

THE FIRST TRANSATLANTIC FLIGHT ON ETHANOL FUEL

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ABSTRACT

A transatlantic flight in a small single engine aircraft powered solely by ethanol was conceived as the most dramatic proof of the reliability of this fuel.

The aircraft chosen for the flight was the prototype model of the Velocity. This is a single engine, all fiberglass, canard type aircraft capable of carrying 4 people. This aircraft was chosen because of its high efficiency and the relatively large cabin space which permitted installation of additional fuel tanks.

The aircraft was fitted with the necessary equipment and the fuel system was modified. Special communication and navigation radios were added. Considerable effort was devoted to the design and the fitting of the survival equipment appropriate for the aircraft and the planned flight.

An extensive flight test program was carried out to determine engine performance as well as best altitudes and power settings to achieve maximum range.

A number of setbacks due to further necessary adjustments and modifications to some of the aircraft systems caused repeated delays in the departure date.

The flight began in Waco, Texas, in the middle part of September. Refueling stops were made in Ohio, New York and Newfoundland, where the Transatlantic flight was launched. The original plan of a non-stop crossing had to be reconsidered at the last moment. Thus, the first landfall was made in the Azores islands. The flight then proceeded to Lisbon, Portugal, and finally to Paris, France.

No engine problems were encountered during the entire flight. The cost of the fuel for the Atlantic crossing totaled \$160.

The success of the flight, and the cost and performance of the fuel when compared to aviation gasoline, demonstrated the superiority and viability of ethanol as an aviation fuel.

1. INTRODUCTION

The purpose of this flight was to demonstrate the reliability of ethanol as a fuel. Unarguably during a transatlantic flight the dependence on the fuel is absolute. The improvements developed during 1300 hours of flight test and data collection in six different

ethanol powered airplanes assured the feasibility of this undertaking.

However, many problems can occur during an extended flight other than those related to the fuel. In case of failure, ethanol would be blamed regardless of the cause. To minimize this risk, all possible precautions were taken in the choice of the airplane and the preparation for the flight.

To avoid delays involved in complying with federal regulations, an aircraft licensed in the experimental category was sought. Selection criteria involved careful consideration of the performance, efficiency and the potential capacity of the airplane to carry fuel. The aircraft chosen was the prototype of the Velocity, a canard type of composite construction with a single rear mounted engine and propeller. Because of the superior strength-to-weight ratio of the composite material and its compatibility with ethanol, this aircraft was ideally suited for this project. Additionally, the configuration of the airplane allowed installation of auxiliary tanks which increased the total range to over 2000 nautical miles, permitting a non-stop transatlantic flight.

2. MODIFICATIONS

At the beginning of May 1989, the aircraft was flown from Florida, where it was built, to Colorado where the engine was overhauled and the necessary modifications were performed.

Since alcohol operates more efficiently at higher compression, the compression ratio of the engine, a Lycoming H10-360, was raised from 7.5:1 to 10.5:1. This was accomplished by reducing the deck height and by installing high compression pistons. The cylinder walls were chrome-plated. The fuel-injection unit was modified to compensate for the lower BTU content of ethanol. Particular attention was paid to the composition of fuel-wetted parts. Ethanol reacts with certain aluminum alloys forming aluminum oxides. There was only a short fuel line in the fuel system made from aluminum, this line was alodized. The rest of the fuel lines were flexible hoses with buna-N rubber as inner core which is compatible with ethanol. No modifications were necessary to the wing fuel tanks since they are made of fiberglass. This material was extensively tested

before the purchase of the airplane by the Southwest Research Institute and found compatible with ethanol.

All cylinders were fitted with cylinder head temperature (CHT) probes and exhaust gas temperature (EGT) probes in order to monitor engine performance. A digital fuel flow meter was installed to obtain precise fuel flow information. An instrument was added to monitor the level of oil in the engine from the cockpit. Additionally, a device was designed and built to enable the pilots to add oil to the engine from the cockpit during the flight.

Preliminary test flights on ethanol were conducted in Colorado where final adjustments to the fuel delivery system were performed.

