THE
CLEAN AIR
CAR RACE
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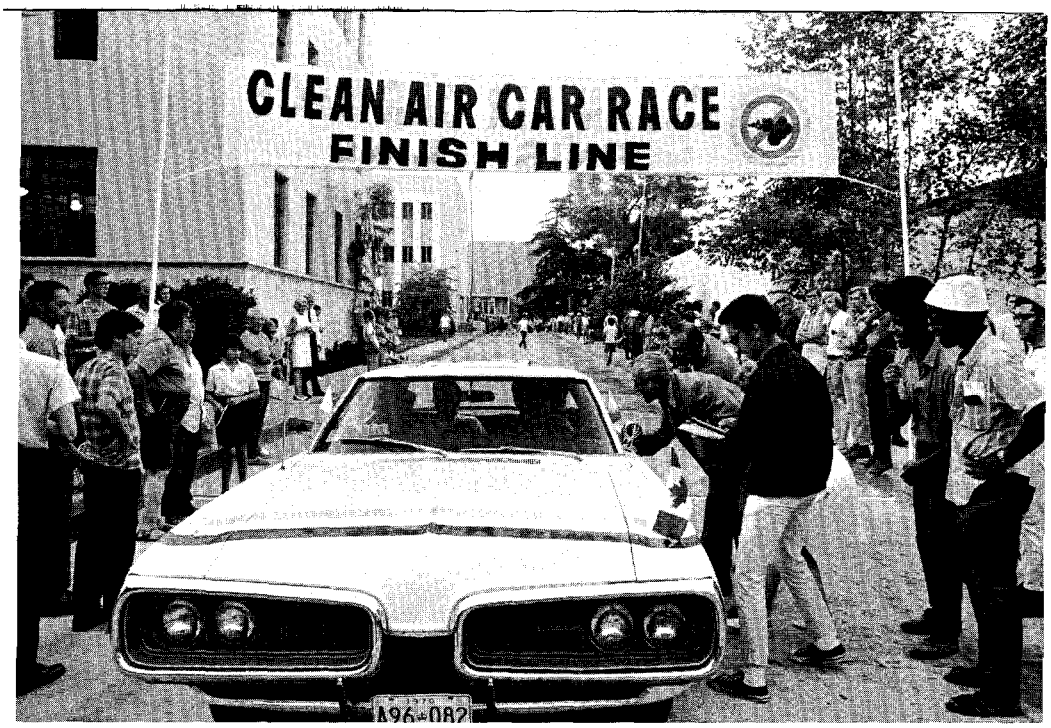


What Went On on the Road

by Mike Lineberry

The concept of a cross-country race to emphasize the possibilities of low-polluting automobiles began rather humbly last October with a phone call from Dr. Richard Thornton at MIT to Dr. Jerome Shapiro at Caltech. The next thing we knew, we had to set up a joint Caltech-MIT committee to handle the growing organizational work—and we had 44 entries from schools all across the country.

The Caltech group started out in October with about 20 interested students and faculty. We first had to agree on a propulsion scheme. (The development time—together with our goal of an economical, safe, and currently available system—made the only consistent choice of power plant an internal combustion engine.) We had then to select the fuel, but that decision was delayed for several months. I guess the excitement of possibly building a fantastic steam or hybrid-electric car was all that held some in the group, for soon we had only three or four active people.

Four months passed, and very little was accomplished. In February we finally got permission to ask for funds from trustees and friends of the Institute. Until then we had the feeling that our only friends were Jim Black and the Alumni Association, who had backed us financially and spiritually when it was most needed.

In March things began moving. Many contributions from trustees were received, and offers of technical support and equipment came in. Interest picked up quickly, and the ranks swelled again to something over a dozen people.

In April we decided to use compressed natural gas as the fuel for our race vehicles. Then began a pleasant and fruitful association with Pacific Lighting Corporation (parent company of the gas companies). Eventually they supplied us with refueling facilities, conversion kits, cash, and a second race vehicle.

During the summer months things went smoothly. A test engine facility was established for component and system tests. The race vehicles (a 1970 American Motors Hornet and a 1970 Ford Ranchero) were modified and refueling trucks were obtained. We refueled from storage bottles on board these 20,000-lb.-capacity trucks. Also, each truck was equipped with a compressor to re-pressurize the banks of bottles.

