Budget 351C Rebuild

Dave McLain (McLain's Automotive Cuba, Missouri) recently rebuilt and dyno tested a 351 Cleveland for Lori Drew's Pantera. Lori is married to Pantera Owner's Club fixture Mike Drew and they own his and hers Panteras. Lori's is a 1971 model with 95K miles on the odometer but the engine was leaking and burning oil and detonated badly under acceleration. At a Pantera Club of Northern California (PCNC) tech session, a valve cover was removed and the engine started briefly to discover one of the rocker arms was barely moving, a clear sign a lobe had worn off the cam. Dave had previously built a 408 cubic inch stroked Cleveland for Mike's Pantera that Mike was very happy with so the decision was made to pull the engine, crate it up and ship it to Dave for a rebuild. Mike reused the crate and steel engine cradle that Dave had made to ship Mike's 408C. Along with the engine, Mike had collected a bunch of parts over the years that he packed in the crate. All totaled, the shipping crate weighed nearly 850 lbs.

Mike and Lori's instructions were to perform a basic rebuild, re-using as many parts as possible to keep the cost down. A generous Pantera Owners Club member donated a set of lightly used (approximately 1000 miles) Ross pistons on a set of stock connecting rods that were fitted with ARP rod bolts. The pistons are part number 80556 which are a forged flat top with 1.668" pin height, large single valve relief and 1/16", 1/16", 3/16" ring grooves.

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Ross_Piston_polished_rods_zpsvy3nm6r4.jpg[/IMG]

Assuming a block deck height of 9.213" and 0.050" piston to head clearance (block plus compressed head gasket) and closed chamber heads, the static compression ratio should be approximately 10.4:1. In addition to the pistons, we'd be re-using some low mileage parts that were on the engine:

Ford Motorsports double roller timing chain set
Aviaid gated and baffled Pantera oil pan
Edelbrock Performer 351C-4V aluminum dual plane intake manifold
Holley 650 double pumper carburetor
Ford distributor with Pertronix ignition module
Robert Shaw thermostat
Crane plug wires

The roller timing set is one that Mike and I picked out at Summit Racing in Reno, NV several years ago. We had them bring out a bunch of timing sets and opened the boxes to check the chains. The Ford Motorsport set used the good Renold chain from France while many of the other boxes contained the poor quality Rolon chain from India. The Holley 650 DP carb was one that Mike had first put on his Pantera in 1989 and later moved over to his GT350 clone Mustang. Mike had it worked over by fellow Pantera owner and Roush employee John Christian. While we might have been tempted to toss the used thermostat in the can, the high quality Robert Shaw unit was nearly new and unfortunately the Robert Shaw units are no longer available new. The right thermostat is crucial in a 351C as it needs to have a shoulder that matches the restrictor ring in the block so that the bypass port works as intended:

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/OHOnews21of38_zpsrl5zhn8v.jpg[/IMG]

The Cleveland thermostat is not shared with other Fords. Using a Windsor thermostat (which the parts counter monkeys will often try to give you) will lead to over-heating because coolant will bypass the radiator. The same thing happens if you remove the thermostat. Mike specifically requested we use a Fel Pro 35041T thermostat gasket, instead of the typical paper gasket, as the Fel Pro can be re-used. FWIW, the paper ones seal well with a light coating of Permatex Form-a-Gasket but need to scraped off when replacing the thermostat.

After the engine was pulled, it was noticed the block did not have a serial number stamped on the back, as DeTomaso normally did, and it was a four-bolt-main block. Except for the Boss 351, closed chamber headed Clevelands generally left the factory mounted on 2 bolt main blocks which means the block (or possibly the entire engine) was replaced somewhere in the vehicle's past. Disassembly and inspection revealed what appeared to be a stock short block in good rebuildable condition. As expected, the cam had a flat lobe. Dave plotted the cam and the specs (196/204 degrees @ 0.050", 117 degrees lobe separation angle, installed on a 114 degrees intake centerline) suggest it was a stock 1970 to early 1971 part. The heads were verified to be of the desirable closed chamber variety but did not have the original (and failure prone) Ford valves. The intakes checked out and were the right 2.19" diameter for the seats but had 0.100" longer stems. The exhausts were 1.65" diameter. However, all the valves had the OEM multi-groove loose-fit keeper design and were replaced with new single groove stainless valves from SI in the standard Cleveland length and stock

2.19"/1.71" diameters. Hardened seats were installed and the left had side cylinder head had 4 bolts broken off that Dave had to extract. The stock pedestal mount rocker arms were inspected and found to be in good condition but are of the lugged variety:

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Lori_Drew_stock_rockers_showing_oil_zpshtqc6y6n.jpg[/IMG]