The aircraft was then flown to Wichita, Kansas, where the auxiliary fuel tanks were custom built and allodized. The back seat of the airplane was removed and anchor points constructed to allow the positioning of the tanks. Three tanks were installed bringing the total capacity of the airplane to 160 gallons. Since ethanol does not vaporize well at temperatures below 60 degrees Fahrenheit, a small 1/4 gallon auxiliary tank for gasoline was added in order to start the engine in cold weather.

A high frequency radio and its components were installed. This radio provides long range communications capability and is required for single engine transatlantic flights. Additionally, an Automatic Direction Finder (ADF), which is used for navigation was added along with a Long Range Navigation (Loran) radio.

The airplane was outfitted with the best available equipment to assure the success of the flight. In the middle of June the Velocity was ready for flight testing.

3. FLIGHT TESTING AND PREPARATION

After a few flights out of Wichita, Kansas, to test the new systems installed, the Velocity was flown to Waco, Texas where an extensive flight test and data collection program was initiated.

Different wooden propellers were tested in search of the best compromise between take-off performance and cruising efficiency. Once the ideal propeller was found, it was covered with carbon fiber to provide additional strength and protection.

Engine performances were recorded at different power settings and altitudes to determine the best range at optimum cruise configuration and at various weights of the airplane.

The hot Texas weather caused delays throughout the test flight program. The high ambient temperatures prevented proper cooling of the engine during ground operations. A scoop had to be built and appropriately placed to permit additional airflow

to the oil cooler. Scoops also had to be built into the wheelpans to prevent the brakes from overheating on the ground. Most of the components of the brake system were replaced. As a result of a serious delamination of the composite material, a large section of the right wing surface had to be rebuilt.

Additionally, difficulties associated with the navigation equipment reception were experienced. This is a problem common to airplanes built entirely of fiberglass material. Filters had to be positioned to dampen engine noises and various techniques had to be used to ensure proper reception.

As a precautionary measure, the alternator was replaced and a new fuel pump was installed. An intercom system was also added.

The survival equipment for the transatlantic flight was designed and custom built by a California based company to fit the pilots and to accommodate the limited space of the cabin. A non-stop test flight to California was then made to check all the equipment and the systems under long distance flight conditions. During the nine and one-half hours non-stop flight from Waco, Texas, to the Mojave desert in California, all the systems worked perfectly. After landing, during an inspection, a crack was detected on the engine mount. The engine had to be removed from the airplane in order for the engine mount to be repaired. All the welds on the engine mount were redone before the engine was reinstalled. A few days were lost in the operation.

While in California, the survival gear was installed and the pilots trained in its use. Particular attention was paid in the preparation of the survival equipment which included parachutes, rafts, emergency locator beacon and all the items which allow survival in case of a ditching. Heavy flotation suits and harnesses with quick connects to attach the parachute and the raft completed the equipment. The training consisted of time tests to secure the parachute and the raft to the harness, followed by egress procedures. Parachute disengagement techniques were also practiced.

The Velocity was then flown back to Waco where the final preparations were made. As a result of the climate change experienced during the stay in the California desert, the wooden propeller had developed a crack in the hub. This last minute problem was the hardest to solve because of the time factor involved. An exact copy of the damaged propeller was not available and it turned out to be very difficult to build one on such short notice. A propeller with the same specifications was finally obtained, but there was no time left at that point to collect precise data on its performance. All the delays encountered had put the flight against the late part of the weather window in the North Atlantic. Thus a decision was made to collect performance data along the route to St. Johns Newfoundland, launch site for the crossing.

4. THE FLIGHT

The initial flight plan called for a refueling stop in New York and a stop in Moncton, Canada, required by the Canadian authorities for a pre-transatlantic flight inspection. St. Johns, Newfoundland, was chosen as the take off point for the transatlantic non-stop crossing and Shannon, Ireland, as the landing site on the other side of the Atlantic. Paris was the final destination of the flight.