The race team consisted of undergraduates Jim Henry, Greg Kandel, Alan Coltri, and Joe Lyvers; graduates Dave Viano and myself; Mahlon Easterling, visiting professor of applied science; Laura Easterling, a freshman at Stanford; and Duane Higa, Ken Abernathy, and Jim Hiers of Pacific Lighting.

We departed for Boston on August 5 on a planned ten-day public relations-practice run. Our two race vehicles, two refueling trucks, and 24-foot mobile home (for rest and recreation) must have been a sobering sight to some sleepy early morning commuters.

Our first day took us 541 miles to Tucson, Arizona. In order to check out the whole team, we changed assignments about every 100 miles. Everyone performed well, especially on the citizen band radio units. I think all of us rather quickly became enamored of our own voices.

The excitement and gaiety that surrounded our departure that morning had, by late afternoon, evolved into fatigue and restlessness. That quickly subsided when we reached the motel in Tucson and the team took over the pool. Later that evening Dave, Jim, and Greg flew back to Caltech to continue work. I flew on for a two-day public relations tour in the Midwest, and the rest of the team prepared for the next day's journey to El Paso. We would all meet again in Boston on August 16.

The next two days were most gratifying to me. Together with public relations men from Pacific Lighting, I visited Dallas and Tulsa. The tremendous coverage of radio, television, and newspapers pointed out the great interest that exists in the Midwest in air pollution abatement. It puzzled us how people in the area with the least pollution problem could show the greatest concern. This was demonstrated again when we were westbound during the race.

The race team proceeded steadily across country. On the next to last day on the road, the team spent five hours getting the refueling trucks into Canada. The Canadians gave the team some interesting alternatives—like paying a duty of one-third the cargo and vehicle value to import the whole works. That would have been a cool $20,000 or so. They finally let the team buy Ontario license plates and enter Canada.

On Sunday, August 16, the four of us

Clean Air cars cluster in Pasadena's City Hall plaza.

who were back at Caltech flew to Boston to meet the rest of the team, which had arrived two days before. We carried a small catalytic reactor that we had tested only two days before. This was to be installed on the Hornet to reduce carbon monoxide and hydrocarbons, and in testing it had done a good job. Catalytic oxidation of our unburned hydrocarbons, methane and ethane, is not an easy task, and this reactor was a special one loaned to us by Englehard Industries.

Coltri met us at the airport, and we went directly to MIT for the first meeting of entrants with the race committee. Forty-four teams were represented, and most came to this meeting feeling rather hostile about major rule changes that had been made. Not much was accomplished in the ensuing three hours, but it became apparent the committee was willing to consider various proposals for changes. That seemed to cool the tempers somewhat.

The race was to be scored by an emissions score, multiplying the sum of a race (or more correctly, a rally) score, a performance score, and a fuel economy score. The emissions factor would be determined by cold-start, seven-mode cycle emissions tests in Detroit, where carbon monoxides, hydrocarbons, and oxides of nitrogen concentrations would be measured, and then multiplied by a measured exhaust volume. The result is contaminants in grams per mile. Emissions tests in Boston and Pasadena would also be done, but no exhaust volume could be measured at either of those places, so the conversion to contaminants per mile is a shaky one based on vehicle weight. The intent was to let the Boston and Pasadena tests indicate any system degradation. Race score would depend on points gained on each leg of the seven-day return trip, with a possible maximum of 1,000. Performance tests, each carrying a 250-point maximum, consisted of acceleration, braking, noise level, and a slalom-course time event. Fuel economy was a 1,000-point test that checked thermal efficiency from Ann Arbor to Oklahoma City.

Our emissions tests were scheduled for Tuesday, August 18. We therefore spent most of Monday checking our vehicles and installing the reactor on the Hornet. We froze the systems late Monday night, and for the next 3,600 miles we didn't change engine settings.

On Tuesday morning we went to a Ford Motor Company mobile test facility for emissions tests. Both cars did nicely, with the Hornet doing superbly well in carbon monoxide (.1%) and hydrocarbons (10 ppm). Actually, the carbon monoxide was zero on their instruments ("Where's the goddamned CO?" bellowed the Ford technician.), the .1% reflecting the lower limit of sensitivity of the instruments. The low value of Hornet hydrocarbons pleasantly surprised us, and was either the new reactor doing a great job or the insensitivity of instruments designed to test the 400-600 ppm commonly found in gasoline-fueled power plants. It later turned out, ironically, that the low value of hydrocarbons cost us a victory in the race.

The next day we reported to Hanscomb Field for performance tests. Noise tests were first, and that took about two hours for the dozen or so cars there.

