown in both diagrams of [Appendix 1](#).

System operation

The AAR kit will be installed within the base A/C on ground with the tanks empty of fuel. Installation will consist on loading and clamping of the fuel tanks and the ramp pallets. Then fluid interconnection of fuel tanks with pumping group and electrical interconnections between all elements. Once it is fully fitted and connected to the A/C power system, the tanks will be filled with fuel. For the autonomous kit option a recharge or replacement of batteries will be also performed on ground as part of kit preparation.

On ground the kit will allow ground refueling of ground vehicles, aircraft or other consumers through a rapid ground refueling port that provides regulated fuel pressure. For this operation A/C engines should be running, except for the autonomous kit option that could operate directly from the batteries.

For AAR operations on air, the ramp will be opened to horizontal position to start the AAR operation. Then the operator will deploy the hose to the required refueling length. Receiver A/C will approach, maneuver and connect the coupling. Once connected, it will be helped by the AAR lights to keep the refueling position while the fuel transfer takes place. When the refueling has finished, the receiver will separate until disconnection happens. After that the hose drum system will automatically recover hose length again to the refueling position or fully rewind the hose if the operator indicates that the mission has been completed. After the refueling, when the hose is recovered and the drogue stored into the tunnel, the ramp will be closed again and the A/C will continue flight in normal configuration.

The drum control system is capable of operating either in hose speed control mode or in hose tension control mode, according to the mission phase. The local control loop is implemented on a dedicated servodrive that receive mode and

performance (speed and force) commands from the Kit Control Unit through digital databuses. Peak power demands take place immediately following a contact with a receiver A/C, when a sudden hose pulling is forced to minimize hose whipping.

[Table-2](#) shows the operating condition of the hose and drogue actuation systems on each phase of the mission refueling segment.

Table-2. Operating conditions of the hose and drogue systems

	Stowed	Deploy	Standby	Contact	Disconnect	Rewind
Drum drive	OFF	Speed	Hold	Force	Hold	Speed
Drum brake	ON	OFF	ON	OFF	ON	OFF
Fuel pumps	OFF	OFF	OFF	ON/OFF	OFF	OFF

Kit performances

The kit integrates a 90 ft trailed long hose for maximum separation between tanker and receiver A/C. Its centrifugal fuel pumps allow a fuel transfer rate of 200 to 250 gpm at a pressure regulated to 50 ± 5 psi at the hose tip. A MA4 coupling is installed at the hose end for compatibility with standard receivers and excellent pressure regulation.

The hose drum system can trail and rewind the hose at a speed of 2 ft/sec, and can provide acceleration rates over 20 ft/s^2 to accept high contact rates while minimizing hose whipping.

The hose can fit a low speed drogue that will allow operations between 100 and 150 KIAS, compatible with most receiver A/C from low speed helicopters to transport A/C and UAVs.

The base kit weights 1,200 kg, with an additional 150 kg for the autonomous option due to the ESS integration. Fuel offload vs A/C range for the base kit is shown in [Figure 4](#):

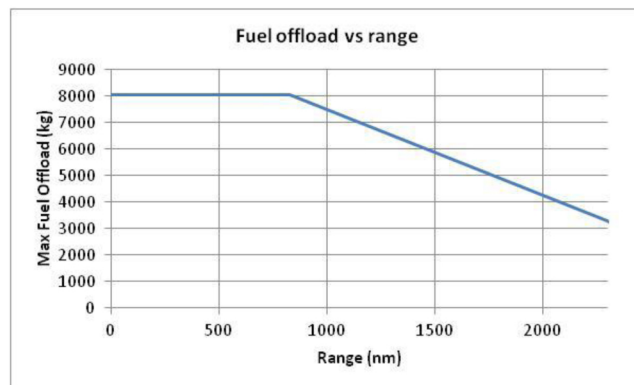


Figure 4. C295 Tanker fuel offload vs range capability with the base AAR kit installed.