To avoid a persistent weather system on the East Coast, an alternate route had to be plotted for the first leg of the flight. In route to St. Johns a refueling stop was made in Columbus, Ohio. Unpredicted bad weather delayed the continuation of the flight for a few days. After resuming the flight, a landing had to be made short of New York, due again to bad weather. Ten days were spent on the ground before Long Island, New York, could be reached. The airplane was refueled by ethanol previously placed at the airport of Suffolk, on Long Island.

The data gathered in route to Suffolk showed that the new propeller was more efficient than the previous one during cruise, but unfortunately did not have the same weight lifting capability. The take off from Long Island with the airplane loaded with 140 gallons of ethanol convinced the pilots that it would not be safe to load the airplane any further. Since there was no time to build or test other propellers, the idea of a transatlantic flight with a landing at the Azores islands, in the middle of the Atlantic, was conceived to allow a lighter take off from St. Johns, Newfoundland.

Three more landings had to be made before reaching St. Johns. Once there, transportation of the ethanol to the Azores islands had to be organized. The airlines could not be used because of restrictions against the transportation of flammable materials. The only maritime shipping company regularly connecting Canada to the Azores islands had suspended its seasonal services. Other means, such as military airplanes flying from St. Johns to the U.S. Air Force base in the Azores, were explored without success. The only alternative left was the possibility of shipping the ethanol to the Azores on the small airplanes that are routinely transferred from the United States to Europe by "ferry pilots". These pilots usually go through St. Johns, Newfoundland, choosing from there the best route for the crossing. The Azores route is chosen either when the weather on the northern Atlantic is bad or when deliveries are being made in Southern Europe or Africa.

Some of the ethanol, provided by a Canadian alcohol producing company and delivered to St. Johns for the crossing, was transferred to 5 gallon tanks, ready to be loaded on available planes going to the Azores.

During the first week in St. Johns, no ferry pilots appeared and the response from the ferry companies contacted about the possibility of their helping in transporting the fuel was not very encouraging. Most of the small airplanes to be transferred overseas had auxiliary tanks installed and were already overloaded. A few bigger airplanes were scheduled to transit St. Johns, but their pilots were hesitant to carry the alcohol.

Finally, one pilot ferrying a twin engine airplane to Africa offered to transport most of the ethanol to the Azores islands. A few days later another pilot loaded more of the ethanol on his airplane.

A snowfall in St. Johns presaged the rapid deterioration of the weather. A decision was made to leave with the arrival of the next favorable weather system. Twenty gallons of fuel were still in tanks waiting to be delivered, but arrangements were made for them to be stored and sent with the next available ferry pilots.

The final preparations were conducted. All the radios and the instruments were retested. The compass was swung and all possible checks were made. The tanks were filled with ethanol at the last possible moment to avoid deformations of the fiberglass landing gear due to the heavy load.

At eight o'clock on the morning of October 21, the Velocity took off from St. Johns, Newfoundland. The take off roll was shorter than expected and the rate of climb better than anticipated given the heavy weight of the aircraft. The engine temperature remained at a safe level and everything proceeded very smoothly. All the radios and navigation equipment worked perfectly. Soon after leaving land and assuming the course at the chosen cruising altitude, the Loran indicated a tail wind of 30 knots.

After about one hour of flight scattered clouds started to appear, becoming thicker at a very fast rate. To stay clear of clouds the cruising altitude had to be repeatedly increased. Communications with the control centers were periodically established to provide all the flight information requested. This was accomplished through airlines flying in the vicinity. The aircraft was equipped with a high frequency radio for long range communications, but a decision was made prior to the departure not to install the antenna which could end up in the rear mounted propeller in case of a break with disastrous effects.

After three hours of flight the gulf stream was reached. The warmer water increased the chance of survival in case of a ditching.

After about five hours of flight the Loran being out of its range, stopped providing reliable information, but the data generated until then enabled the pilots to calculate the strength and direction of the wind. Navigation proceeded solely by dead reckoning.

After six hours of flight the needle of the ADF started to move to the right indicating the ground station on the island of Flores. The calculations of

the pilots though, placed the island of Flores one hour away and straight ahead. Accordingly, a decision was made to ignore the instrument and continue navigation by dead reckoning. At that point, a slow let down through the clouds was initiated to allow the pilots to look for the island of Flores. After about 40 minutes a shadow in the horizon was detected. That shadow turned out to be the island of Corvo located 20 Km north of Flores. The island of Flores was then easily spotted.