There are two types of stock 351C rocker arms (lugged and unlugged):

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/OHOnews16of38_zpsdsyg293s.jpg[/IMG]

The ones with a lug on top have a clearance problem with cams of 0.550" or greater lift. The pushrod tube can contact the lower position of the rocker arm when the valve is fully open. Dave compared the two styles of rockers side-by-side and there is a noticeable difference back under the pushrod seat where the angle up from the bottom of the pivot is less steep on the lugged style and would get closer to the pushrod. He noted it would really be a problem if a 3/8" diameter pushrod was used. I offered up a Crane rocker arm guideplate conversion kit and 1.7:1 Crane roller rockers but it was ultimately decided to keep the lugged rockers and just limit the lift of the cam. In keeping with the budget rebuild theme, a hydraulic flat tappet cam was chosen with emphasis was on low and mid-range performance with a 6000 RPM red line, assuming 91 octane fuel. Mike had run a Comp 280H Magnum flat tappet cam in his Pantera's previous 351C (open chamber 4V heads with domed pistons and Blue Thunder dual plane) and found it pretty lazy below 3000 RPM so wanted something that worked better down low. The Comp 280H has 60 degrees of overlap with specs of:

Comp 280H Magnum 280/280 degrees seat duration (230/230 @ 0.050"), 0.530"/0.530" lift, 110 LSA

So we'd likely be looking at something around 54 degrees of overlap. Specific instructions from Mike were:

"The goal is to maximize torque in the low- and mid-range, with a 5500 RPM power peak and 6000 shift point. This engine will never see more than 6000 rpm so there's no need to build it with a cam that is dead down low, and would continue to build power at 6500-7000 rpm. For simplicity and cost sake, this means a traditional non-roller hydraulic cam."

I had some time to kill on a flight to Finland, so I modeled the engine in Dynomation and ran a bunch of off-the-shelf hydraulic flat tappet camshafts through, along with a few mild hydraulic rollers. Some of the cams evaluated were:

Isky 264 Megacam 264/264 (214/214) 0.525"/0.525" 108 LSA 2000-5800 RPM
Isky 270 Megacam 270/270 (221/221) 0.542"/0.542" 108 LSA 2000-6200 RPM
Lunati 10320311 275/275 (225/225) 0.550"/0.550" 108 LSA 1800-5800 RPM (old p/n 07111)
Erson E220421 296/296 (228/228) 0.545"/0.545" 108 LSA 3000-6000 RPM
Bullet 138268 268/268 (218/218) 0.528"/0.528" 110 LSA Good idle, good street and off-road performance.
Lunati 10320302 276/276 (221/221) 0.524"/0.524" 110 LSA idle-5600 (identical to Ultradyne below)
Ultradyne 276/276 (221/221) 0.524"/0.524" 110 LSA Performance and economy for 4WD's, pickups, and Panteras.
Elgin E-1801P 284/284 (222/222) 0.539"/0.539" 110 LSA
Crower 15173 280/287 (219/225) 0.530"/0.524" 110 LSA 2300-6300, 3800 RPM peak torque, 5700 RPM peak power
Crower 15174 289/295 (227/233) 0.555"/0.547" 110 LSA 2400-6400, 3900 RPM peak torque, 5900 RPM peak power
Erson E220222 284/296 (220/228) 0.545"/0.545" 110 LSA 2500-5500, strong mid-range
Comp Cams 270H 270/270 (224/224) 0.519"/0.519" 110 LSA
Comp Cams 280H 280/280 (230/230) 0.530"/0.530" 110 LSA
Bullet Custom 1 275/275 (223/223) 0.567"/0.567" 109 LSA Bullet HF275/328 CRA lobes (Ford lifter diameter)
Bullet Custom 2 275/277 (223/228) 0.567"/0.580" 111 LSA Bullet HF275/328 and HF277/335 CRA lobes
Reed TM276H-11 276/276 (223/223) 0.543"/0.543" 111 LSA

Many of the profiles were eliminated with the decision to stick with the lugged rocker arms due to the maximum lift considerations. I also evaluated all combinations of the following Reed Torque Master lobes:

Seat...0.050" Lift (w/1.73:1 rocker ratio)
252....205....0.497"
264....214....0.519"
272....218....0.531"
276....223....0.543"
280....227....0.548"

Dave likes the Torque Master lobes. They are quiet, reliable and run well. Since the engine won't be spun past the HP peak very often, there's no need for the usual extra exhaust duration so a single pattern cam was picked. Also, on a 351C with 2.19" canted valves, I might widen the LSA to 111 degrees to reduce reversion but, with the minimal overlap, that's not an issue so we stayed with a 109 degrees LSA. The cam was sourced through Steve Demos (formerly of Reed Cams) and with the smallish 650 CFM carb, small port dual plane intake manifold and shorty Pantera headers is quite mild:

Demos 272H-109 272/272 (218/218) 0.531"/0.531" 109 LSA 108 ICL

Valve springs are PBM/Erson 3100 set at 1.810" intake and 1.860" exhaust for loads of 110 lbs seated, 270 lbs open intake and 93 lbs seated, 250 lbs open exhaust. There were no signs of valvetrain instability on the dyno up to the 5800 RPM maximum that was run on the dyno.

IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Lori_Drew_rockers_springs_zps8kzaiusa.jpg[/IMG]

All the older dual plane intake manifolds we've had on the flow bench have had good and bad runners and have benefited from plenum entry work. Dave did some minor work on the plenum and port exits and welded the exhaust crossover shut:

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Lori_Drew_Performer_plenum_zpsbtdzu2ot.jpg[/IMG]

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Lori_Drew_Performer_runner_roof_zpsfmub3uot.jpg[/IMG]

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Lori_Drew_Performer_runner_zpskf3l6dn0.jpg[/IMG]

On the dyno, the engine was tested with the restrictive Euro GTS headers and ANSA mufflers but will get the stainless steel Wilkinson Euro GTS replacements that performed much better in previous testing. This shot shows the entire Euro GTS Pantera exhaust with the mufflers rotated to clear the dyno:

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Lori_Drew_GTS_headers_mufflers_zpshcxahdp9.jpg[/IMG]

and a shot from the front showing just the headers:

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Lori_Drew_351C_on_dyno_zpsukbzjwso.jpg[/IMG]

The Pantera Euro GTS Ansa muffler bodies are quite small with long tips:

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Lori_Drew_GTS_mufflers_zpsex7zrshf.jpg[/IMG]

and the GTS headers are oddly sized with large 2" outer diameter but short (16 to 22 inches typically) primaries along with a short tri-y style collector having a small 2 1/4" ID outlet:

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Lori_Drew_GTS_headers_zpsipaecpjs.jpg[/IMG]

In testing, the headers do pretty well on peak power but give up quite a bit of peak torque (25+ ft-lbs) when compared

with more conventional long tube headers. The mufflers are quite restrictive, costing on the order of 50 HP on 500+ HP engines.

When Dave first fired the engine, it didn't sound so hot so he pulled the donor plug wires off and replaced them which made the engine sound much better. Turns out several of the wires were bad. The cam was broken in, rings seated and some pulls made to optimize the timing and jetting. With the closed chamber heads, best timing was 14 degrees initial and 36 degrees total. Dave ordered a 4 hole 1 inch tall spacer that he modified into a design with two oval shaped holes to match the oval holes on the dual plane Performer intake.

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Lori_Drew_phenolic_spacer_zpsfafucadx.jpg[/IMG]

The spacer helped torque by about 5 lbs-ft but peak HP was unchanged. The best pull was with the GTS headers but without the ANSA mufflers:

378 HP @ 5700 RPM
396 ft-lbs @ 4100 RPM

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Drew%20351C%20No%20Mufflers_zpsjzywch24.jpg[/IMG]

With ANSA mufflers and a 1" spacer, it made:

355 HP @ 5800 RPM
388 ft-lbs @ 3900 RPM

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Drew%20351%20C%20With%201%20Inch%20Spacer_zps0g1rzpnj.jpg[/IMG]

The ANSA Euro GTS mufflers cost 23 HP and 8 ft-lbs on this combo. The non-GTS ANSA mufflers are even more restrictive while the Wilkinson exhaust should be closer to the open header pull. The engine ended up peaking at 5700 RPM with nearly 400 ft-lbs of torque so I'd say we pretty much nailed Mike's request. With their overly large ports, its easy to kill the bottom end on a 351C-4V with the wrong combo (too much cam, not enough compression, wrong intake and/or headers) but this build demonstrates that with nothing more than a well thought selection of parts and careful assembly, a 351C-4V can make quite respectable torque in a daily driver RPM range.