That night I flew to New York City. It was my first visit to Manhattan, and I was quite a conspicuous tourist. I spent a culturally stimulating evening attending *Oh! Calcutta!* and visiting a few discos. I felt great the next morning at five when I arrived at NBC studios for the "Today" show. Bob McGregor, race director, and Nancy Wood, a Worcester Polytechnic Institute entrant, were there too. The interview came off acceptably, and we then spent the day in Manhattan trying to see everything (a monstrous mistake) and returned to Boston that night. (My feelings about New York City summed up? I hated it.)

On Friday, Joe, Dave, and I went north along the coastline to Cape Ann. It was picture-book New England at its best. We returned to Cambridge refreshed and relaxed, and again traveled to Hanscomb Field for acceleration and braking tests. We didn't do very well in these, but we didn't expect to. We had tuned our vehicles for minimum emissions rather than maximum performance. In braking, the scale was so high that an anchor and plow would have been required for maximum score.

Friday evening provided us a lot of excitement—our motel burned down. It was a hell of a fire. Many people in the motel took the opportunity to bail out without paying their bills, and for a while pedestrians were in fear of their lives from arriving fire engines and departing guests.

Saturday and Sunday were spent attending meetings and taking care of last minute details. We all were getting a little anxious for the race to begin. Sunday night a kickoff banquet provided us the opportunity to hear the governor of Massachusetts speak. That was a worthwhile thing because most of us concluded that Reagan wasn't so bad a governor after all.

Monday, August 24

At about 6 a.m. we left Cambridge bound for Toronto. It cost an arm and a leg in tolls crossing Massachusetts and

New York. We spent a few minutes of "break-time" in Niagara Falls and were pleased to find no delays in crossing into Canada this time. However, ecstasy turned to horror when I then got one of the fueling trucks lost in Niagara Falls, Canada. The racing vehicles went ahead and finished the leg with me somewhat behind.

Tuesday, August 25

A short drive to Detroit for cold-start emissions tests. Most of us got about three and one-half hours sleep the previous night, and we were not in very good shape.

We arrived in Detroit about noon after a scenic drive through Canada. The race vehicles were taken to Ethyl Corporation for tests. After a seven-hour wait, during which Joe and I sacked out on the grass, our vehicles were tested. The Hornet did quite well; in fact, we found out several days later it was the cleanest car in the race. The Ranchero did fairly well, with hydrocarbon emission higher than we expected. We returned to Ann Arbor and impounded the vehicles for the night.

Wednesday, August 26

Left Ann Arbor at about 7 a.m. for Champaign, Illinois. Some minor mechanical problems with the mobile home became an everyday occurrence. Today it was a fan belt that failed.

Thursday, August 27

The longest day of the race—680 miles. We left Champaign for Oklahoma City at 4:50 a.m. The mobile home trouble of the day was the thermostat.

Late in the day a crack appeared in the flexible exhaust pipe used to install the Hornet catalytic reactor. The noise level picked up considerably. We decided to drive it that way the following day and fix it the next night in Odessa, Texas.

We dined on buffalo steak at the impound barbecue—a rather handsome meal.

Friday, August 28

The team, led by the Hornet sounding like a Sherman tank, proceeded to Odessa, Texas. After another barbecue (which the team was beginning to abhor), we spent about an hour fixing the Hornet tailpipe and replacing a defective check valve.

The mobile home defect today was bad points, replaced at night.

Saturday, August 29

This leg was frightfully uneventful, and the scenery didn't do much to remove the boredom. We learned that the Hornet was the unofficial leader in our class, and that picked up our spirits considerably.

Another barbecue in Tucson.

