VW Bus

History & Technical Data

Caltech

EAS Division of Engineering and Applied Science

SAE SOUTHERN CALIFORNIA
An SAE International Section

history of the VW Bus

In a city choked by a thick blanket of toxic haze, entire buildings are swallowed by a low-hung putrid fog. Their architectural details are obscured, leaving silhouettes – a mere impression of a cityscape. A sepia hue is imposed by the sun's light, filtered from above. The acrid fog, rich in ozone, draws tears as lungs burn. On one such day in late 1965, Wally Rippel, a Caltech sophomore, attended a history class that discussed the roles of federal and state governments post-Civil War. Due to the foul air, the discussion shifted towards what these governmental bodies could do to mitigate smog.

Throughout the discussion, the pronoun "they" was used excessively, referring variously to the federal government, the state of California, and car manufacturers as responsible parties. Eventually, a classmate's remark, "We are they," sparked a pivotal moment of inspiration for Rippel. He asked himself: "What should I be doing about smog?"

Driven by this question, Rippel sought to learn about smog. Thanks to a lecture given by Caltech professor Arie Haagen-Smit, Rippel gained some quick insights, including the main takeaway that approximately 80% of LA's smog was due to automobiles. Based mainly on that information, Rippel concluded that the internal combustion engine should be replaced. His first thought, inspired by the Gemini space capsule, was to look at hydrogen fuel cells, where water was the only emission product.

Discussions with a JPL energy system engineer revealed the prohibitive costs, limited lifespan, and inadequate power of contemporary fuel cells. Rippel then turned to the possibility of battery electric vehicles (EVs). He calculated that if every vehicle in the US were electric, electricity generation would have to increase by less than 25%. Thus, even if power plants were fully responsible for the remaining 20% of air pollution, the net result would be a 75% reduction in air pollution. Battery energy storage, however, was a problem. Only one battery existed which had acceptable economics: the lead-acid battery. Despite economic viability, the stark challenge remained: a single gallon of gasoline stored as much energy as one thousand kilograms of lead-acid batteries.

Rippel then thought about batteries from a theoretical point of view and concluded that it should be possible to greatly improve battery-specific energy. If so, that could enable electric cars to ultimately replace gas cars. He met with several chemistry and physics faculty in hopes that Caltech might be interested in tackling the "battery problem." Interest was lacking; battery technology was considered "messy" and "unscientific."

Rippel pressed on and decided to convert a gas vehicle to electric drive, which could then serve as a catalyst to motivate battery interest at Caltech. Design plans were formulated, a summer job was obtained for "seed funds," and a 1959 VW bus was purchased along with multiple electrical and electronic components. A set of 20 six-volt batteries and a series-wound traction motor were generously donated by a Michigan firm – Electric Fuel Propulsion.

Rippel carried out the needed machine work before, between, and after classes. He also designed and fabricated a 30 kW onboard charger. It was the first time on record that an EV would be equipped with fast onboard charging. By late 1967, he had an EV with a sixty-mile range, a top speed of about 55 mph, and a one-hour fast charge capability. He drove the vehicle daily between his parents' home in Hollywood and Caltech.

Despite media and campus interest in Rippel's vehicle, battery research did not gain popularity at Caltech. Undeterred, Rippel came up with the "crazy idea" of a cross-country EV race between Caltech and MIT as a means of motivating battery interest. He shared his race idea with Caltech's dean of engineering, Dr. Fred Lindvall. The goal was to have the dean write a letter to MIT's engineering dean announcing the race idea. Dean Lindvall questioned the idea, but after some prodding, gave in and agreed to write a letter to MIT's Dean Brown. Dean Brown also thought the idea was foolish – the word "stupid" was used. The race idea would have likely died had Dean Brown not made the "mistake" of expressing his negativity in the presence of some undergrads. The students concluded that if the Dean thought the idea "stupid," then it must be "cool."

A student group was formed, and plans were assembled to convert a car and "teach Caltech an engineering lesson." Senior Leon Loeb became the designated leader. Under his leadership, the MIT group obtained a donated 1968 Corvair from GM and a 2000-pound pack of nickel-cadmium batteries from Gulton Industries (valued at $20,000). Development was started on a brushless motor drive featuring a transistorized inverter and an axial gap motor (part of a grad student's PhD thesis). A 100 kW three-phase thyristor battery charger was designed and fabricated by MIT junior Richard Van Brunt, and a 12-volt, 500 W auxiliary power converter was designed and built by senior Sumner Brown.

Finally, after two iterations, race rules were agreed upon between Rippel and Loeb. With the help of Electric Fuel Propulsion and electric utilities, some 55 recharge points were set up across the country for use by both sides. The race was to commence on August 26, 1968, at noon MIT time (9:00 AM Caltech time). MIT's starting line was Caltech's finish line and vice versa. Driving and charging would be 24/7 for both sides with no designated rest times. The central goal was to test both propulsion and battery charging under worst-case conditions. Towing would be penalized at five minutes per mile, while the use of an emergency generator would add a thirty-minute penalty for each use.

