Engine
(Rebuilding Begins)
(2010)

6/18/2010

Well the engine disassembly revealed serious problems that will require some professional help.

Today I took the fuel injectors to ProFormance Fuel Injectors in Clearfield. They will call me today or later for a quote on rebuilding (their recommendation) the injectors.
Earlier this week the engine parts (pistons, rings, gasket kit, etc.) came in from Japan (Gene Youngberg; Stauffer Diesel), and I dropped them off at DL Automotive (a local speed shop). They said it will take about 2 weeks to finish up the head and block. They also agreed to try to clean up the corrosion in the intake manifold and heat exchanger housing. They will use bead blasting which removes only the corrosion. Warned me not to use assembly lube on cylinder walls. It's just to viscous and could break a ring. Use engine oil instead.

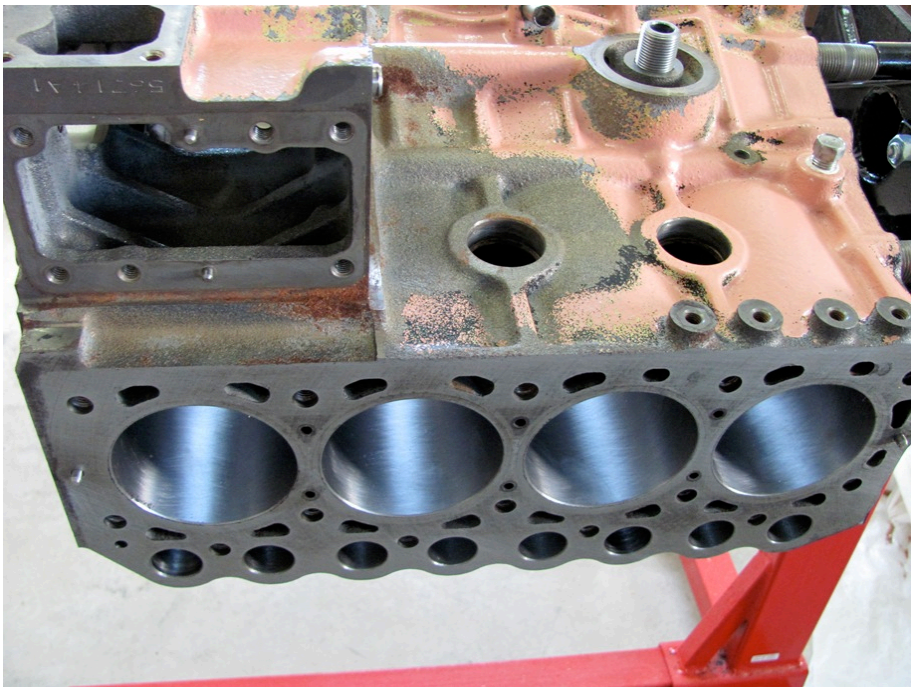
I'm now considering what to do with the heat exchanger. In particular, how to deal with the severe pitting that's occurred to the housing, how to prevent this problem in the future, and how to clean the tube bundle. I thought about anodizing the heat exchanger housing and was referred to a company in Altoona and they referred me to a company in Indiana, PA. I left a message but didn't follow up. I'm not sure that anodizing will be worth it since most of the corrosion was do to misuse, but I should follow up. Also I should ask them about chrome plating all the boat's fittings or at least stripping them to bare bronze. Also contacted a PSU expert on corrosion (Digby Macdonald), but he's away until Aug. (said in email that aluminum is bad for this application (Cu/Ni best), but that hard anodizing followed by chromate conversion coating is best if aluminum is to be used). Mark from DL Automotive suggested that I clean the tube bundle. Suggested Peak's Automotive using ultrasonics. Peak's no longer has this capability. Sent email to John Miller (Vetus) asking for advice on this matter. Still waiting for a reply. With regard to the existing pitting, John Miller suggested using RTV silicone with the normal o-rings in heat exchanger to stop any leaks. I could also apply epoxy and machine the surface, although it's not clear that the epoxy would stay bonded to the aluminum with all the temperature cycling. I need to pressure test it in any case. They make a device for autos, which I should explore.

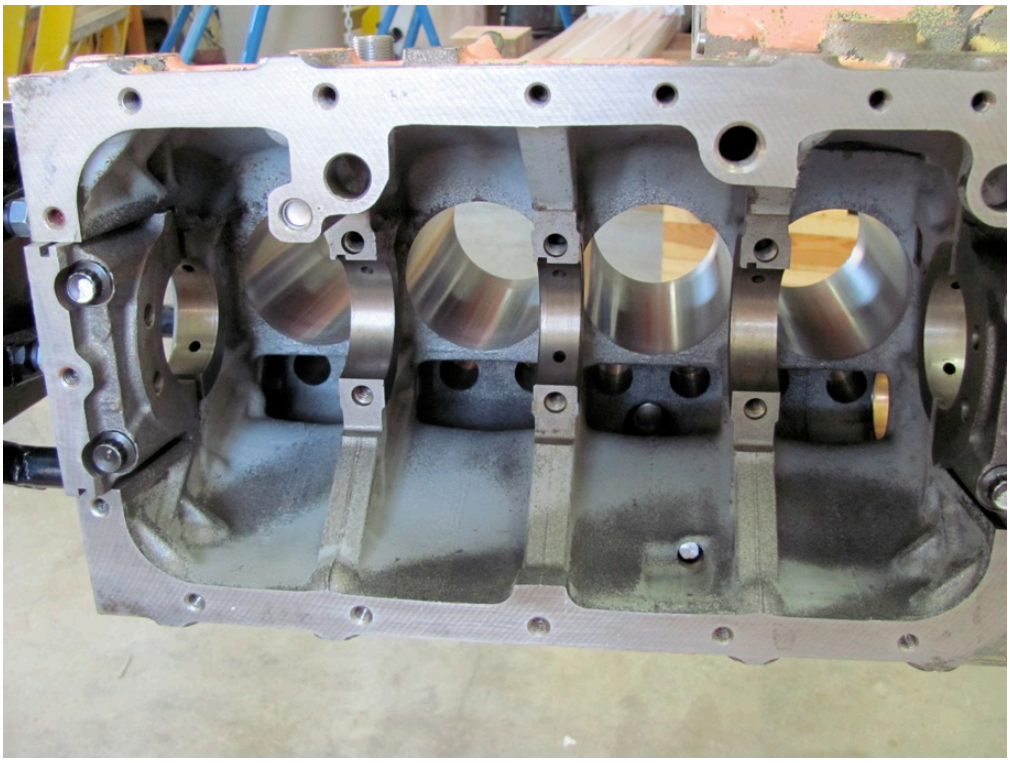
I'm considering replacing the fuel tank. Peak's Automotive on Cherry Ln can clean the existing stainless tank, but Nigel's book warns (John Miller confirms) that stainless will corrode at the welds. I can already see evidence of corrosion on the existing tank. Evidently welds are subject to corrosion both from the inside (fuel) and outside (salt water on oxygen depleted areas where tank contacts support structure). I called the manufacturer of the tank (ABCO in Canada) to learn their experiences with stainless fuel tanks. They said that it must have been a special order. They recommend aluminum for fuel tanks. So it looks like replacing it is the best bet. The existing tank is not a standard shape, however. Tanks at Jametown Distributers and others are mostly rectangular. Either I need to somehow fit it to the existing space or maybe build one with wood/

epoxy. John Miller suggests that I look at the ABYC specifications for fuel tanks, but to get a copy of the specs requires a membership fee of $200+. It might be worth it, however.

7/8/2010

DL Automotive finished the block and head. Looks very nice – cleaned and polished. They were able to clean up the cylinder bores except in a few spots above the rings, so it should be fine. Notice the shiny brass-colored insert at the bottom of the second pic. This is the camshaft bearing and is a "crush" fit. This part came from Japan, but DL Automotive installed it. Requires a special tool. Got everything back in the garage – mounted the engine on the engine stand. The gantry crane comes in handy again, although now I'm using the chain hoist I bought from Harbor Freight instead of the one I borrowed from Carson Baird at PSU's Learning Factory. Works well.

