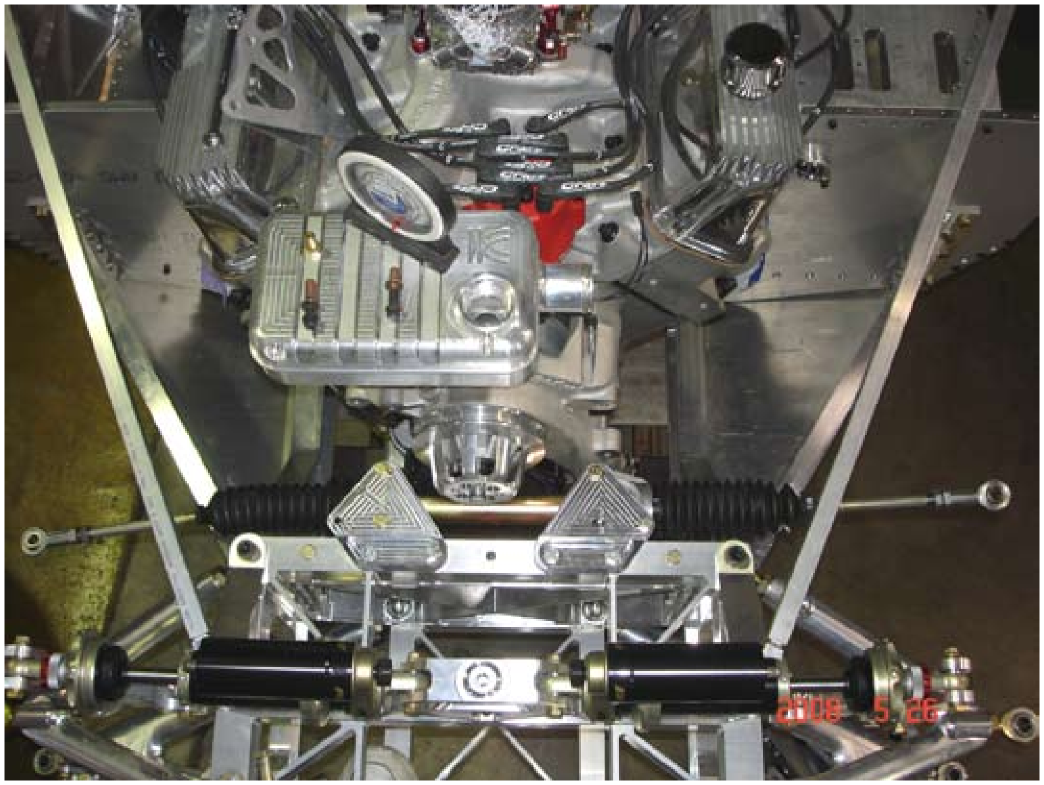
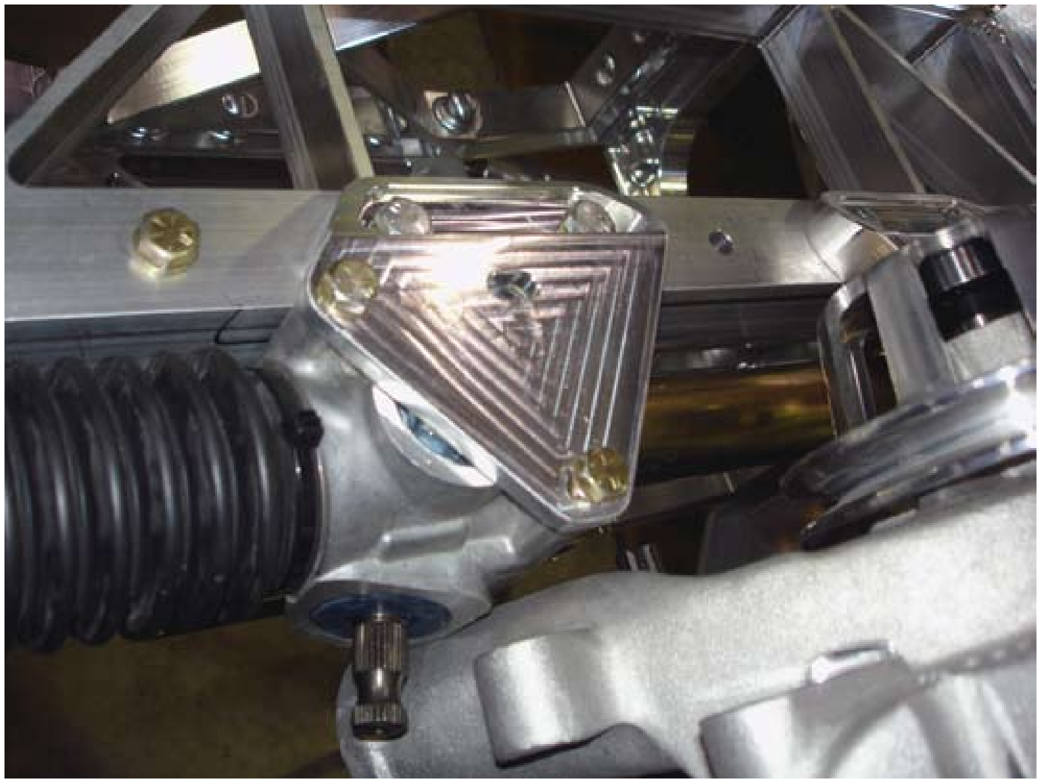
STEERING RACK

