BREEZY RLU-1

Construction and test report of the flying diaper stand D-EPCF

The headline already shows which comments you have to deal with when building a Breezy. When I did my PPL in the mid-80s, I really only wanted to fly ultralights. The open constructions of the early ultralight aircraft fascinated me with their simplicity and the original spirit of flying that they exude to this day. During the following years I learned to fly increasingly complex aircraft and only after many years as a flight instructor and freelancer in commercial aviation did I finally want to go back to the roots. I stumbled upon an old black and white photo of the first Breezy by chance on the Internet and knew immediately that I wanted one of those aircraft.

At the beginning of the 1960s, three pilots who were friends in Chicago found the dusty wings of a PA12 and decided to build a retro plane that would resemble the first flying machines in aviation. They bought a Continental C-90 and went on welding away. At the EAA meeting in Rockford at that time, the aircraft was an absolute eye-catcher and many asked for plans, which of course did not yet exist. Due to the many inquiries, they then measured the aircraft and supposedly sold around 1000 plans to date. I estimate there have been around 500 built so far, most of them in the US, of course. In Europe, as far as I know, there are currently 4 copies in Belgium, France, Switzerland and now, after 14 years of construction, one in Germany. So I got the 13 drawings and in 2005 I flew to Oshkosh where I saw a Breezy in person for the first time and was also allowed to fly it. It was even better than I imagined - I immediately thought flying a Breezy is like swimming naked! The plans are professionally drawn and contain all the information you need - except for the wings, which you have to look for yourself ... So I started by building the fuselage and looking for Piper wings.

The hull

Four years of sawing, grinding and welding. The plans call for the use of SAE 4130 steel tubing. After consulting with my engineer Ingo Luz, I decided on the German equivalent DIN 1.7734.4 and TIG welding. 1.7734 is about 15% more tensile and now three times as expensive as 4130. The material also has the advantage that it practically does not harden during welding, which means that there is no need for subsequent heat treatment. Instead of the original diameter and wall thicknesses, I chose the next larger metric dimensions. The associated weight gain was negligible, the reinforcement of the structure was enormous. The whole hull weighs about 70 kg, but it turned out to be so long that I had to chop a hole in the back wall of the garage …

I only built simple jigs, meticulously ground the tubes with a straight grinder for an optimal fit and tacked the parts with a small TIG device. Then I brought everything to Roman Weller in Schwäbisch-Hall, who finished the welds in three long sessions. Afterwards, no distortion due to the welding could be seen. Then blasted and immediately primed with highly toxic but unsurpassed zinc chromate. The top coat is PU car paint.

A video about this construction phase can be found on youtube under 'Breezy Project'

reengineering ?

A plan-compliant Breezy only rotates at a relatively high take-off speed because

1. the angle of incidence of the wings is 0 °,

2. According to Carl Unger (one of the three designers) the tail feathers are quite small, and
3. the center of gravity is well in front of the main landing gear.
4. In addition, the nose wheel is unsprung and on hard landings the first station of the fuselage compartment tends to give way ...

   I therefore made the following changes: The main landing gear was lowered by an inch and the nose wheel was provided with a rigid suspension that raises the bow by another two inches. This results in a significantly higher angle of attack during take-off. Tailfeathers are off a Piper J-3. I did without the Piper spindle trim and built a Flettner trim with an adjusting lever instead. This lever is attached to the right of the seat and is self-locking. This means that it can be operated like the elevator control of the control stick. As a result of these changes, I had to redesign the entire last station and do a stress test. In order to be able to share the flight experience with the person in the back seat, I installed the complete double control of a dismantled J-3. The wheels and brakes are from a C172, the foot brake cylinders are from a J-3. The braking effect is good despite the combination of the Scott heel brake cylinder with the disc brake cylinder. Frankenstein would have enjoyed it ...