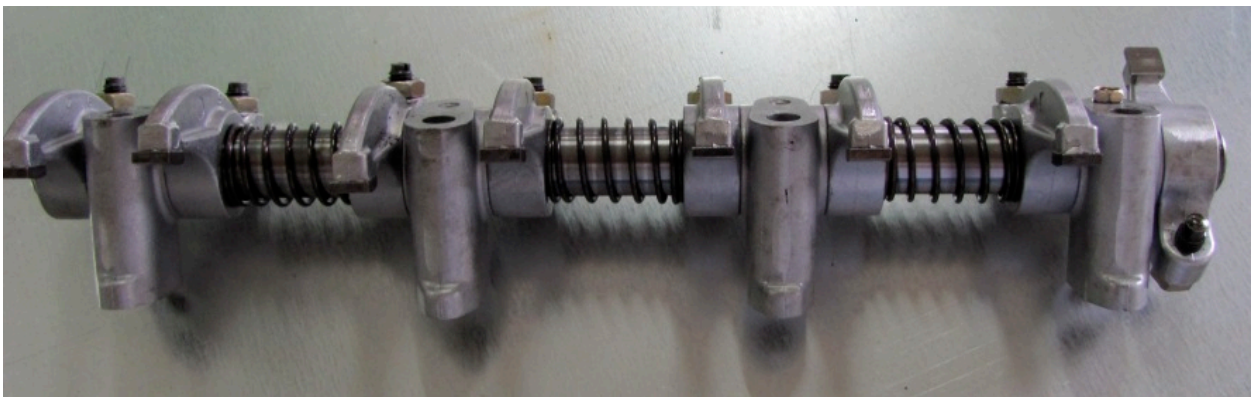




DL also installed the valves with new guides and seals in the cylinder head. Reconditioned the seats as needed. They also mounted the connecting rods to the new pistons using the new wrist pins and lubed the contact surfaces.

I began to review the service manual on part inspection. I guess I should have cleaned and inspected everything as I took it apart, but I was in a hurry to assess the engine's condition. Now if I find something out of spec, I'll have to wait again on parts. Which reminds me – I still have an outstanding partial order with Fawcett's. I'm delaying because I don't want to order the mounting pads and coupling until I'm sure about the engine. So on with the inspection … first the crank shaft … I mic'd the main bearing journals and connecting rod journals, and they all seem to be in spec. I then assembled the connecting rod bearings and mic'd them, but the results were not promising. It appears that the bearing are out-of-round – maybe they aren't seating correctly in the housing. I had similar problem with the one main bearing that I checked. Mark at DL Automotive suggested Plastigaging the bearing, which I hope to do this evening. If the bearings are bad, it will cost about $200 to replace them, and some of them will have to come from Japan.

I also disassembled, cleaned (CRC Brake Cleaner), and reassembled (assembly lube) the rocker arm assembly.



I cleaned the lifters, but noticed that the wear pattern wasn't right. According to Carson Baird (race car mechanic), the cam lobes are suppose to contact the lifters off center, which causes the lifters to rotate a bit on each cycle. My lifters seem to have contact in only one spot (not rotating). Carson suggested that maybe the lifters don't have enough clearance. I measured 0.002″ clearance between the lifters and the lifter bores in the block, which should be ok; however, there was a burr on the edge of #1 lifter bore and the bore surfaces were rough. Mark from DL suggested that maybe someone tried to run the engine w/o proper oil. In any case, he felt that the lifters and cam were ok. He suggested (as did Carson) that I clean up all the bearing journals and lobes (several of which showed some discoloration/corrosion. I mounted the cam shaft in the lathe, and using 800 grit emery paper (Carson's suggestion), followed by grey Scotch-bright pad (Mark's idea), I polished all the lobes and journals. I then did the same for the crank. Both came out looking like new. I should mention that spinning the shafts in the lathe didn't work as well as polishing each surface by hand – the lathe made a nice holder, however. I also bought a hone and honed each of the lifter bores.

Using brake cleaner and compressed air, I thoroughly cleaned the block, head, crank, and cam shaft, making sure to treat all the oil passages – don't want any grit in the oil!

Some asides … Carson's says that the new low sulfur diesel fuel doesn't contain enough lubricant – suggests using a product from FPPF as a supplement. FPPT makes a variety of products. The CAT parts store in Bellefonte has one that combines CTane with lubricity.

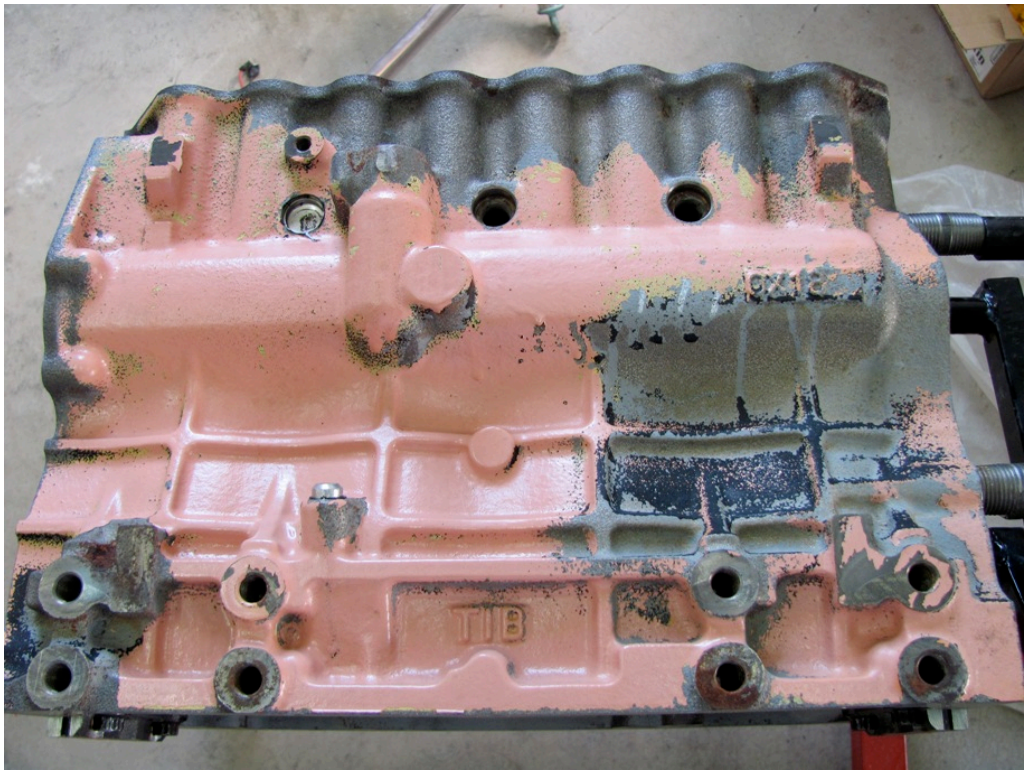
John Miller from Vetus suggests using Rydlyme to remove the scale on the heat exchange tube bundle. Ordered 1 Gal from Apex Eng. Lisa at Apex suggests using 50% dilution with water and recirculation, although just soaking (occasional sloshing) for say 2 hours is fine. Can save the diluted solution for future use. (8/9/2010: this worked great).

Bought some paint from CAT parts in Bellefonte. Engine paint – doesn't need primer.