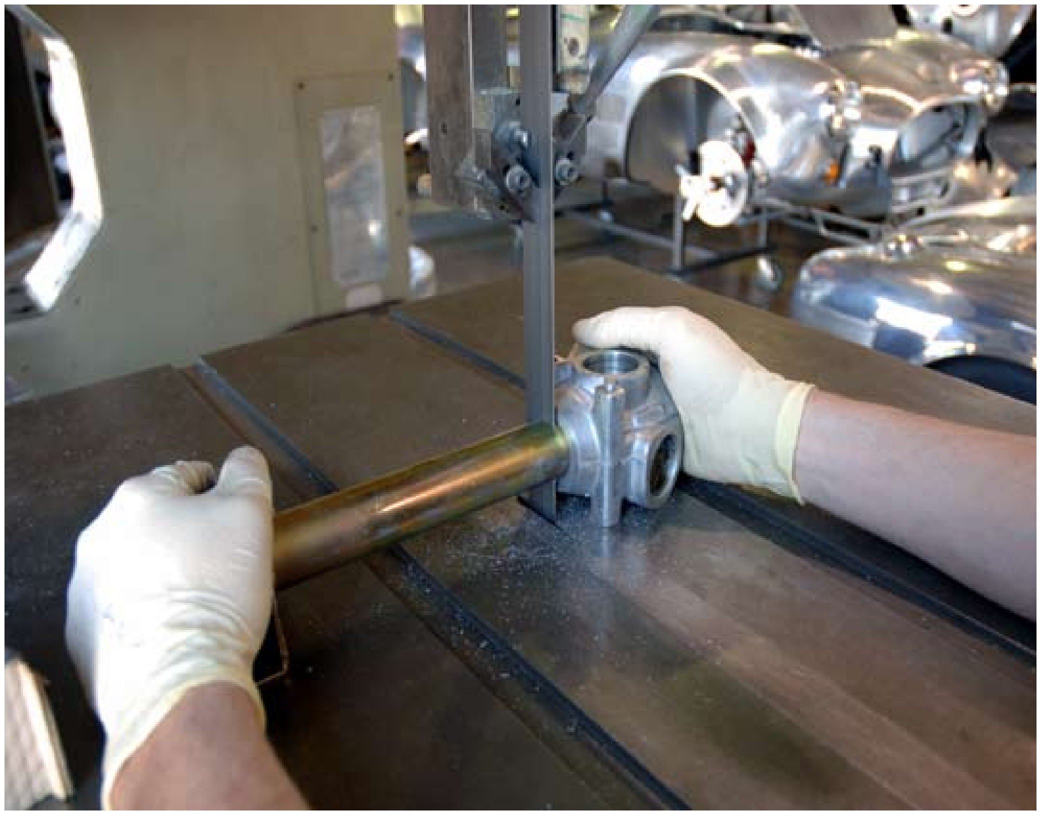
Do, or do not. There is no try.

Yoda, George Lucas





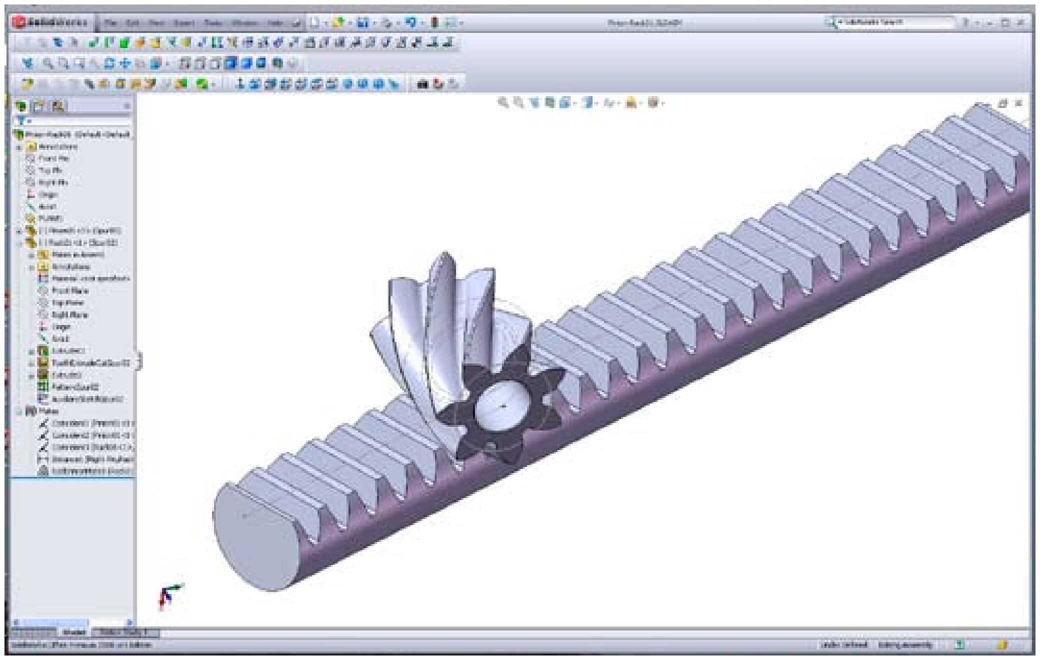
We purchased a steering rack from a highly regarded manufacturer. Then, when we tried to align the car, the measurements randomly kept moving all over the place. With the help of a laser, we finally isolated the problem to loose bushings in the housing. When we took the steering rack apart, we noticed the rack bushings were kept in place only by a triangular swage on the housing—which, in turn, squishes the bushings into a very sloppy, triangular shape! When I told the manufacturer the end play in his rack was 0.060 inches, he said, "What'd you expect—an Indy rack?" The only way to fix this problem was to cut the steering rack apart on the band saw and make our own tube and bushings.