After years of searching, I finally found my wings - they had been sleeping in their original crate in a Bundeswehr hangar since 1957 and were intended as a precautionary replacement for an L-18C, the military version of the PA-18. The original covering of course was brittle and had to be replaced by Ceconite, inside they are like new - you have to be lucky ... By installing a second wing tank, 136 liters of usable fuel are now available. From the beginning of the project it was clear to me that with a pushing propeller directly behind the wings I would have a pretty bad hand for the mandatory noise protection measurement. So I was looking for a motor that rotates significantly lower than the C-90 with at least comparable power. I quickly found out that most Breezies are equipped with an O-235, many with an O-320 or even an O-360. The higher weight of these engines didn't seem to be a problem, more power is great anyway, but of course that doesn't change the propeller speed. I didn't want a Rotax, it might have been a bit too light and I was already toying with the Australian Rotec R3600 radial engine, but on closer inspection it was ruled out because the wings would have had to be cut out too far to make room for it. Unfortunately, one hears a lot of different things about its reliability and workmanship, to put it mildly. On the Internet I came across Edy Schütz, who had just finished building his Breezy with a Mazda rotary engine from the RX-7 and thus fulfilled Switzerland's strict noise protection requirements. I found that at least once very interesting and so I flew to the Speck airfield near Zurich to look at his plane and its engine. Of course I was very skeptical with my half-knowledge about these engines, but the concept and Edy's expertise have convinced me and meanwhile I think I have learned a lot about them.

The Rotary engine? That's yesterday's news !!
The Mazda 13B rotary engine has been used with great success in the car racing scene and in experimental aircraft since its appearance in the USA, where the RX-7 was introduced as a Porsche killer in 1978. Mazda built around one million (!) of these engines. It is a two-chamber Wankel with three essential parts that move to generate power, namely the crankshaft and the two rotors. The crankshaft is actually not a crankshaft at all, because there are no connecting rods or crank pins - rather, it converts the circular movement of the rotors into an equally circular movement of the shaft. It has a slightly

eccentric shape and never (!) did one fail. The rotors drive the eccentric shaft (as it is correctly called) directly without a connecting rod and rotate three times as slowly as the shaft. Even at speeds of up to 8000 rpm, the speed of the apex seals is not higher than the piston speed of corresponding gasoline engines. The 13B rotary engine is a 4-stroke engine without valves and camshaft, slot-controlled through the side inlets and the rotating rotors.

Small remark off topic: An RV with Mazda rotary engine recently set the time to climb world record for piston aircraft - 10,000 feet in 100 seconds ('rotary time to climb world record' on youtube)

What about the legendary oil consumption?
The engine oil, which only serves to lubricate the eccentric shaft and dissipates a large part of the heat, practically does not come into contact with the combustion residues. Constructive disadvantage: oil has to be injected into the combustion chamber to lubricate the seals. The 'metering oil pump', which takes over this task depending on the engine speed, is used for this. In order to exceed the reliability of this system, the racing drivers and homebuilders in the USA came up with the following: The pump is removed without replacement and two-stroke oil is added to the fuel instead. This oil is of course better suited for this purpose than the 20W-50 from the oil pan, because it burns much cleaner. A mixture of 1: 140 is sufficient for operation, which corresponds to the amount that the pump normally injects. The whole setup is incredibly simple and robust compared to piston engines. Elaborate? Complicated? A Lycoming needs an oil check before every long flight, a 13B when refueling - at least that's acceptable to me.

Broken seals?
It is true that NSU's Ro80 rotary engines had major problems with it. The Japanese had of course recognized the problem and looked for other materials. Seals made of specially developed alloys or ceramics have been around for a long time, which can withstand the toughest conditions.

Doesn't he drink a lot?
It is true that the rotary engines used in automobile construction and of course the Mazda 13B are very thirsty. Compared to gasoline engines, the specific fuel consumption is up to 30% higher. This is largely due to the imperfect combustion chamber geometry of the Wankel, which is only as efficient as comparable gasoline engines at a relatively high engine speed / power output. And so we come to the crux of the matter: As we all know, typical car engines on the road mostly work at 15-30% power, while aircraft engines are mostly operated at 60-80% power-setting.
The Mazda 13B is a very reliable engine, provided it is always supplied with sufficient cooling and lubrication. It is not a problem to permanently demand 70% power from it, because it is very robustly built and can withstand high continuous speeds without any restrictions. (see above: average piston speed, no valves, no camshaft). 13Bs have already flown for 2000 hours with 6000-7000rpm without complaint.
Because the combustion chamber geometry of the Wankel engines has a high degree of efficiency at this speed, they do not consume more than comparable older aircraft engines.
My 13B weighs firewall forward including coolant and oil about the same as an O-360, has about 180 hp and consumes about 35 liters per hour in my plane (which is an aerodynamic disaster) at the moment ... . MOGAS!