Picked up rebuilt injectors from Pro-formance. Approx. $120

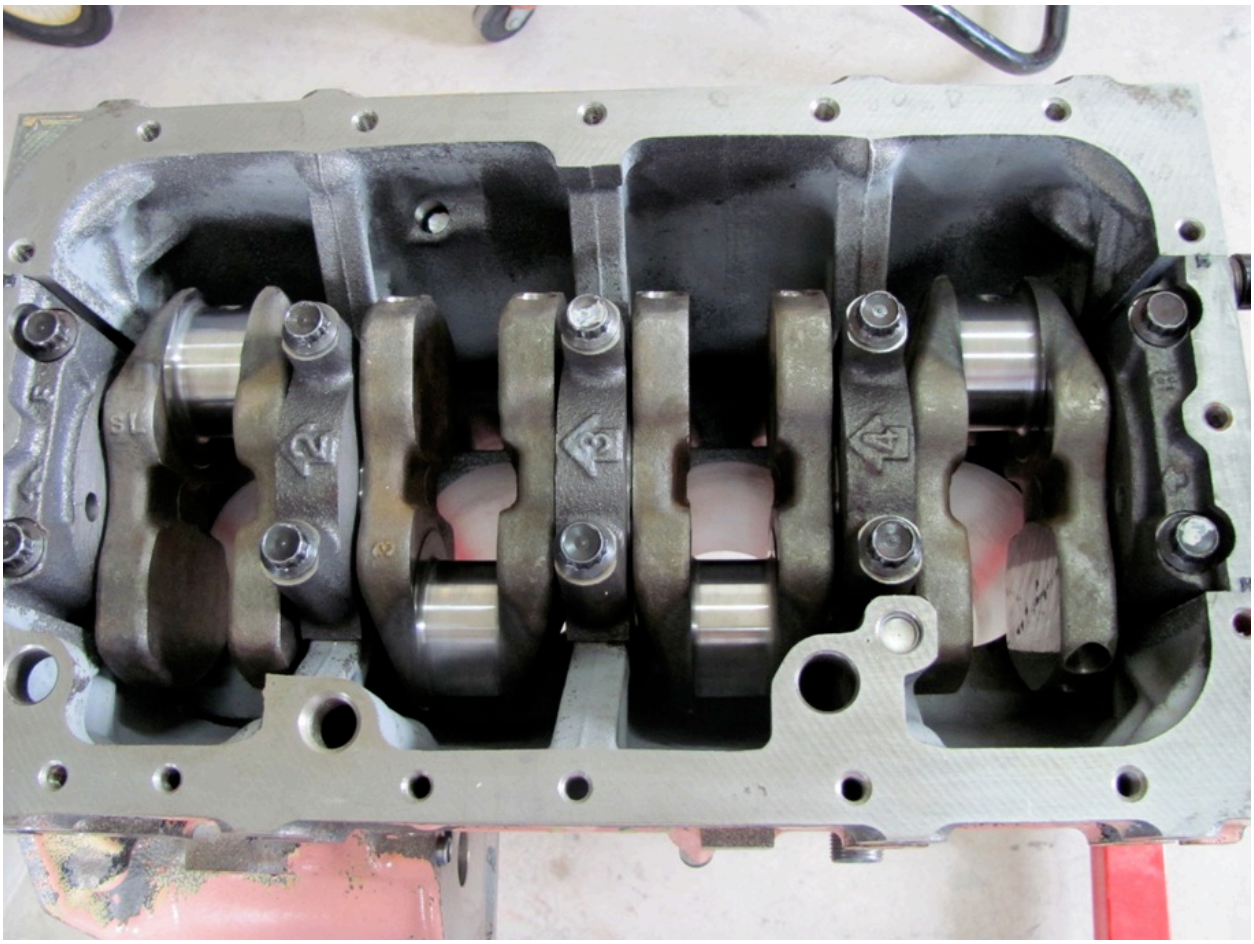
7/14/2010

I received the freeze plugs from Stauffer and installed them with black RTV silicone. In the pic below, you can see one of three freeze plugs installed (shiny disc in the upper left).

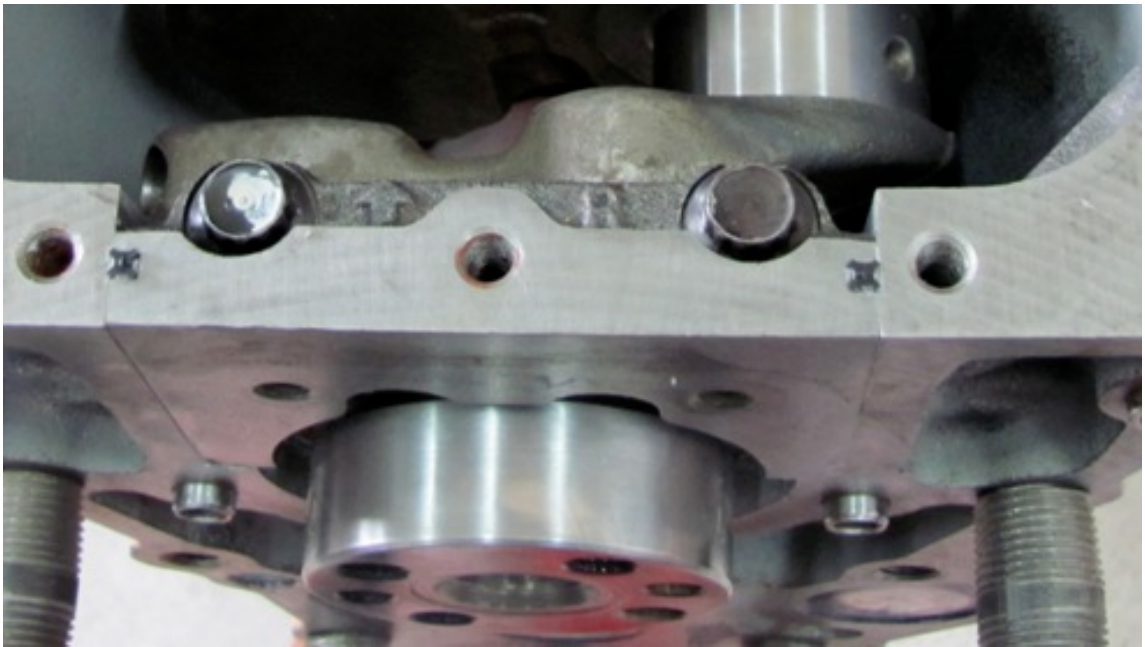


Used a socket and hammer to seat them. Three small ones on one side of the block, two larger ones on the other side, and one in the rear. Have to be careful that the socket has sufficient clearance, otherwise plug will crimp onto the socket when it contracts in the seat.

After cleaning and polishing the main bearings and journals (800 grit emory followed by grey Scotch pad), I Plastigaged the bearings. All were within spec but near the upper end of the range. Carson suggested that the range listed is to be viewed as a tolerance not an indication of wear and that more clearance is better than less. So I assembled the crank to the block using assembly lube.



The front and rear bearings were a bit harder to install than the others – hard to keep them flush with the block – not perfect no matter the effort. Also, the rear seal received a coating of Permatex Gasket Maker on all mating surfaces – evidently to prevent oil leaks into the bell housing. Front bearing is covered with timing gear cover, so it doesn't receive the same treatment. (8/9/2010: I noticed later in a different part of the manual, where they mention coating both bearings! Oh well, it's too late now.) Also installed 2 linear seals in the front and rear



bearings. Lubed them with black silicone and pushed them into place. They appears as two small X's in the pic below.

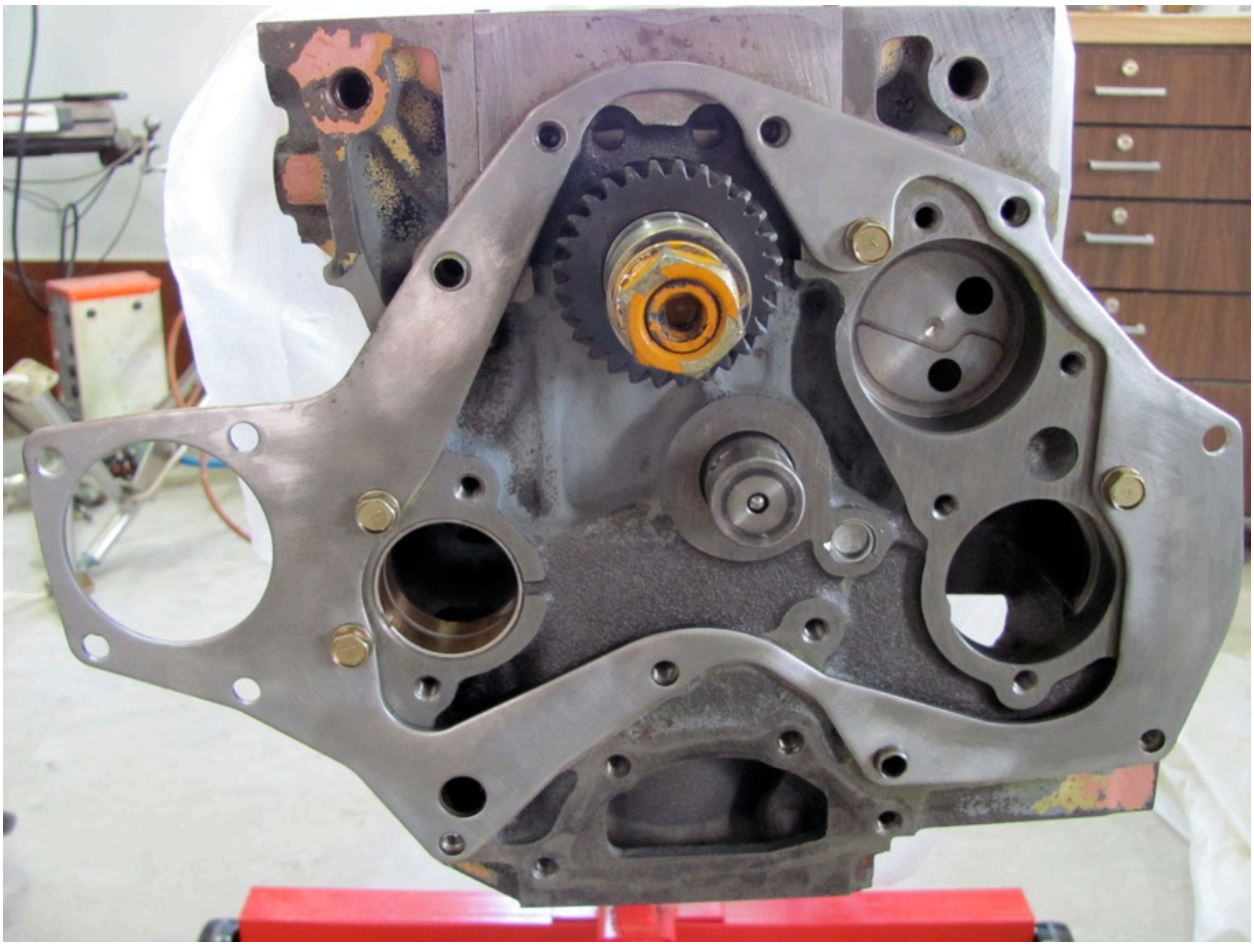
They protrude a little to mate with the oil pan, I presume. When all done, the crank spins freely.