Milling the remaining part of the tube out of the housing.

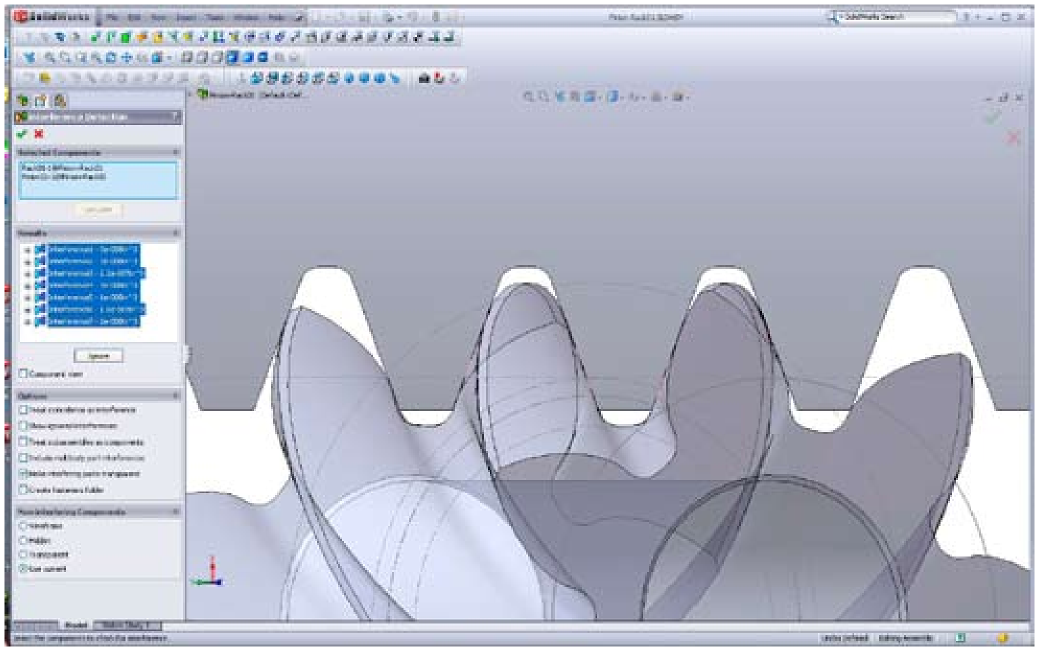
Warming up the housing to get it to expand.

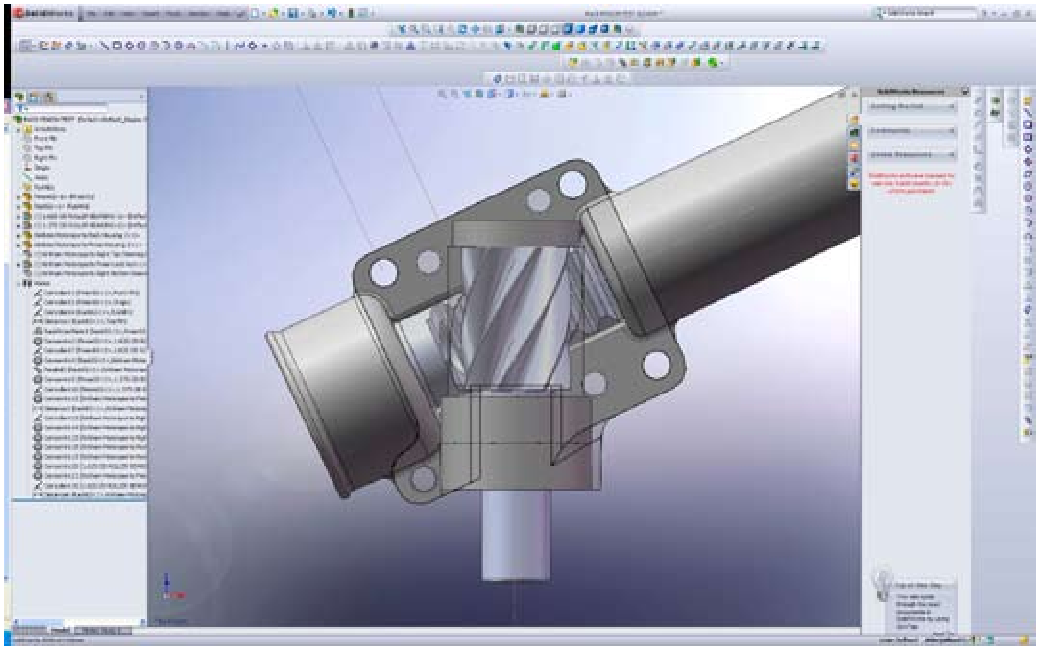
We made a new steering tube and pressed it into the housing (below). We cut a special snap ring (right) out of titanium on the water jet to hold the bushing in place. Titanium is a wonderful spring material—and it doesn't rust.