Failure mode
Just like probably most of us, I have so far spent almost all of my flying hours behind or between the commercially available Lycoming or Continental aircraft engines. I enjoyed every moment of it knowing that I was relying on a proven and reliable engine. It's nice that we have these engines,

even if they are perhaps no longer up-to-date. I really like these engines! As for the reliability of a Wankel in flight operations, I cannot say anything, because there are simply no statistics on the few hundred flying 13Bs. Of course, I have read a lot about it on the Internet and would at least like to describe my personal impression.
Basic information about flying car engines: Automobile engines usually come from mass production and are only very reliable if you don't change anything and leave them in the car where they actually belong. When used in an airplane, the conditions change, some of which are not critical, but unfortunately others are . Usually little or nothing is changed on the 'long block' of a car engine, but with the aggregates it looks completely different, and these aggregates like injection, (double) ignition, carburettor, carb heat, cooling and above all reduction gears are the parts that are changed and that can lead to problems when building your own. I think one can say that conventional aircraft engines have failed more than once because of burnt valves, torn off connecting rods or broken crankshafts and camshafts. These scenarios immediately lead to engine failure.
What if an engine doesn't have all of that?
Experience with the 13B in racing has shown that the engine usually continues to run for 20-30 minutes with slightly reduced power after it has lost all of its coolant and / or lubricant. This is understandable if you look at the basic structure. Mind you, I don't want to gloss over anything or demonize anything else, just share my thoughts. I'm just at the beginning of testing myself and hope that everything continues to go well ... I had my engine block built by Bruce Turrentine, a well-known rotary supplier in American racing. I built the entire periphery like carb-setup, double ignition, cooling, exhaust system, etc. myself. And these are exactly the components that I have to pay particular attention to for the reasons mentioned above.

Ignition and carburation
The 13B of my series has electronic ignition and injection in the car, the direct predecessor had transistor ignition and carburetor. The electronic engine control unit of the RX-7 is considered to be robust and reliable, but it has two essential properties that make sense in a car but make no sense in an airplane. 1. It is not redundant 2. It stops the engine when it overheats.

Double ignition
Modern rotary engines like the 13B have two spark plugs per rotor housing (trochoid) for better combustion of the mixture in the flat combustion chamber. The first spark plug (leading plug) ignites at full load about 20 ° before top dead center, the second spark plug (trailing plug) at about 10° before TDC. Because of the two spark plugs, it is quite easy to split them up between two ignition systems and thus obtain the desired redundancy. The loss of the leading ignition leads to a loss of power of around 15%, the loss of power if the trailing plugs fail is very small and can only be detected on the dynometer. Fortunately, the shaft of the crank angle sensor is identical to the distributor of the previous model. I bought such an ignition distributor second-hand, overhauled it according to the manual and modified it in such a way that the respective leading plugs of the two trochoid no longer run over the distributor finger, but each plug is individually controlled with its own ignition coil. The trailing plugs run via the distributor finger as before, but have their own power supply via the additional 'right' on-board electric system, consisting of an additional battery and a second alternator from a forklift. This second alternator is located on the engine where the air conditioning compressor was previously in the car. Additional advantage: the water pump is now driven by two V-belts instead of one. The described conversion of the ignition system comes from the American racing scene and is called DLIDFIS (dual leading ignitor direct fire ignition system)

Carburator
A redundant electronic injection would certainly be possible, but I'm not a development company and prefer the old-school variant with a carburetor ... As already mentioned, the 13B is very popular on the racetracks in the USA and so there is a well-stocked accessory market. Conversions to Weber racing carburettors are very popular - I have always found it very nice, not least because these carburettors can be optimally adapted to any engine, provided you have understood what all the screws and nozzles are good for ...
So I bought four things first:
1. A custom intake manifold for Weber dcoe

2. A 45 dcoe Weber twin carburetor
3. A detailed manual for installing and tuning a Weber racing carburetor
4. Another manual on the same subject ...