The flight plan had been filed for the island of Santa Maria with the island of Fajal designated as an alternate. Since no navigational instruments were effective at that point, rather than continuing in bad weather and visibility to the island of Fajal, 150 miles away, a landing in Flores was considered the safest course of action. The runway in Flores was located downwind of a mountain and ended in a cliff with high waves reaching the end of the runway. Rain, bad visibility and strong gusty winds further aggravated the unfavorable circumstances. A non conventional approach had to be made in order to safely land the airplane.

The airport that day was closed but firemen soon arrived and the airplane was secured between two fire trucks.

After seven and one-half hours of flight, the landing in Flores was a very welcome one. The most difficult part of the crossing had been completed.

Everything had worked beautifully during the flight. Due to a tail wind component of approximately 30 knots an average ground speed of 158 Knots had been maintained during that first leg. As a result only 68 gallons of fuel were consumed. The problem experienced with the ADF turned out to be due to the thunderstorms present in the area at that time. It worked fine after that instance.

The flight was resumed three days later. The island of Santa Maria, where the ethanol was to be delivered, was reached. The last 20 gallons of ethanol left in St. Johns had still not arrived. The flight to Lisbon could have been made with the already available fuel, but considering the potential difficulties in locating ethanol in Portugal, a decision was made by the pilots to wait for the extra ethanol.

During a visit to the American Consulate, who had invited the pilots to the island of Sao Miguel, an interesting discovery was made. On this island an alcohol distillery had been in operation since the previous century and was currently producing ethanol. A guided tour was given by the operators of the facility who offered to provide the ethanol necessary for the completion of the flight. Just that day though, the remaining ethanol arrived at Santa Maria.

After refueling, the airplane took off for Lisbon, Portugal. This second part of the crossing was extremely easy and pleasant. Everything worked fine all through the flight including the navigation

instruments. Most of the flight took place on top of a solid deck of clouds but Lisbon was reached in good weather. The landing was made after six and one-half hours of flight.

Unfortunately for the ethanol cause, the wrong news day for completing the transatlantic portion of the flight had been chosen. The Berlin wall came down that day, and only few journalists and one American television crew were at the airport.

Even though there was enough ethanol in the airplane to reach France, it turned out to be easier to find ethanol in Lisbon than in France. A production facility was located right outside the airport. This facility donated and delivered the ethanol to the airplane.

A persistent low pressure system forced a protracted stay in Lisbon.

During this time, a meeting was arranged with the Portuguese Parliament Representative of the Environmental Party who showed a major interest in ethanol and its potential to alleviate the heavy pollution problem of Lisbon.

The flight then continued with a landing in Bordeaux, France, where a presentation about the flight was given at the local university. A stop was also made in Tours where the city had converted two city buses to run on ethanol. City officials paid a visit to the airplane, which generated a great deal of interest.

Paris was finally reached. That day the Romanian revolution had broken into the streets. Consequently little media attention was given to the event while the local representatives of the ethanol industry showed no interest in taking advantage of the potential publicity.

The airplane was then taken to Italy. Newspapers, magazines and the three National Television channels carried the story of the flight and interviews with the pilots. A Swiss television crew filmed the airplane in Italy and produced a short documentary about ethanol and the flight.

The airplane was then shipped back to the United States where, upon its arrival, it was displayed in front of the Capitol in Washington. During this time the U.S. Congress was debating the amendments to the Clean Air Act regarding oxygenated fuels.

The National Aeronautic Association (NAA), which officially sanctions aviation records in the United States, recognized the flight with an award presented to the pilots by the president of the NAA during the display of the aircraft in Washington.

Currently the Velocity is used in an ethanol demonstration project funded by the United States Department of Energy.

5. CONCLUSIONS

In a Wall Street Journal article, a fuel specialist from one of the major oil companies expressing pessimism about the undertaking of this flight and the reliability of ethanol was reported as saying "If you stall in a car, you park it; but in a plane that's it."