After all that work, we put the problem rack back in the car and found there was a shimmy in the steering wheel when driving. We traced the problem to the pinion bearing. Unbelievably, the manufacturer cantilevered the pinion in the rack housing on a sloppy bearing that couldn't take thrust loads. As the driver turned the steering wheel, the pinion rode up or down the rack before the slop ran out of the bearing and the rack started to move—translating to the vibration in the steering wheel. So, the "non-Indy" steering rack went into the trash and we went to the drawing board and designed our own steering rack from scratch.

Notice there are always three faces of the pinion gear in contact with the rack at all times to minimize backlash. Making our own rack worked out better in the end anyway. We were able to design the pinion angle, travel/revolution, and package size exactly how we wanted it.

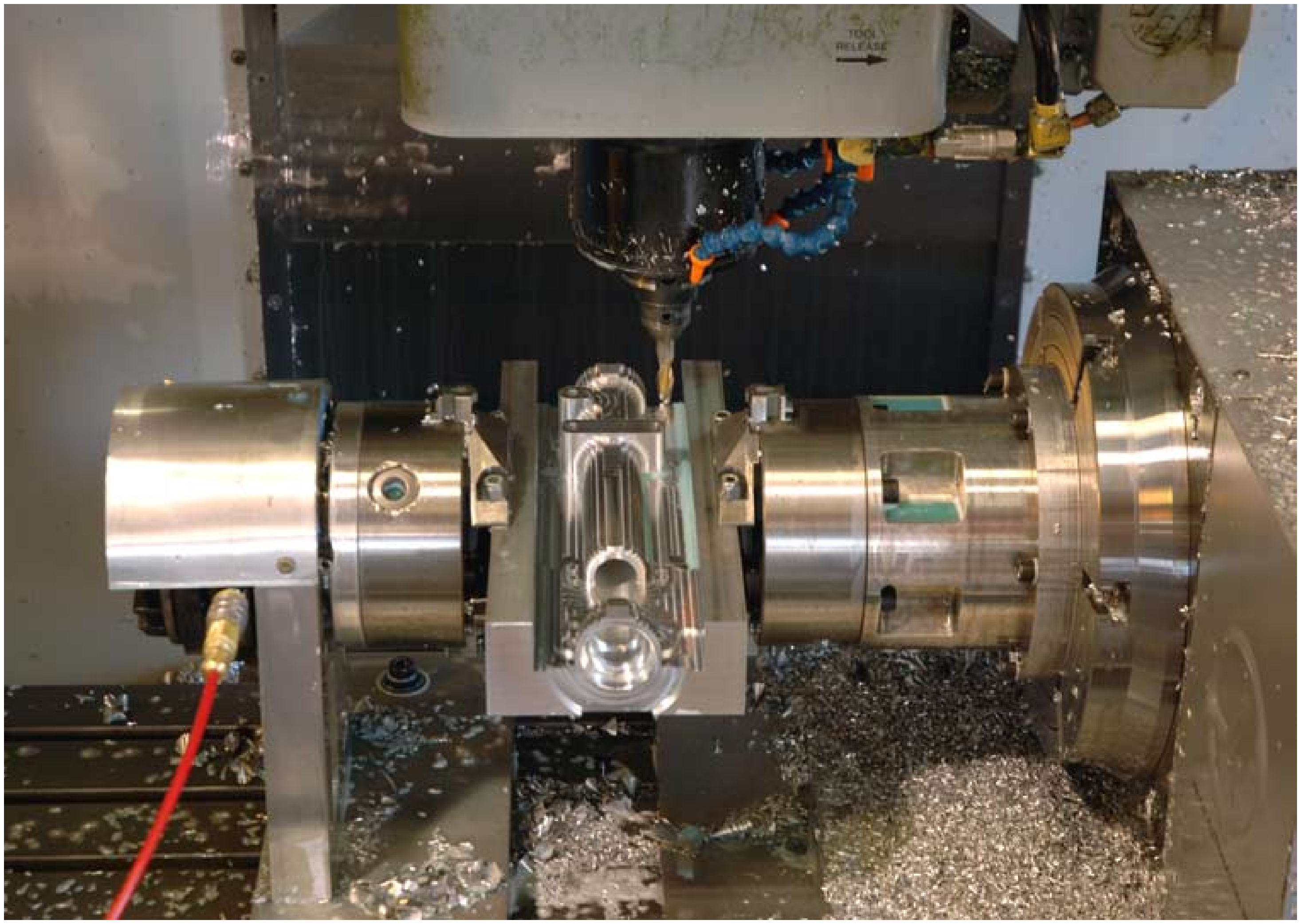




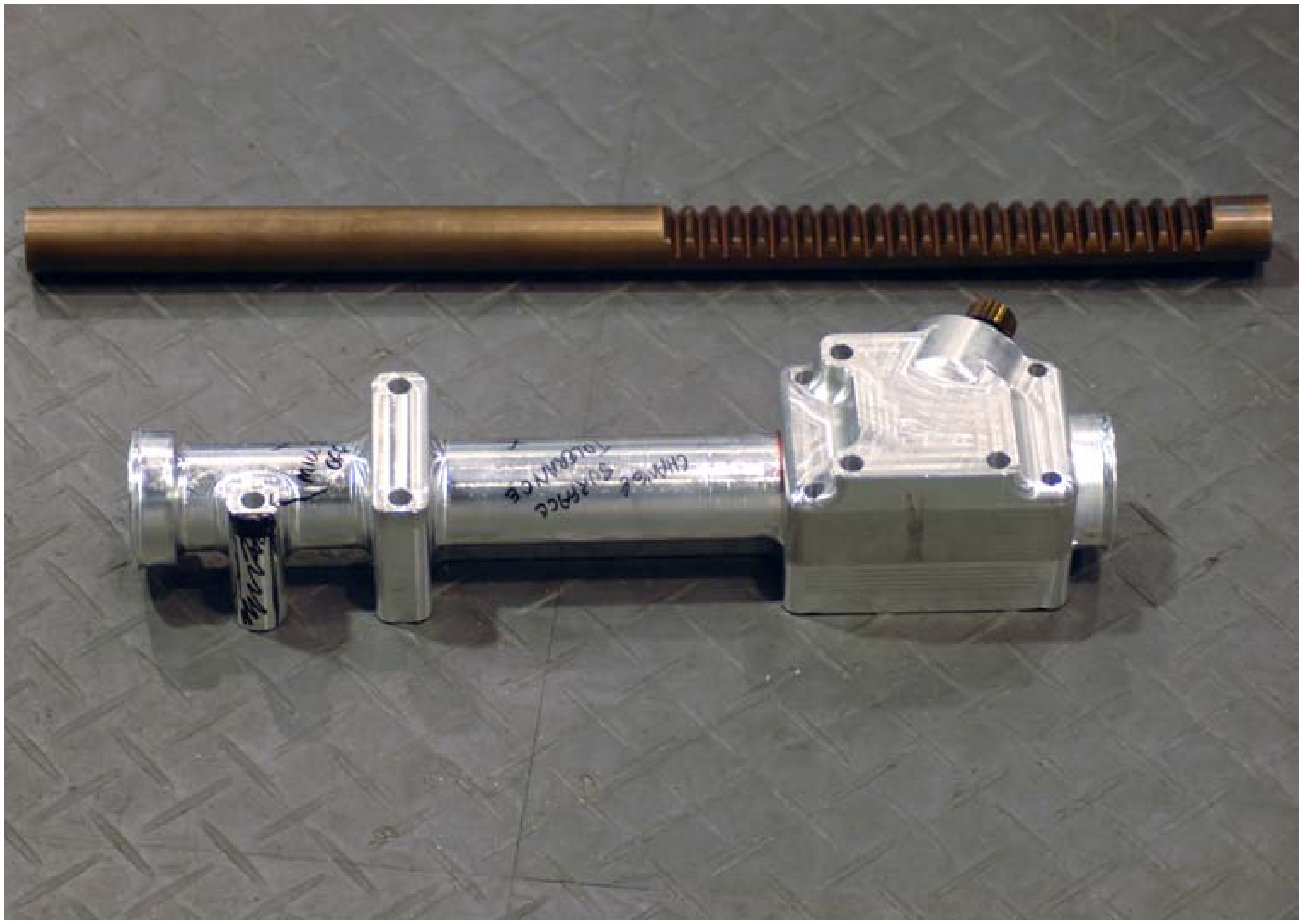
We custom made the pinion at 25 degrees to clear the water pump on the engine.

Making the rack turned out to be quite challenging. When we machined the first rack for the prototype, the rack stress relieved and bent into a banana. We were able to straighten it almost perfectly...but we wanted Larry's rack to be perfect. So when we machined his rack, we rough machined it and then straightened it.