It took me weeks to understand everything and another months until the engine ran smoothly. When tuning the carburetor, I used a wideband lambda probe in addition to the EGT sensors. The search for the cause of a stumbling engine run at around 3000rpm cost me many weeks, because I was looking for the fault in the jetting of the carburetor. Finally it turned out that the pickup coils for the GM ignition modules, which I had installed, had to be polarized the other way around in the series of my ignition distributor in order to function properly ... In the meantime, the engine starts better than my Daimler in any weather, regardless whether cold or warm. It now runs silky smooth and transitions perfectly over all three carburetor circuits in the entire speed range. On top of the carb heat box is a large K&N air filter. My examiner Werner Koch said I should build a different cover to keep out any rainwater flowing in from the side. After two weeks of unsuccessful thinking, the problem was solved with a courageous grip in the kitchen cupboard – SS frying pan lid.

cooling
A rotary engine emits 30% of its heat through the oil and 70% through the coolant. The original oil cooler of the RX-7 is very well built and big enough - much bigger than e.g. that of an O-360. As a radiator, I wanted to have a nice, shiny aluminum one that is sufficiently sized and fits exactly into the fuselage compartment under the engine. After some research I found an aftermarket cooler from Mishimoto, which is actually for a Mitsubishi Eclipse. Of course, the connections had to be moved and brackets welded on. I also installed a SPAL fan, which I never really needed until now, except for the engine test runs in the hot summer.

Exhaust system
The exhaust from a 13B is like the breath of a fire-breathing dragon ... With the lack of valves, the engine is really TERRIBLY loud and the exhaust gases can reach temperatures of up to 1800 ° F / 980 ° C. The target EGT in cruise is 1650 ° F. Paul Lamar, an elderly American rotary guru whom I met at AERO, recommended to use a pre-silencer and a muffler. The material had to be highly heat-resistant, so apart from the pricy and difficult-to-process Inconel, only stainless steel was considered. The presilencer is actually just an empty Can, crossed from front to back by a pipe with two tasks:
1. To cool the front silencer a bit from the inside
2. to use the heated cooling air to preheat the carburetor.

The pipes, clamps etc. are made of SAE321, the muffler is a Hushpower Flowmaster also made of SAE321, all from a hot rod shop in Chicago. I imagined reaching a gentle, pleasant tone - it worked. I have no doubt about getting the increased noise certification in connection with the propeller.

Reduction gear
In order to get closer to the goal of lower tipspeed and thus less noise, you obviously need a 'gearbox'. Tracy Crook, a Florida Wankel pioneer, designed a reduction gear for the 13B many years ago and has operated it successfully in his RV for as many years. I don't know how many units he produced and sold, but there are certainly several dozen, because you can always find them mentioned positively in the relevant forums. It is directly bolted to the engine and contains a planetary gear set from a GM automatic transmission, designed for up to 300hs. It can be used both as a tractor and as a pusher and is connected to the engine's oil circuit. My gearbox has a reduction of 2.85: 1. The cruising speed at 65kt is 5200rpm, the propeller turns at 1825rpm. The takeoff speed is 6000 / 2100rpm. Due to the flat combustion chamber geometry of the Wankel, the power strokes overlap very smoothly, similar to a 6-cylinder four-stroke engine as can also be seen on the diagram. There are no peak loads in the power cycles, which usually occur in Otto engines and make the use of gear reduction gears more difficult.

propeller
The choice of propeller was relatively easy. From the various American forums I knew: it had to be a Cattoprop. Craig Catto is my age (60) and has only built propellers his whole life. I haven't found a single negative comment on his propellers on the net. His propellers can often be found at the Reno air races. A adjustable pitch propeller was out of the question anyway, because the different speeds of a Breezy that you have to know as a pilot are: 1. Vr 60 mph 2. Vx 60mph 3. Vy 60mph 4. Vref 60mph 5. etc ..... Craig had already built several propellers for engine-gearbox combinations like mine. I gave him the above speeds and my desired rpms. Although he had a delivery time of 18 months at that time, he sent me the gem after 6 weeks, probably because I told him that I would be exhibiting my project with his propeller at the AERO at the german EAA booth. He then came by himself, which made me very happy. The propeller shows its use immediately. It is a three-bladed 68 "diameter and 60" pitch. The blades are as wide as shoeboxes and the sound is incredibly smooth and bubbling at my low speeds.