If you were to remove the lift restriction imposed by the lugged rocker arms and run more aggressive hydraulic flat tappet lobes, there should be more power to be had, even with the same modest cam overlap. I ran a cam of the same 54 degrees overlap but using more aggressive cam lobes:

Bullet 275/277 (223/228) 0.567"/0.580" 111 LSA

through Dynomation and, with no other changes, the simulation predicts an additional 13 HP peaking 200 RPM higher. The lobes might be a bit noisy, though. If you were to build a similar engine for a Mustang or Cougar, previous testing of 1 3/4" long tube Mustang headers have added 25 to 30 ft-lbs of peak torque and the MPG Stinger exhaust stuffers were also worth some peak torque. If the intake doesn't have to fit under a stock Pantera engine screen, I'd wager there's another 20 to 25 HP to be had with an Edelbrock Performer RPM Air Gap high rise dual plane and, perhaps, a carb with 50 more CFM. For comparisons sake, here are some A/B measurements I made of the various dual planes available for the 351C. The measurements represent the drop from a straight edge laid across the carb pad to the closest point where the end rail bends inward (each end). Measurements are in inches:

Intake	A	B
Edelbrock F-351 Performer 4V	3 3/4	4 3/8
Edelbrock Performer RPM Air Gap 2V	4 1/2	5 5/8
Ford aluminum 4V	3 1/4	4 3/8
Scott Cook	3 3/4	5
Blue Thunder/Shelby/Holman Moody	4 7/16	5 3/8

Note that both the Scott Cook and Blue Thunder dual planes are the canted pad versions but both are available with flat carb pads for Panteras that mount the engine level. Note that, being an air gap design, the Performer RPM would be slower to warm up.

I'm quite interested in hearing what Lori's Pantera does for fuel economy. If I'd thought of it at the time, Lori's engine would have been perfect to test my ported spread bore Offenhauser Dual Port intake manifold with Carter Thermo-Quad. The vacuum advance unit on the Ford distributor was blown so Dave replaced it with a single diaphragm style that is adjustable and measured how much each turn of the adjustment changes the total:

[IMG]http://i1127.photobucket.com/albums/l621/danielcjones2/351%20Cleveland%20Stuff/Lori%20Drew%20351C/Lori_Drew_351C_vacuum_advance_zpsldclegoc.jpg[/IMG]

Dave connected it to the ported vacuum source so it is not active at idle and one turn on the adjustment equals 5 degrees change in the amount of timing it can add to the engine under light load conditions. There's one turn of adjustment "into" the pod so it gives the engine five degrees more when its at part throttle above idle. In the Pantera, with the center bulkhead cover removed, there is access to the front of the engine so Mike and Lori can adjust it from there for best cruise fuel economy. Here's a link to a video of Dave messing with the carburetor/idle settings and the vacuum advance:

https://onedrive.live.com/redir?resid=a9d064308c1f92bf!87848&authkey=!AGb4h-XRCGW9F1Y&ithint=video%2cmp4

Overall, the engine parts list looks like:

Holley model 4777 650 CFM double pumper carburetor with added electric choke
Edelbrock Performer 351C-4V aluminum intake manifold (with port and plenum work by Dave McLain)
Closed chamber 4V Cleveland heads
Valve job, hard exhaust seats and resurfaced, machined for Viton seals intake and exhaust
SI stainless valves in stock 2.19"/1.71" sizes
PBM/Erson 502S retainers
PBM/Erson 3100 valve springs set at 1.810" intake and 1.860" exhaust for loads of
110 lbs seated, 270 lbs open intake
93 lbs seated, 250 lbs open exhaust
Ford Motorsport aluminum valve covers with baffles that are welded in place to keep oil off of PCV and breather
351C block bored to 4.020 bore size (with 3.5" stroke = 355 cubic inches displacement)
Ross flat top forged pistons
Ross forged flat top pistons, part number 80556, single large valve relief, 1.668" pin height
Mahle 1/16", 1/16" 3/16" standard tension ring set
Ford 351C connecting rods, polished, shot peened, ARP bolts
King rod and main bearings, 0.002", 0.0028" clearances
Ford 351C crank, polished, rotating assembly balanced
New Power Bond damper
Stock timing pointer corrected
Engine Tech gasket set
Ford Motorsport timing set
Aviaid gated and baffled Pantera road race oil pan and matching pickup
Stock volume/pressure Melling M84A oil pump
New Melling oil pump drive shaft
Joe Gibbs BR oil(8quarts)
Hastings LF 115 filter
Custom grind flat tappet hydraulic cam from Demos Cams using Reed 272H Torque Master lobes:
272/272 seat duration, (218/218 degrees @ 0.050"), 0.531"/0.531", 109 LSA installed on 107 degrees ICL
Stock Ford 351C non-adjustable rockers (with oil deflectors) and pushrods
Distributor is stock Ford with a Pertronix Ignitor kit and adjustable vacuum advance
Autolite 25 spark plugs gapped at 0.045"
Edelbrock aluminum water pump

Here's a shot of the assembled long block:

ori was pleased the that the total cost of the engine build, including intake and head work and a full day of dyno tuning came in at less than $3000.

Dan Jones