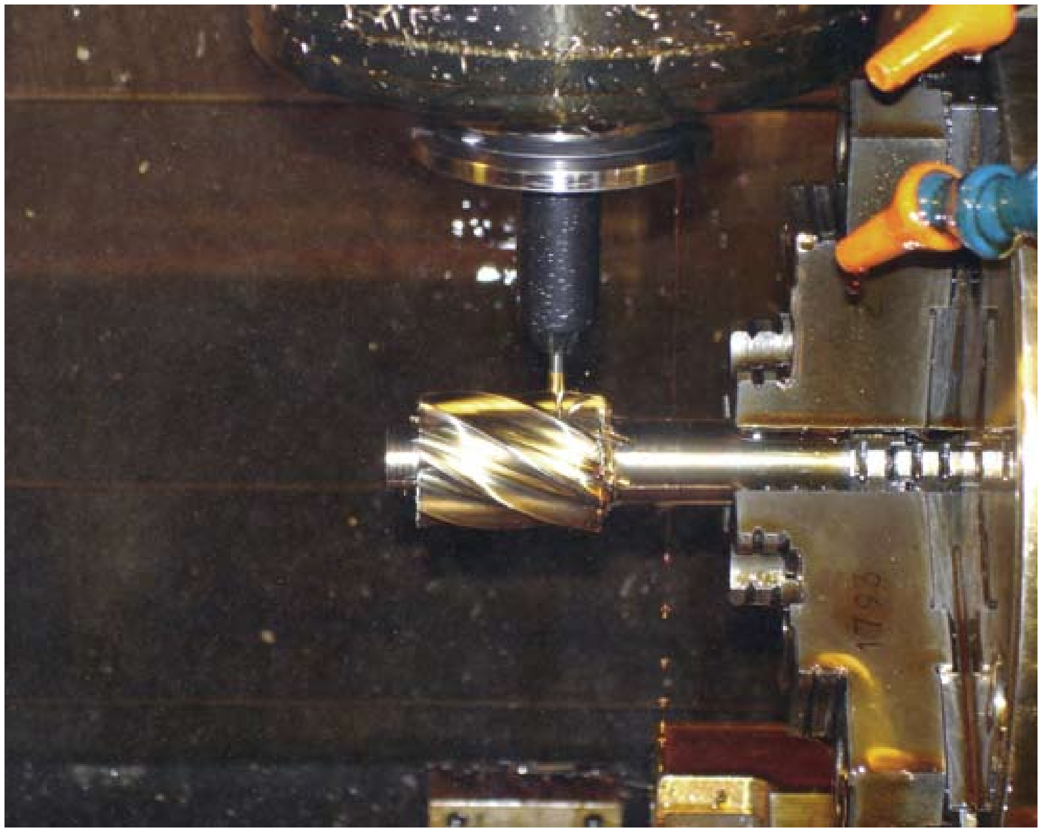
After we straightened the rack we did a finish pass of the final 0.010 inches.



Instead of making the rack out of three different pieces (like everyone else), we cut the rack housing from a single block of aluminum. That way we were guaranteed to have a perfectly straight rack housing.



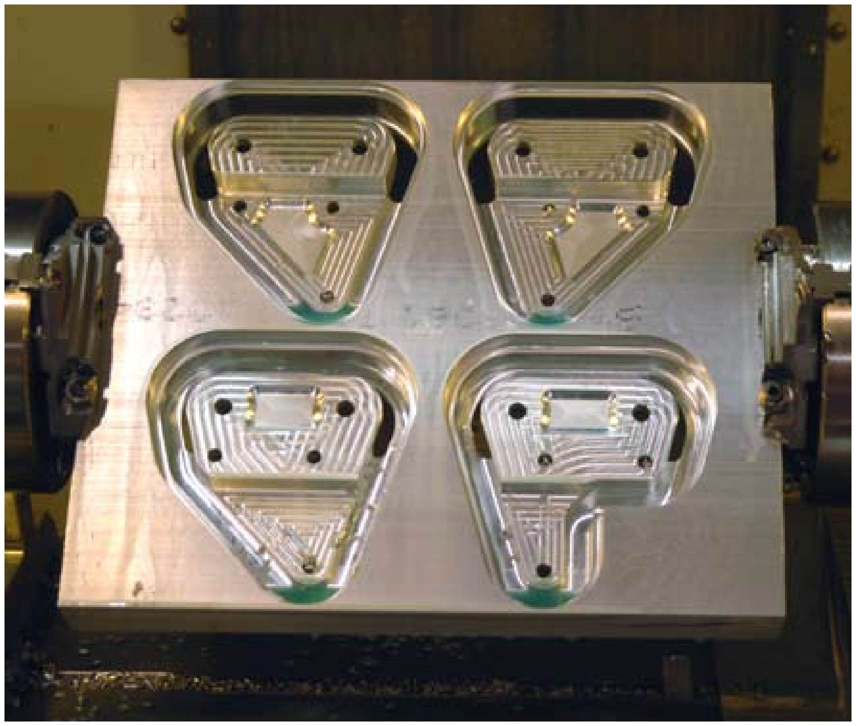
The bronze color of the rack indicates it has been heat treated. The rack housing is now completed for the prototype car as well. Notice the writing on the rack and the colored-in areas. Those areas were modified for the delivered car.