Electrics
The aircraft has two separate electrical systems due to the double ignition. The (main) switches, fuses, circuit breakers and instruments are clearly separated from each other in the panel on the left and right side. If an alternator fails, you can still charge both batteries with the remaining alternator via a crossfeed switch. All electrical consumers are sensibly distributed between the two electrical systems, e.g. fuel pump1 left, fuelpump2 right, radio left, transponder right, landing light left, taxilight right, beacon left, strobe right, etc. Both alternators have a combined output of 115 amps. This means that I have enough power not only for avionics, beacon, strobe, Harley-Davidson landing lights and a large taxilight, but I can also easily operate electrically heated clothing on both seats.

Cockpit and instruments
A Breezy is usually completely naked, you sit completely unprotected in the open air. In principle, that's very nice, but other things were more important to me. It was clear to me that my engine was significantly heavier than a C90. I needed a counterweight in the bow so as not to spoil my W&B. E.g. the batteries also started their journey from the very back to the very front after the weighing ... I've also always enjoyed flying long distances, and my Breezy shouldn't miss anything in terms of instrumentation. The panel is of course total overkill but still much more helpful than lead. I had the panel done for me by schaeffer-ag.de. You can download a simple software and even I managed to enter everything exactly as I wanted. Took some weeks and was a lot of fun – afterwards press enter and email away, 10 days later you can install it. The instrumentation consists mainly of the round gauges that I have always liked, only the compass had to be on top of the front cowling to protect it from interference. It is a Plastimo boat compass that could be compensated very well. Of course, all instruments are lighted ... I connected a small bluetooth receiver to the radio - after all, I'm a musician ...

An engine monitor developed by Tracy Crook is used for comprehensive engine monitoring and can display almost everything that is conceivable. All recorded motor data from the last 20 minutes can be read out via an inserted USB stick, which is very practical for testing. I installed sensors for: Oil temperature, oil pressure, water temperature, water pressure, fuel flow, 2xEGT, lambda probe, outside temperature, carburetor intake temperature, pitot and static etc. The device shows, among other things, fuel burn, miles per gallon, pressure height, IAS, engine running time (hobbs), oil change intervals, on-board voltage and much more - only a clock is missing ...

Nose art
Finally I widened the fuselage and adjusted everything to my body size. My friend Klaus Hoppe, who did all the painting work, is an advertising technician by trade. In addition, he is a gifted car mechanic and restaurateur. He built a beautiful hood made of glass fiber for me and provided it with the decorations I wanted. I wanted the lettering “Like Coca-Cola font and somehow glittering like mica on bumper cars, like gold or something - can you do that?” His answer: “So you want gold or not?” - “Have You got gold?? ”-“ Of course! ”He still had a residue of 24K gold dust from a previous order ... .. The girl was scanned from a poster and the clouds behind it were painted with airbrush. Afterwards, clear laquer over it – it is glossy and smooth like a billiard ball.

Permit to maiden fly ...
The german EAA recommended Mr. Ingo Luz as the engineer and Mr. Werner Koch as the inspector for my project. With both of them there was a trusting cooperation from the beginning that gave me a lot of pleasure. My project is of course a real exotic one and the result looks like the main attraction of a merrygoaround. So I'm all the more grateful for having been taken seriously at all ...
It would certainly have been easier to build a kit airplane, because most of these wonderful kits that are available today are now well documented and make the certification process much easier. The options for changing a plans built experimental are extremely tempting and a curse and a blessing at the same time ... Fortunately, Edy Schütz made the structural calculations of his Breezy available to me, which were already recognized in Switzerland and also accepted by the FAA. He had calculated the entire plane for a maximum take-off weight of 794 kg in ANSYS. The empty weight is 520kg, these values correspond to a comparably equipped Supercub without windows, roof and fabric... The complete printout of the structure calculation is as thick as a telephone directory and I don't understand a single line of it ... The luggage area behind the back seat is designed for 40kg and offers enough space for a complete set of camping gear for two people. To the left and right of it, external load carriers are also welded on just in case ...