Then onto the pistons. DL Automotive already installed the pistons to the rods, so I just had to install the rings.

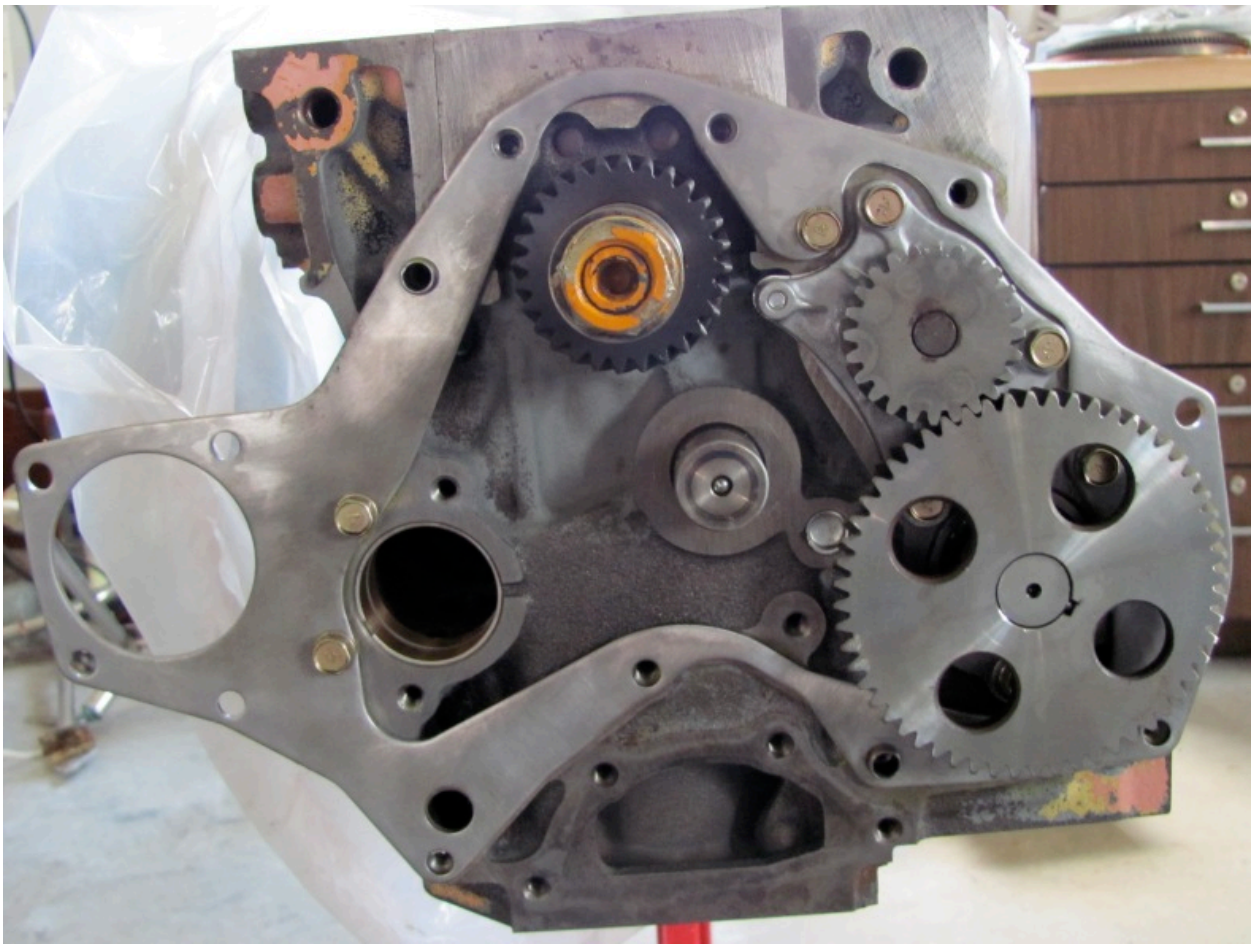
All went well with the first one; however, on the second one, I broke a compression ring. It turns out that it's easier to install them by hand than to try to use the (awkward at best) ring pliers. So that cost me $100 and a 2-3 week wait on new rings. I Plastigaged and installed the remaining three pistons with rings (motor oil on cylinder walls and rings) and all went well. The crank turns

quite a bit harder now with all the ring drag. I need a bar between two bolts on the crank (rear seal hub) to turn it.

Installed front plate with gasket.



Installed the oil pump. Cleaned & polished the cam shaft and the fuel pump cam shaft. Installed both with assembly lube on contact surfaces. The pic below shows the oil pump (small gear) and fuel pump cam (large gear) installed.



Timing gears installed. Power take off (PTO) installed. Timing cover with gasket installed. That closes up the front of the engine

Carson reminds me that main seals should be replaced. These don't come with the gasket set, so I ordered them from Stauffer – in stock so they'll be here with the rings. It will be a bit of a nuisance replacing the front seal with the timing cover already installed.

I'll now start looking for seals for the raw water pump and transmission.

8/8/2010

I received the ring set sooner than expected. I installed the rings on the last piston by hand (no ring pliers) and inserted the piston into the block. I Plastigaged the bearing and found the clearance to be about .002″ or a bit less (ok). While installing the last piston, I realized that for the other pistons, I might have rotated the ring compressor while tightening it, and this would have put the ring gaps in the wrong position. So I went back and removed each piston to check. Sure enough, some of them were incorrect.

I checked the crank end play with a dial indicator (.002″; ok), and the connecting rod thrust clearance with feeler gages (.008″ each; ok). The manual indicated performing these checks on disassembly, but things were such a mess I didn't take the time to do it then.

Ok, time to close up the lower end. I installed the oil pipe/screen and tightened the lock nut. Then I cleaned the block and oil pan mating surfaces with lacquer thinner, applied Three Bond 1207C (came with gasket kit), and bolted the oil pan in place (to the specified torque).

Some time later, I was browsing through the pics I took during disassembly and noticed that the oil pipe takes a gasket! Darn!!! Sure enough, a careful look at the manual shows a seal washer between the lock nut and the block, and I found the part in the gasket kit. So it's off with the oil pan, install the washer (with some black silicone on the treads even though the manual doesn't call for it), clean off the old oil pan gasket, and reinstall the oil pan. What a pain!