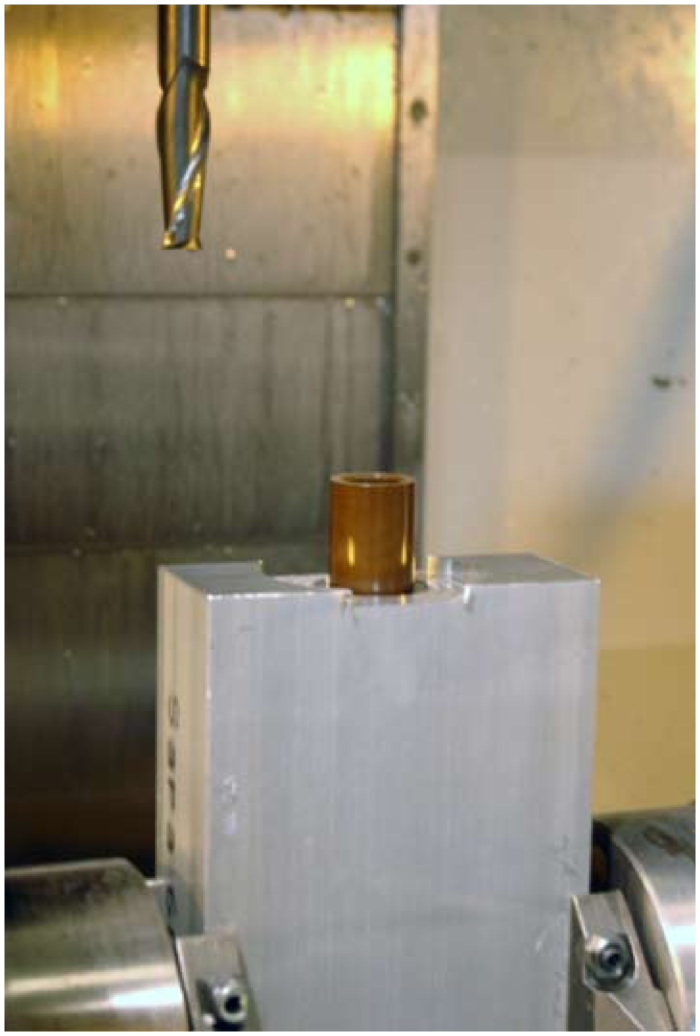
The pinion is machined on our 4-axis mill with a tiny 1/16 inch ball mill. We then profile the gear pattern.

The pinion had to be extremely short so it would not hit the engine.

We machined the rack and pinion from Maraging 300. Maraging 300, like its name, has an ultimate tensile strength of 300,000 psi. All stainless materials are NOT the same! When Maraging 300 is hardened, it achieves a Rockwell hardness of about 52 RC—perfect for gears. Because the material is precipitation hardened—not quench hardened—we didn't have to worry about micro cracking. Maraging 300 is used to make the gears in F1 race cars. Interestingly, it is one of the only materials that can be used to make uranium centrifuges. Notice the boss on the back of the gear for a bearing—we supported the pinion on both sides to prevent any cantilever motion as the pinion was heavily loaded.

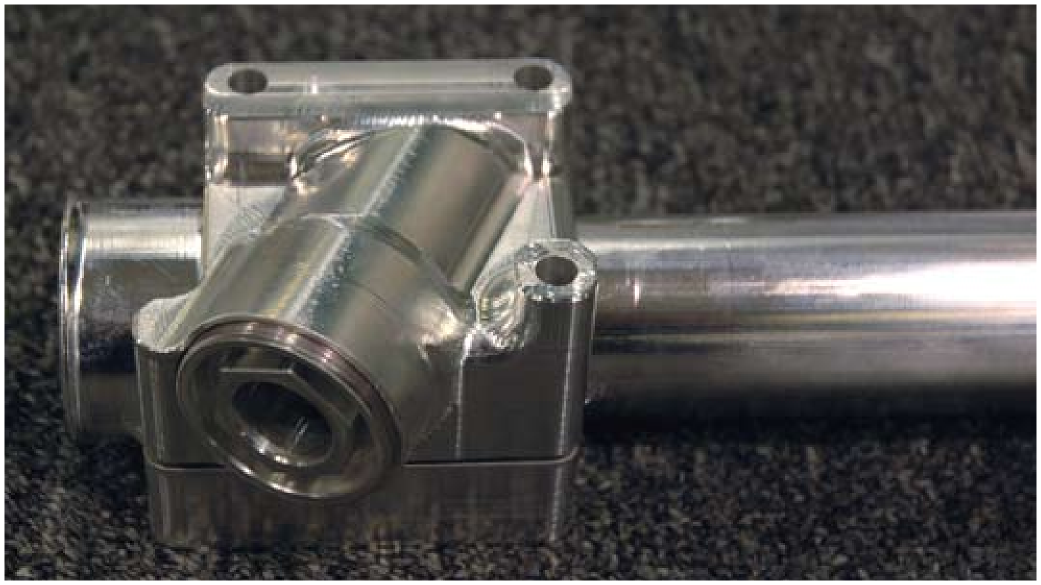


We mounted the steering rack in double shear to prevent it from flexing under extreme driving. Here are the top and bottom steering rack plates coming out of the machine.



We used Vespel for the bushing material. Vespel is an extraordinary plastic that is made by DuPont. It has almost unbelievable properties. It can flash to 900F degrees and has a working temperature of 550F degrees. Here you can see the Vespel bushings were machined in place so they would be perfectly in line with the rack.