As part of the second official expertise, a reinforcement of the front seat and its backrest was required due to the attachment of the harness, which could be carried out afterwards relatively easily. The use of the Wankel engine was not made difficult by any additional requirements. During the entire construction period, Ingo Luz and Mr. Koch visited again and again to assess the construction progress and to discuss the next steps. I estimate that in the past 14 years I've built about 3000 hours and researched about twice as much on the net. In the summer of 2017 I had already brought the plane to Mengen to start the ground testing. During my numerous visits to Oshkosh, I got to know some Breezy pilots who shared their experiences with me and helped me a lot. But the most important contact was my friend Arnold Zimmermann, who first invited me to OSH in 2005 to show me his Breezy. Arnie has given 12,000 (!) rides with his N3AZ over the years without ever charging anything. A close friendship developed and I was always allowed to be a guest in his house. Arnie let me fly his Breezy as much as I wanted, so I was able to gain valuable experience before my first flight. As expected, the plane is very docile, but you really have to get used to the missing horizon reference before you feel reasonably safe. You sit right in the front and the rest of the plane is behind you - but you quickly get a feel for it by trying to feel the seat turning under your bum ;-). Due to the open fuselage, the plane is almost insensitive to cross winds, but it always stumbles a bit like a dead leaf in the wind. Yawing around the vertical axis stabilizes by itself from about 10 ° left and right, when the vertical stabilizer grips better.

I knew all this and since I was probably the pilot in Germany with the most Breezy experience, the FAA entrusted me with the supervision of the test flights. The first attempts at taxiing were completely unspectacular until the moment when she suddenly took off unexpectedly in autumn 2019 ... But after about 150 meters I wriggled her down again and was overjoyed to have left the ground under me for the first time. Then summer 2020 came and I was on part-time work, so I had all the time in the world to prepare for my first flight. I always wanted to do the first flight all by myself without ana audience. On June 30th, under the best conditions, I was at the field early in the morning, only Dirk Lohmann on the tower and Alois with a student pilot in his gyro in the traffic pattern. I did two short hops on the runway first. Then one last runup and full throttle. The first 20 seconds were the pure adrenaline shower, but after a short instrument check to make sure that all temperatures and pressures were ok, it was just nice and relaxed. I only flew one traffic pattern and then taxied back to the hangar. Actually, I expected to be very excited after this moment, but I was totally calm and almost emotionless as if it had been routine. I think I was well prepared…. In the evening, of course, I partied like a seventeen year old...

The following 22 short test flights to date have led to the following findings: The trim tab was just big enough to trim the required speeds from Vs to Va. It has been replaced by a larger one and is now perfectly dimensioned. The target cruising speed could not be maintained, the plane just didn't want to keep the altitude as stable as I expected and desired. A really stabilized cruise only

occurred at around 70kt. The still immense drag of this iron monster even at slow speeds and the proximity to the back of the power curve were in my opinion the cause. I installed a set of 'Micro Vortex Generators' that I bought in OSH years ago. These things are really magical - it now flies incredibly stable - on my last flight I was able to trim out 50 kt without any problems and now have significantly lower fuel consumption per hour. If I want to I can of course still fly 80kt, but that's not that much fun. I have not yet flown the entire envelope, but the stall speed is now probably around 40kt. The fine-tuning of the carburetor is also still in progress. I'm still flying a little rich and slowly feel my way up to the optimal engine temperatures by carefully changing the jets. The carburetor has no manual mixture adjustment, but I don't plan to fly higher than 6000 ft on a regular basis. The rotary engine can withstand very large differences in density . David Atkins from the USA once had an RV with the same engine and carburetor and could climb to 12000ft without manual mixture adjust. Short videos of my test flights can be found on youtube under 'Rotary Breezy'

Conclusion

The construction of this flying machine was the most creative time of my life and during this time I not only learned a lot but also met many interesting people and made good friends. People on the airfield and on the ground always wave at me. - Why ?

Because Breezy flying is like swimming naked ...