I learned a valuable lesson from this, however. The manual is written for professionals. It's not comprehensive. It assumes that you know basically what you're doing. So the section on installing the oil pipe/screen doesn't mention the washer. It assumes that you should know that, and that you can check the parts diagram to confirm. I also learned that the gasket kit contains many parts that aren't needed (for some other engine) and that some parts aren't included, but pretty much required. On some occasions, the sequence of steps indicated in the manual doesn't make sense. So I've taken some liberties there. For example, after installing the oil pan, the manual says to install the tappets, then the rear oil seal, rear plate, etc. But that doesn't work for me! The engine is bolted to an engine stand and so the rear end is inaccessible! So I skipped that part and moved onto the head.

I coated the tappets with assembly lube, inserted them into the block and rotated them until they moved smoothly. I ordered 2 long M10x1.25 bolts from Fastenal and cut off the heads (abrasive

wheel) to act as guides for the head. Installed the head gasket, head, the torqued down the head bolts – a little at a time using the pattern shown in the manual. Next the push rods (a little assembly lube on both ends), then the rocker arm assembly. This time the manual reminds me to install the valve caps – thanks! Next it's time to adjust the value clearance.

Valve clearance:

This was an interesting adventure! Thankfully the manual provides a detailed explanation of this process. First thing to do is to locate the top dead center (TDC) timing mark on the crank shaft pulley. Oh, did I forget to mention that I installed the pulley? Anyway, the mark is a little groove in the edge of the pulley. Ok, so I found the mark and turned (with some effort) the crank until the timing mark lined up with a protrusion on the timing gear cover. At this point, rotating the crank +/- 20 degrees should not cause the rocker arms of #1 piston to move. If they do, then piston #1 is not on the compression stroke, but #4 should be. So the rocker arms for #4 should be still and you can just adjust #4. Then you rotate the crank 180 degrees and adjust #1.

Well the theory is fine but it didn't work for me! When I rotated the crack a little, both #1 and #4 rocker arms moved! Uh oh! Did I install the timing gears incorrectly? After a mild heart attack and some serious thinking, I realized that I was looking at the wrong timing mark. Sure enough, 180 degrees around the crank pulley is another mark – a bit hard to see with all the pitting. Once I got my head on straight, all went well. After adjusting the valves, I installed the rocker cover.

The intake and exhaust manifolds were next. No problem with the intake, but the exhaust manifold is part of the heat exchanger and the gasket surface is quite pitted. So I put it on my Bridgeport and skimmed off a few thousandths to clean up the surface.

Fuel system:

The fuel system is next. First the injectors with the appropriate seal washer and torque. Then the glow plugs (no washers) with the metal strip the connects them. Then the fuel injection pump, doing the best I can to keep the fuel ports clean. Next the governor assembly. When I disassembled the fuel system, I thought that this might be a bit tricky. There's a linkage and spring that connects the fuel pump to the governor, and I was afraid that I would remember how it went. So I took lots of pictures. Unfortunately, of all the pics I took, these were out of focus (didn't know how to take close ups at the time). The manual has pics, but the manual is about a 10th generation photo copy and the pics are too dark to see much. Fortunately, It wasn't that difficult after all. I could pretty much figure it out from the exploded diagrams.

Next came the fuel injection lines. Again, I tried to keep things as clean as possible. First, I removed the protective plastic caps from the injectors (ProFormance installed these and then painted the injectors). Unfortunately, some of the paint leaked into the fuel return annulus, so I had to carefully clean out the paint. I then put the fuel leak-off header in place, washer, lock nut, and finally the fuel feed lines from the fuel pump. The leak-off header is there to return any excess fuel from the injector back to the fuel tank. Things seemed to go well. I had checked the exploded diagram to make sure that I had the right parts in the right order. Sometime later, however, I was browsing through another section of the manual and there it showed the washer

below the leak-off header not above it. Oh crap! I called Stauffer, and they said you should have washer on both above and below. The problem is that these are crush washers – can be used only once. So now I've ruined my washers and had to order new ones. When they came in, I took a close look at the leak-off/injector interface and concluded that only one washer was needed – between the injector and the leak-off header. I also checked my pics, and I couldn't see a washer directly under the lock nut. So I'm using one! We'll see what happens.

On disassembly, I keep all the fuel lines, fuel filter fitting, and lift pump together as a unit, so installing them was straight forward. The only connection was to the high pressure pump via a banjo fitting. The fitting has two seal washers, which I learned have to be replaced, and these are not provided in the gasket kit. So I had to special order them (Stauffer) and now I'm waiting of them. In the mean time, I removed the cover from the fuel lift pump to inspect the filter element. (There are three fuel filters in this system: a Racor primary filter and water separator, separate from the engine, a secondary fuel filter on the engine, and a filter element inside the lift pump.) Very clean. There is even a magnet inside to catch any metal particles, but it too was clean. The cover was rusted, however, so I bead blasted it and painted the outside with CAT yellow. I discarded the old secondary fuel filter. I found a spare in parts bin that came with the boat. I lubed the o-ring with engine oil and temporarily installed the filter to keep the fuel system clean. Before I start the engine, I'll need to remove the filter and fill it with fuel.

To test run the engine, I plan to run the fuel inlet and return to a plastic fuel container. I just need to run these hoses and install the banjo fitting at the fuel pump, and I'm ready to go.

Lubrication system:

Not a whole lot to do here. The main thing was to replace the front and rear main seals. These were not part of the gasket set, but Carson said they should be replaced. Another special order and wait. I must say that Stauffer has been very good about this. Gene Youngberg (the sales rep) has always been available and very helpful. All deliveries have arrived ahead of the estimates, even on parts coming from Japan.

The rear seal is fairly large (4″ diameter?) pressed into an aluminum housing. I cut out a plywood disc the same size as the seal and pressed the old seal out (arbor press). Then I pressed in the new seal. The seal housing then bolts to the block with a gasket (coat the seal lip with oil). The seal housing straddles the joint between the main bearing block and the block itself. This is why it's important to have the bearing block flush with the engine block. As I mentioned earlier, I couldn't get these perfectly flush – high on one side, low on the other by about .010 – .015″. I hope this doesn't keep the gasket from sealing!

The front seal was a bit trickier. It's pressed into the timing gear cover, and I installed the cover before I learned that I needed to replace the seal. Note that the manual doesn't recommend replacing them. I'm acting on advice from someone (Carson) who has years of experience building race cars. So first I had to pry out the old seal with a screwdriver without scratching the metal surfaces. You just have to slip the screwdriver (small but beefy one) under the lip and behind the seal and pry. Out it comes. Clean the surfaces as best you can, coat with oil, and tap the seal into place with a hammer. This works but this seal seats below the surface, so you can't

seat it all the way with a hammer. Fortunately, I had a deep well socket the same diameter as the seal, which by tapping on the socket, I could seat the seal completely.

Installed the pressure relief valve (with seal washer), oil filter (I had a spare; coat o-ring with oil), oil pressure switch. The manual calls for a special tool to install the oil pressure switch, but I had a deep well socket that worked just fine. The manual also calls for Three Bond 1102 sealant on the threads, but this wasn't included with the gasket kit and isn't readily available in the States, so I used Teflon tape (on the recommendation of the local Mitsubishi car dealer and confirmed by Carson).

Cooling system:

Installed the coolant pump, replacing the pulley on the front because it was so pitted. Tested the thermostat in hot water to be sure it opened when it should. Installed the thermostat housing with thermostat. A hose runs from the pump to the bottom of the heat exchanger, on the opposite side of the engine. The hose that comes as original equipment from Vetus passes in front of the engine. On this particular engine, the previous owners ran a custom hose assembly around the back of the engine. Evidently there isn't enough room in the engine compartment for a front mounted hose. Well to get the engine out of the boat, I had to cut this hose – well maybe I didn't "have to" but it seemed like the right thing at the time. Now I'm having second thoughts. Here's the problem. The hose connections on the pump and heat exchanger are sized for a 1-3/8″ ID hose, which is an odd size. To run the hose around the back requires 4 tight bends, so you can't just run hose – you need to use 90 degree pipe elbows. But they don't make pipe fittings to fit 1-3/8″ hose – at least I haven't found any to date. The previous owners used short sections of 1-3/8″ hose at the pump and the heat exchanger and then ran 1-1/4″ hose the rest of the way, which fits 1″ pipe just fine. But this means that the pipe connections to the 1-3/8″ hose are suspect. Also this means that you need two different sizes of hose, which are expensive and only come in long lengths. Did I mention what a bargain this boat was!!! Well at this point, I'm still undecided as to what to do. I might just have to machine some custom fittings.