The pieces were now in place for a historical event. Never before had any vehicle crossed the American continent under battery power. Now, two battery-powered vehicles were poised to become the first. Adventure and inspiration lay ahead for both teams. Also lying ahead would be technical problems that neither side could have imagined.

On race day, network and local camera crews tightly surrounded the Caltech vehicle during the final countdown. These, in turn, were surrounded by a throng of students, faculty and onlookers – many expecting to hear the cranking sound of an engine start. None came.

At “t minus zero,” the VW suddenly came alive and briskly accelerated north on Creasy Street, surprising both the media and onlookers.

Before MIT reached their first recharge point, their Ni-Cad battery overheated and the car had to be towed. Later, the same day, the problem was solved by applying some 200 pounds of ice to the battery. Thereafter, ice was applied during each recharge. MIT also had repeated problems with their auxiliary power converter and three-phase charger.

On the Caltech side, the first major problem occurred about ten miles east of Seligman, AZ, when the motor armature blew apart due to an unwise downshift. A massive logistics effort from Caltech’s five-member team enabled the acquisition of a new motor, its air freight and road transport, mechanical modification, and finally, installation in the bus. In all, the total downtime was only twenty-three and a half hours! Caltech’s next wake-up call came before dawn in Amarillo, TX, at the main post office when recharge was attempted. Misconnection of the recharge lines led to instant shorting of three charger diodes, which then resulted in a massive current surge and an electrical arc which lit up the early darkness. The diodes were replaced and no further problems of note were encountered for the remainder of the race.

On day 6, MIT reached the charge point at Amboy, California. With the Caltech campus just 225 miles away, and the Caltech vehicle having more than a thousand miles remaining, MIT could taste victory. Shortly after starting recharge, diodes in the MIT charger failed and were replaced. When charging was again attempted, a catastrophic failure occurred – complete with a loud bang and smoke. Richard Van Brunt, designer of the charger, concluded that the problem was likely due to a voltage spike caused by the recharge station. The decision was made to tow to the next charge station at Newberry. Unfortunately, the car was left in first gear, and towing speeds surpassed posted limits. At Newberry, MIT discovered that both the motor and transmission had been destroyed during the tow. Only one option remained: the vehicle had to be towed 165 miles to the Caltech finish line.

A day and a half later, at about 7:30 AM, Caltech crossed the finish line at MIT. When penalties were computed by the official race observer, Machine Design Magazine, MIT still ended up winning the race – by some two and a half hours. With this unwelcome news, the Caltech team got some much-needed sleep at an MIT dorm. Late that afternoon, when they awoke, they learned that Machine Design had made a math error. In fact, Caltech had won by half an hour!

The “Great Electric Car Race” was now history. For the first time, a vehicle had crossed the continent under battery power alone, pointing to the future world of EVs we see today.

technical data:

The converted VW bus, which won the "Great Electric Car Race" between Caltech and MIT in 1968, was a converted 1959 VW Microbus (Deluxe, 21 windows, and sunroof) powered by a custom electric drive developed by Wally Rippel. The original four-speed transmission and clutch were retained. The electric drive consisted of twenty six-volt lead-acid batteries, a contactor-diode controller, a series wound traction motor, a thyristor (SCR) charger, and a DC to DC converter for lighting and auxiliary power. The contactor-diode controller served as a backup, which was used when problems with a solid-state system remained unsolved.

Battery

Type	Lead Acid (designed and manufactured by Electric Fuel Fuel Propulsion
Modules	20 six-volt, flooded (vent caps)
System voltage	120 V (20 modules in series)
Capacity (2 hr. rate)	215 Ah
Max charge rate	200 A
Cooling	Forced air
Weight	43 kg/module (860 kg/battery pack)

Motor

Type	DC brushed, totally enclosed
Manufacturer/model	Baker, Model 1265
Number of poles	4
Rated voltage	120 VDC
Continuous power	15 kW
Peak power	30 kW
Max.rpm (centrifugal limit)	4000 rpm
Weight	87 kg

Controller

Type	Contactor/diode (custom)
Number of steps	4
Regenerative braking	Current applied to field winding from 6 V system

Charger

Type	Three phase, hybrid SCR bridge plus custom air core inductor
Input voltage	208 or 230 VAC
Power rating (cont)	30 kW (200 ADC @ 150 VDC)
Cooling	Forced air
Weight	23 kg (approx.)

Auxiliary Power Syst.

Type	DC to DC converter, transformer isolated (custom)
Input circuit	Four 2N3055 transistor H bridge inverters, 8 kHz
Output circuit	Center-tap-rectifier, ballast resistor, and 6-volt, 215 Ah battery
Control	Hysteresis On/off, based on battery voltage
Rated Output current	50 ADC

Instrument Panel

Display	Battery volts, Motor volts, Battery curr., Motor curr., Recharge curr.
Controls	Power on/off, Regen. on/off, Charger on/off, Recharge current

Vehicle Performance

Top speed	88 km/h (55 mph)
Zero to 30 mph time	10 sec
Range (at 55 mph)	96 km (60 miles)
Recharge time (208 V)	45 minutes (80%)
Energy efficiency	0.17 kWh/km (0.28 kWh/mi @ 88 km/h)