Sunday, August 30

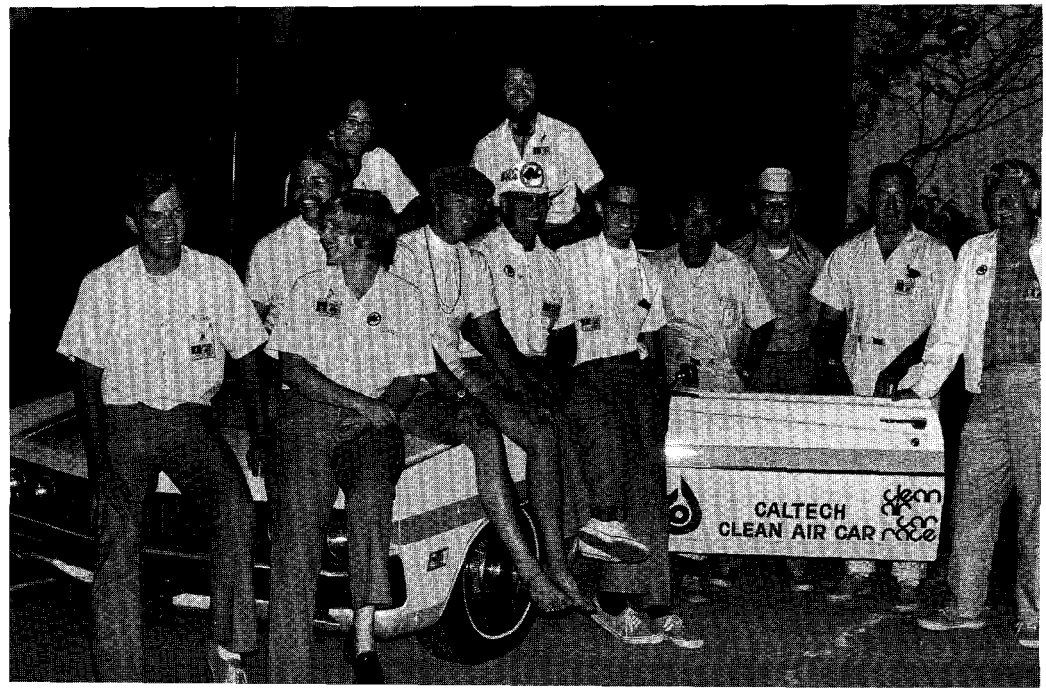
It became apparent on this last day that many teams wanted to be first to Pasadena. We did not feel obliged to participate in this foolishness, and proceeded as we had the previous six days. Our refueling trucks had some minor problems in the hills out of San Diego, and one had to switch to natural gas to avoid vapor lock.

The reception we received at Caltech was the most memorable event of the race. None of us had anticipated the enthusiasm or the crowd. We were all extremely gratified. We had traveled 7,200 miles without major trouble, and we had the distinction of owning the cleanest car in the race in Detroit. It was good to be home.

The next day the final emissions tests were conducted. We found that our hydrocarbon emissions had increased to 50 ppm for the Hornet, while the oxides of nitrogen had dropped to about half the Boston level. The emission-scoring formula was such that we went from the top of the heap to the bottom. We tried in vain to argue the injustice of the rating system but it was, in all honesty, too late. It was our conviction that one of the cleanest cars in the race was ranked below those that emitted two or three times the contaminants we did.

The selection of Wayne State as overall winner of the race was also something of a disappointment. They had run on unleaded gasoline (and failed to meet the 1975 federal emission standards). Suffice it to say that the circumstances surrounding the selection of the winner seemed to negate a portion of our effort —which was to make people aware of alternate schemes.

Now the 1970 Clean Air Car Race is history. We assume there will be future events of this kind periodically. The momentum generated in involving students in working toward solutions to the automobile emissions problem should be sustained. At the Institute there will be an active group of us going on in automotive emissions research and development. We hope this first step, while not large, has been a significant one.



Caltech's Clean Air Car Race team at the end of the run.

THE
CLEAN AIR
CAR RACE
II

What Went On Under the Hood

by James Henry

When MIT challenged Caltech to an "Urban Car Competition" in October 1969, they had a nearly completed hybrid-electric vehicle, and we had nothing. This seemed a fair challenge to Caltech students and so, in a hastily called meeting, the challenge was accepted. The next order of business was to decide what kind of car we should enter. This was quickly taken care of. It would be a clean car, cleaner than the 1975 emission control standards. It would also be reliable, cheap, and simple. It had to be. We didn't have the time, background, or money to complete anything else. At this point the group had the wisdom to adjourn and go to the library to find out just what the wonderful vehicle we had described and, while we were at it, what the standards were.

A week later Mike Lineberry and I came back with the answer. Keep the internal combustion engine, convert it to use a gaseous fuel, and begin modifying as necessary. And that was what we did.

For the next five months we spent our time investigating the equipment we would need to convert and modify our car. Another group simultaneously investigated how we would pay for our car and its modifications. Finally, in May, we gathered in the Old Steam Plant around a new American Motors Hornet loaned to us through the efforts of Orrin Fox, American's Pasadena dealer. We were armed with the conversion equipment given to us by Dual Fuel Systems, a subsidiary of the gas company in Los Angeles, and tools paid for by trustees, alumni, and many other friends of the Institute.