Once I solve the hose problem, I need to pressure test the system. This is particularly important because the heat exchanger is severely pitted, so the tube bundle might not seal properly allowing the coolant to leak into the raw water system. They make a coolant system tester for autos but they're pricey. I'll see if I can come up with a way to use my air compressor.

Raw water system:

For most of the engine parts, I've been able to get them from Mitsubishi through Stauffer, at a significant cost savings. The raw water system, however, is unique to Vetus. So some parts have to come from them. The raw water pump is an exception. Engraving on the case shows that it's a Jabsco pump, and I found a dealer in Florida (Depco Pump Co.). I was able to download a parts list from the Jabsco web site and order parts from Depco. I replaced the two seals, an o-ring (water slinger), the cam, the impeller, cover plate gasket, and a cover plate screw that I broke taking it apart. I didn't plan on replacing the cam but after cleaning the original, I couldn't get the screw, which attaches the cam to the housing, to bite. The original cam was bronze and the new one is plastic with a bronze insert for the screw. The new cam is a bit thicker, but the rep

said that's not a problem. The screw that came with the new cam was also too short, so I ended up milling a deeper counter bore in the housing so that more threads engaged the cam. You just have to be sure that the screw doesn't end up proud of the cam where it would damage the impeller. In addition to the screw, red Permatex thread lock is applied to the cam and screw to lock everything in place. The new impeller is also different than the original – more flutes but shorter. The rep said this is an improved design.

All other raw water parts have to come from Vetus. The closest retailer is Fawcett's in Annapolis, MD. I've been delaying ordering to be sure that the engine was salvageable and that I understood what I needed. So I just now placed the order:

- O-ring for raw water pump.
- 2 o-rings to seal the tube bundle in the heat exchanger.
- Temperature sensor and seal washer on the raw water injection housing (the previous owner substituted a steal plug, which may very well have contributed to the corrosion problem.)
- Gasket between the heat exchanger and the exhaust/raw water injection fitting.
- Spare oil and fuel filters

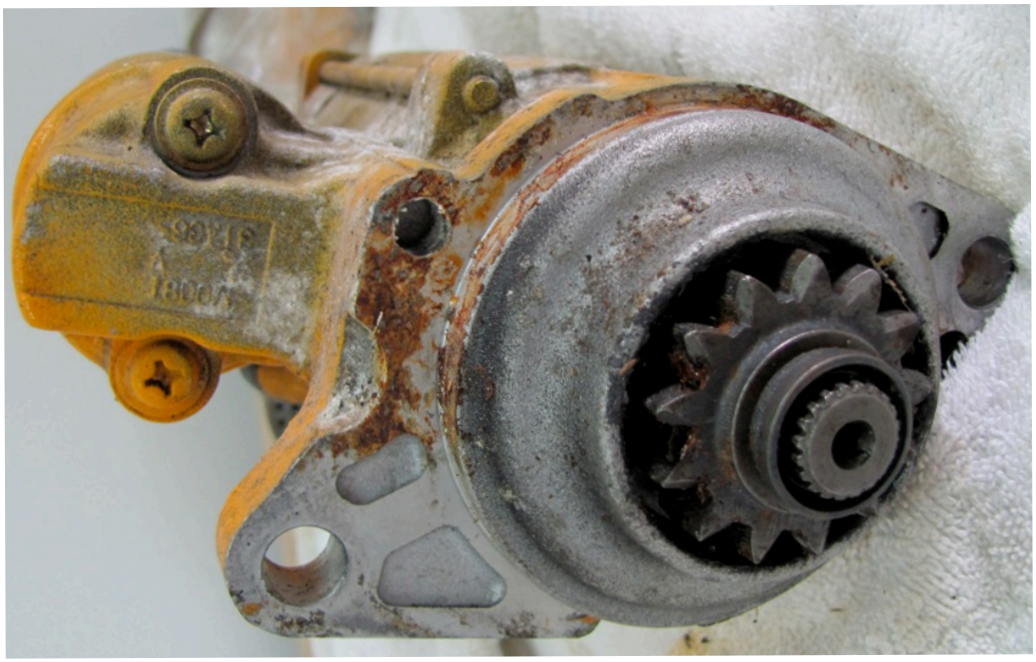
As luck would have it, several key parts had to come from Holland – 8 weeks delivery unless I pay a $100 premium. The big concern here is the pitting of the heat exchanger, and I don't want to wait 8 weeks to resolve this. So, I'm determined to get the o-rings elsewhere. I started locally – no luck. I called Vetus and they were kind enough to give me the sizes (actually the sizes are listed in the parts manual). By the way, in spite of the high prices, Vetus has been very helpful with this project. John Miller in their Baltimore office, has been super. Given the sizes, I was able to find the o-ring for the raw water pump at McMaster-Carr, but I can't find the heat exchanger o-rings anywhere. I did find one that's close (same OD but 3mm x-sect. instead of 2.5mm). So I placed the order with McMaster-Carr.

I also found the old temperature sensor in a box of parts that came with the boat. I found a suitable seal washer at a local auto parts store. So at least I have a way to plug the hole until the new sensor comes in (I assume that the old sensor doesn't work or why would they have replaced it with a plug?). The problem is that the steel plug left a lot of rust in the threads, so I'll need to buy a tap and clean the threads – $50+, ouch.

A hose runs from the raw water pump to the heat exchanger. This is a custom hose from Vetus, with one end expanded to fit the larger fitting on the heat exchanger. The original hose seems to be in good condition, but the previous owners added a pipe fitting and a short piece of hose to the end that connects to the pump. Why? I don't know. Once I get the o-ring from MC and install the pump, I'll attach the hose to see what's going on. I might have to order a new hose – another expense, another delay!

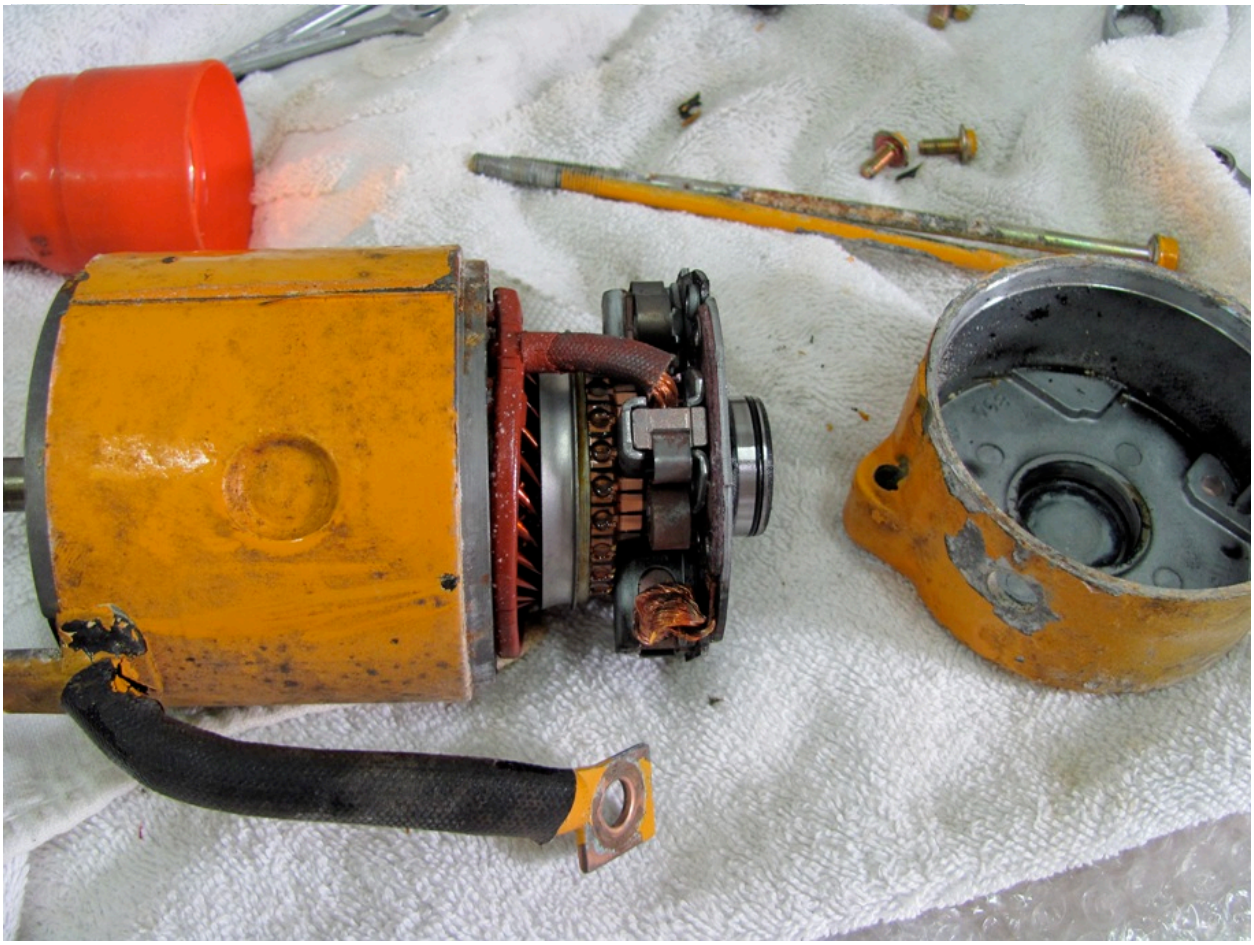
Starter:

The starter looked ok from the outside – a bit of corrosion, but not too bad.



I decided to take a look on the inside, just to be sure. Oh boy! The manual describes in fair detail how to disassemble and inspect the starter, but as I found out a bit later, not this particular starter! First you remove two Phillips head screws holding the solenoid.

Unfortunately, the screws were Locktited in place and I destroyed the heads getting them out – at least I got them out. Next, remove the two long bolts holding the chassis together. Even though there was some corrosion, they came out without a hitch. Then two screws holding the brush holder – no problem. This allows you to remove the rear cover. It's a bit of a tug because the rear armature bearing seats into the cover. This bearing has a tiny o-ring in a groove around the outer race. I'm not sure of its purpose, and the manual doesn't mention it. There is also a thin thrust washer in the case, but it didn't come out easily, so I left it alone. The pic below shows the rear case (right), the long bolts, the short brush holder screws, the armature still in the housing, the brush holder with brushes on the commutator, and the rear bearing with o-ring. The "red" thing is a flashlight.



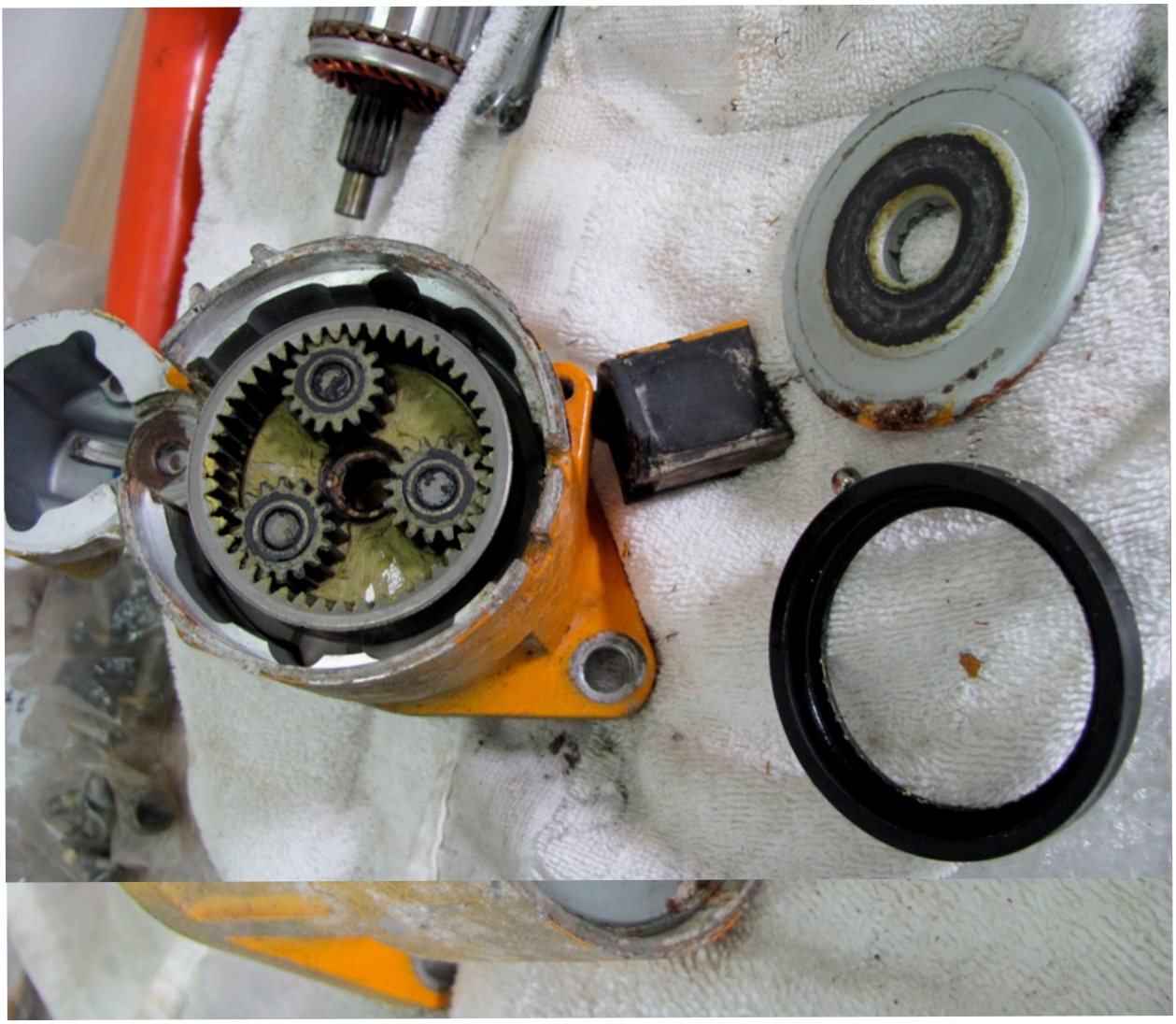
Now the fun part! Removing the brush housing from the armature. There are 4 brushes, two that are wired to the brush housing and two that are wired to the stator. All 4 have stiff springs holding them down against the commutator. You have to pull the springs clear of the stator brushes to get the brushes out. The springs are quite stiff and there isn't much slack in the wire, but I was able to get them out. Then you can slide the brush housing off the commutator, at which time the remaining two brushes snap down deep into their holders. Wait 'til you see the fun I had putting them back.

Anyway, the brushes are like new. In fact, I then noticed that there is a small inspection port on the case, covered with a rubber grommet, that allows you to inspect the brushes with removing anything! Why didn't the manual tell me that? Oh well, I wanted to inspect the gears anyway.

With the brush housing removed, I can pull the armature free of the case. All of a sudden I see a single ball bearing laying on the bench! Where did that come from? From what I can see, it must be a thrust bearing for the end of the armature. Well at least that's where I'm putting it, because the manual doesn't mention it.

Now I'm ready to get to the gears. The case comes apart in three sections. The rear case, a middle case that holds the stator, and the front case that holds the gears. The front case has a plate covering all the gears. There is just a hole in the center to take the splined shaft of the armature. (The black piece to the right in the pic below is a rubber grommet that fits on the top of the housing.)

I can't see much of anything. So while I'm trying to see how to remove this plate, it happily chooses to cooperate by falling out! This reveals a large rubber seal and also drops out. Now I can see that this is a planetary drive, quite unlike what the manual describes.



The three planetary pinions come out without a hitch, but to pull the rest of the gear train, I've got to remove the main pinion gear – the one that engages the flywheel. Well the manual is quite clear on this procedure. The pinion is held in place with a special snap ring and a collar that locks it in place.

You find a socket that fits the outside rim of the collar but has a hole big enough for the shaft, and you hit it with a hammer. In theory, the collar slides down the shaft clearing the snap ring, which you can then remove. In theory! Well I hammered … and … hammered a bit more … nothing. Then to the arbor press … still no luck. Then I realized that you have to shim the planetary apparatus from the underside to give the collar enough travel downward. A bit more hammering and it came free.