The success of the transatlantic flight on ethanol was the only appropriate answer to such a statement. The complete confidence the pilots had in the fuel was justified by ten years of developments and use of ethanol as an aviation fuel. The transatlantic flight simply represented an irrefutable public demonstration of reliability.

No problems related to the fuel were encountered either during the preparation or the flight itself.

Considering the price of ethanol in the United States at the time of the flight, the cost of the ethanol for the transatlantic crossing totaled \$160. If aviation gasoline had been used, the cost would have increased to \$230. This represents an increased fuel cost of 44%. At today's prices, a 52% increase in cost would have been experienced. This figure takes into account the difference in miles per gallon between ethanol and aviation gasoline.

The use of neat ethanol as an aviation fuel represents the only application economically competitive at today's market costs. The ethanol technology in aviation is proven. Delivering superior performance at a lower cost.

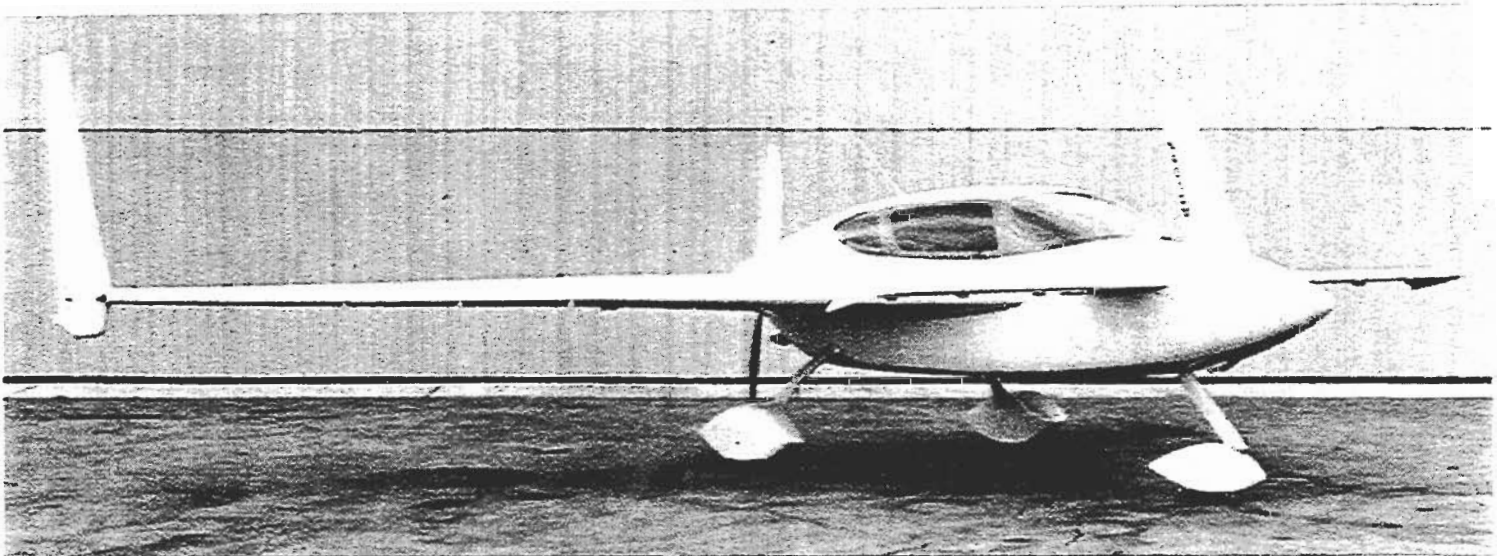
technical and economic reasons suggest an immediate wide spread adoption of this fuel.

If the other characteristics of the fuel are considered such as renewability, environmental compatibility and independence from Middle East oil supplies, the use of ethanol as an aviation fuel becomes compelling.

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In 1989 this experimental single-engine airplane flew from Waco, Texas to Paris, France on ethanol fuel to provide an irrefutable public demonstration of the reliability of alcohol as an aviation fuel.