Three months later the Hornet and a Ford Ranchero loaned by the Pacific Lighting Company crossed the finish line of the 1970 Clean Air Car Race, having fulfilled the criteria we had set. So what went on under the hood?

The principal modification was the addition of equipment to allow the engine to operate on natural gas. For the Ranchero this was the only modification. The Hornet was also equipped with a catalytic reactor to further reduce hydrocarbons and carbon monoxide. With these simple changes both cars were able to meet the 1975 emissions standards easily. In the tests in Boston, both were able to better the 1980 standards.

In the Detroit emissions tests, which were far more comprehensive than those now used for the certification of vehicles, the race cars were tested after 1,000 miles of hard driving. Only seven cars were able to meet the 1975 standards in those tests. Two were using natural gas, four were using a similar system with propane, and one was using methanol. Of the seven, the Hornet was the cleanest, falling short of the 1980 standards by a mere seven hundredths of a gram per mile of oxides of nitrogen.

The cleanliness of gaseous fuel systems demonstrated in Detroit is an inherent feature of this type of operation. A vehicle with such a system needs no "smog device" other than the positive crankcase ventilation valve. The system is a proven one, having long been used in stationary engines, fork lifts, and on cars in areas where the gasoline supply is limited. Only recently has attention been focused on this type of operation for the reduction of emissions.

The system consists of a tank appropriate to the fuel used, a regulator unit which controls fuel pressure, and a gas-air mixer which serves the same function as a carburetor in a gasoline system. In our conversion we used equipment distributed by Dual Fuel

Systems. The fuel is compressed natural gas, and it is stored in conventional transportation bottles. Because of the high pressures used to store the fuel, the regulator is a two-stage unit. The high-pressure regulator is the type used in welding outfits. The low-pressure unit is a household-type natural gas regulator. The gas-air mixer replaces the air cleaner. Because the gasoline carburetor can be left intact, a pull knob is provided on the dashboard which allows the selection of either natural gas or gasoline as the fuel. In this way, if a supply of natural gas is not convenient, operation can continue on gasoline. Operation of the vehicle is unchanged on natural gas. A slight loss of power results, principally from the re-tuning to minimize emissions, but the car is quite drivable and acceptable in all respects.

Because the difficulties of vaporization and mixing of the fuel are eliminated, a much better control of the combustion process is attained. On natural gas operation the choke, fast idle, and manifold heat riser become unnecessary. To reduce emissions the system is adjusted to provide a lean mixture, normally 25 percent more air than is required for a chemically correct mixture, something which is impossible with gasoline. This ensures sufficient air to burn all the hydrocarbons and oxidize the carbon monoxide to carbon dioxide. Peak combustion temperatures are also reduced, inhibiting the formation of oxides of nitrogen. As an additional benefit, natural gas is about 90 percent methane. Methane has been shown to be nontoxic and unreactive as a smog-forming hydrocarbon. This means that emissions on natural gas are less harmful as well as being lower.

Benefits from natural gas operation do not end with clean air. They also include a clean engine, which therefore needs less maintenance and repair. At 5,000 miles our spark plugs had no deposits at all. At 8,500 miles we are still using the oil which was installed at the factory, and it is still clear.

A less obvious but equally dramatic benefit is improved safety. The necessary strength of the tankage reduces the likelihood of a tank rupturing in an accident to near zero. If the fuel is somehow lost, the buoyancy of natural gas, the range of inflammability, and the higher ignition temperature make the fire hazard far less than that with gasoline. Probably the best case for the safety of natural gas is that it is used to operate Disneyland's fleet of passenger-carrying vehicles—including cars, trams, and even boats. Here the conversion was done for reasons of safety and the reduced insurance rates which resulted.

The most important feature of the system is its practicality. Many firms that operate fleets of vehicles are converting them to use natural gas as fuel. The average cost of conversion is $350 and it takes about four hours. The cost can be recovered in reduced fuel and maintenance costs. Conversion equipment is the same for all vehicles and is now being commercially produced and sold. The conversion is so versatile that it has even been applied to diesel engines.

The only missing element is the resolve to forge ahead with the change. The members of the Caltech Clean Air Racing Team are now in the process of converting their personal vehicles to natural gas.

What are you doing?

The author in action—testing the theory that if it doesn't work, get a bigger hammer.