Now the manual says this procedure effectively destroys the snap ring – although it looks ok to me – so I'm to replace it. I wonder if this is a standard part for a starter? Fat chance! Well, we'll deal with that later.

Now that the pinion is out, I should be able to slide the gear train out the rear. But it doesn't come free. Oh, I can now see that there is a yoke that connects the solenoid to the gear train. When the solenoid is energized, this yoke extends the pinion out to mesh with the flywheel. So I have to remove the yoke, but the yoke is locked into place with a plate that is CRIMPED to the housing. If I remove it, I'll have no way to keep it in place when I put it back! So my goal was to

inspect the brushes and gears. Instead, I can't see most of the gears and the brushes could have been checked through the inspection hole (although, frankly you can't see much through that hole – you would have to know what to look for.).

Well, now I get to put it all back together! First, I have to reinstall the pinion, but I should replace the snap ring. Checked all the auto parts stores – no luck. I did get a tip about a small starter repair place nearby – Milesburg Auto Electric. Darned if that guy didn't have the part in stock! Not only that he explained how to install it and the brushes – although he assured me that it wouldn't be fun!

The trick to installing the snap ring is to put the collar on the shaft, push down on the spring loaded pinion, and slip the snap ring over the shaft into a groove cut into the shaft. Now the tricky part … while pulling up on the collar, you compress the snap ring with two small screwdrivers. At best, this requires three hands! So, I called on a neighbor for help. I machined a tool to slip under the collar to provide the upward force, and the two of us were able to get the collar to snap into place.

Now I assembled everything in reverse order (new lithium grease on the gears that I could reach) until I got to the brushes. The plan is to retract the two brush still in the housing so that the housing straddles the commutator. Then, you install the remaining two brushes that are wired to the stator. I found that I could retract the first brushes most of the way by hand and insert small pins under the springs, holding them in place. This allowed me to slip the brush holder over the rear armature bearing. Then with a pair of snap ring pliers, I was able to retract the brushes enough to get them onto the commutator. Now for the last two brushes. In anticipation of this step, I passed pieces of string underneath the springs. Then pulling on the strings, I was able to retract the springs enough to insert the remain brushes.

The rest of the assembly went fine. I replaced the Phillips heads screws with hex-head bolts – lock washers under the small screws and medium Locktite on the main bolts. Using jumper cables from the van, I tested the starter. Ran smoothly.

Transmission:

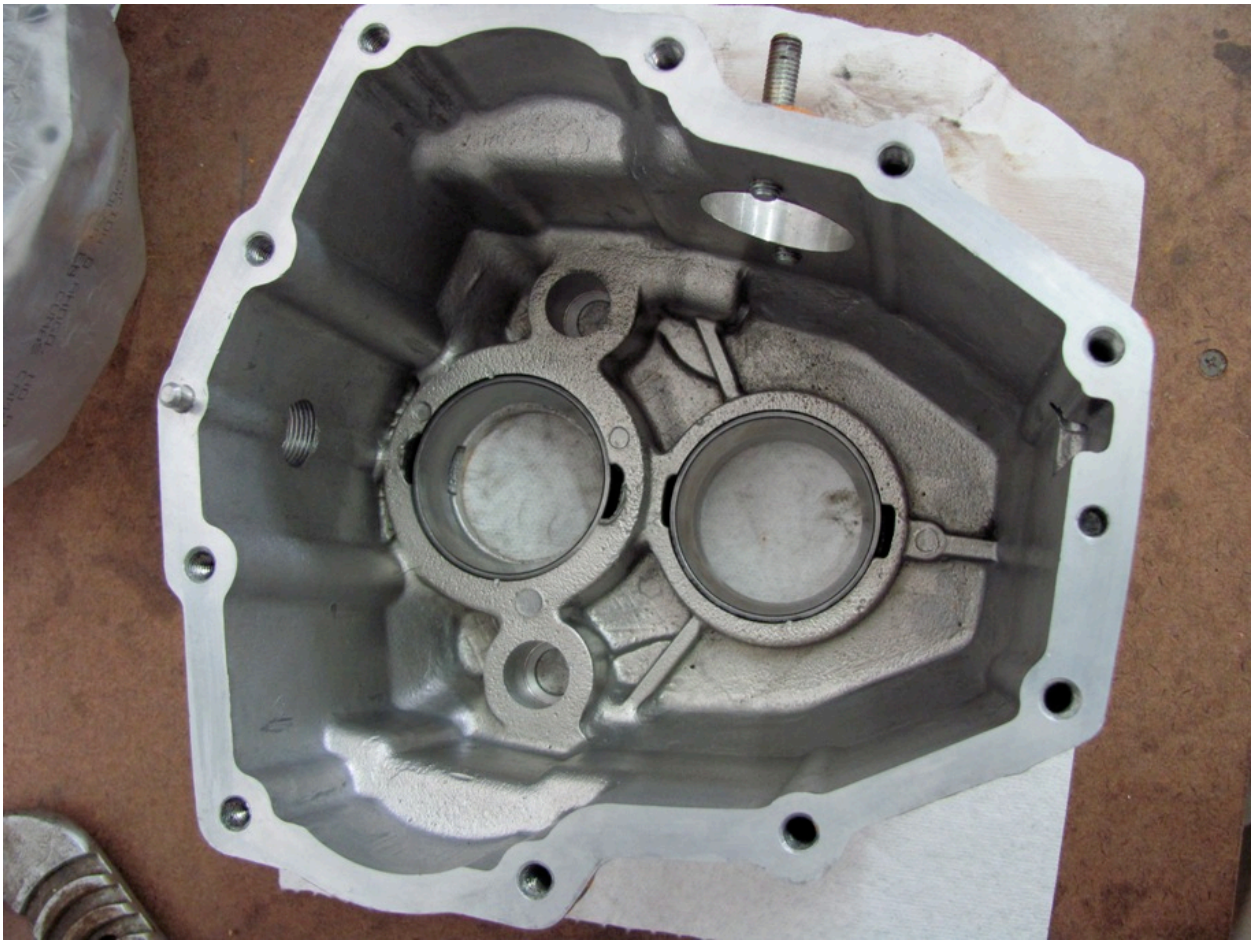
This is another component that may have been best left alone. But not knowing the history of this engine, it's risky not to inspect everything. So the first step is to get the service manual. After some research, I found my transmission was made in Italy under Technodrive, model TMC 60M, but in the US it's a Twin Disc MG360, with a distributer (Transmission Engineering Co.) in PA. From them I got the manual and ordered replacement seals. The manual is a bit on the terse side and a somewhat inaccurate translation from Italian. Not that I can read Italian. It's just that when the manual says to connect part A to part B and there isn't a part B, I know something's a miss.

The disassembly went ok and everything looked fine, except possibly one of the bearing cups. This transmission is equipped with tapered roller bearings, which are required to be preloaded. To accomplish this, shims are installed behind one cup on each of two shafts. The shims are sized to provide the necessary preload. One of the bearing cups with shims is shown below.

Now to prevent the cups from rotating in the housing, they should be pressed into the housing; however, I was able to remove both cups by hand. The pic below shows the housing with the cups removed.

So on reassembly, Carson recommend that I Locktite them in place. This was a bit tricky because the thin shims did not lie perfectly flat, so the cups had to be installed under pressure. So after

applying the Locktite, I installed the shafts and bolted the housing together until the Locktite cured. I then disassemble it again, applied ATF (automatic transmission fluid) to the bearings and reassembled for the last time. The pic below shows the housing with cups installed.



Here we see the three shafts. Top is the input shaft, middle transmission shaft, bottom output shaft.

When the seals come in, I'll install them and adjust the shift mechanism per the manual. My only concern is that the output shaft now turns somewhat harder than before I took it apart. Carson assures me that this is not unusual because of the preload and should get better after the transmission has been "run in." In retrospect, I should have checked the preload (measure the shaft end play without the shims and then check that the shim thickness is correct). I assumed that if the preload was right before I opened it, it should be fine afterwards. I did read later on a web site that you should rotate the shafts as you tighten the bolts so that the bearings self correct any misalignment, but I didn't know to do this at the time. There is also a VERY small chance that I interchanged the shims. I did label them with marker when I removed them and kept them in separate baggies, but I inadvertently removed the marks when I cleaned the parts. I could disassemble everything again to measure the preload, but this would be a lot of work. Not to mention that I'd have to deal with the Locktite on the cups.