Vespel has the lowest coefficient of "stiction" known, so the rack moves incredibly smoothly. As you might guess, this is the material used in F1 steering racks, satellites, and space shuttles. Only a few inches of the raw material for the bushings was over $500.

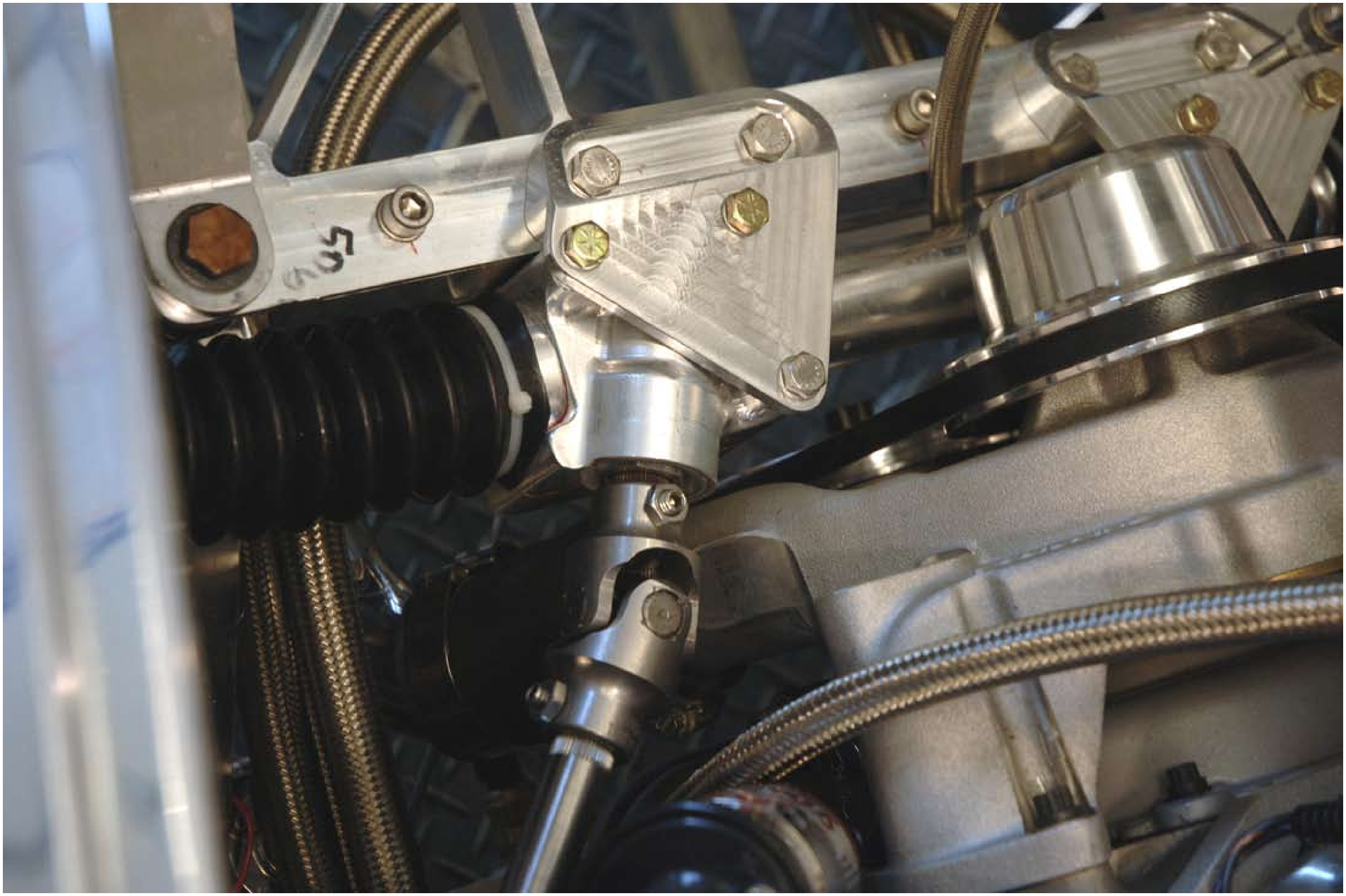


We designed the steering rack with a nut that fit around the pinion so we could clamp the pinion bearing securely in place. This design enabled absolutely no relative movement in the pinion.

The underside of the pinion housing.

Left: Notice the machined Vespel in the housing as well as the machined hole in the far left of the housing. The hole creates another anchor point to support the rack as far out as possible.

Below: Final assembly of the rack. We used Mobile 1 synthetic grease for the gears. Also, if you look closely, you can see the rack is not bronze colored any more. After heat treat, we polished the rack to a mirror finish so it would slide as smoothly as possible.



The final installed steering rack. It just barely clears the water pump. You can see the water pump pulley actually sits over the top of the rack. The steering shafts are all made of stainless steel in the entire steering system. The steering U-joints are stainless steel as well. We wanted this car to resist the ravages of time for as long as possible.