Rebuild Manual for the Boge Electronic CDS Strut (controlled damping suspension) used on the Alfa Romeo 164S, 164Q, 164QV

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Special thanks to Soren Snitker for donating a pair of old CCD struts for the benefit of this project.

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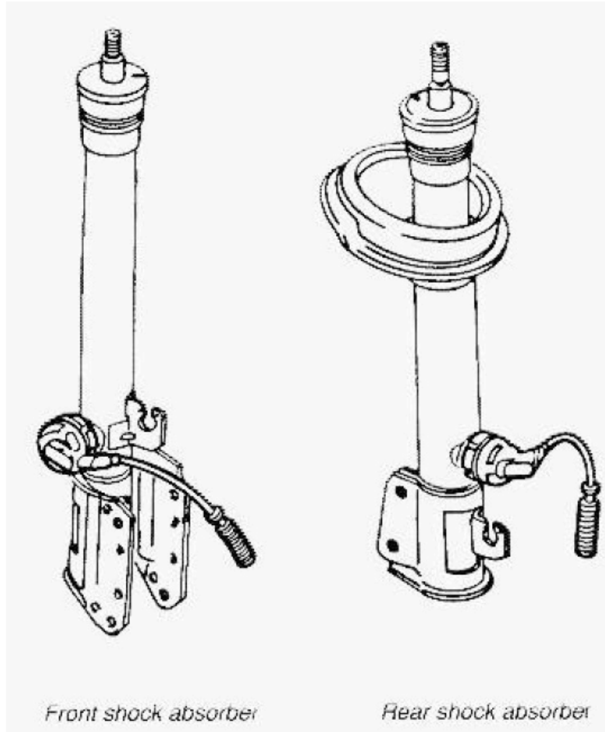
n.b. Manual now addresses the *complete breakdown* of the strut including the removal of the inner tubes, disassembly of the piston and solenoid assembly, and salvaging of CDS struts with non-CDS parts



The Boge CDS struts used on the Alfa Romeo 164 are of the highest German manufacturing quality for their time and purpose. According to the manufacturer they feature:

- induction hardened, chrome-plated piston rods, machined and super polished to exact roundness.
- superior double lip, low-friction seals for long life and consistent performance
- calibrated piston and foot valves
- valves flow-rated, calibrated and tested to be within 1% of engineering tolerance
- seamless cylinder tube according to the highest quality Swiss seamless steel tubing technology

These positive features along with the horrendous replacement price for electronic-type struts (ca. $1000/unit) are just some of the reasons that justify rebuilding these unique components when they are leaking or are no longer performing well. Poor performance is usually first noticed on the “auto/soft” setting with too much sway or “wiggle”, or when the unique floating quality of the suspension becomes exaggerated; very seldom will the “sport/rigid” setting (= default) lose its special stiffness unless the struts have lost too much oil. There is one caveat to the rebuild: the piston rods must be in unblemished condition without any significant pitting, scoring or loss of chrome and naturally the solenoid must be functional. Regarding possibilities for salvaging a CDS strut with non-CDS parts, including rod and inner tube, see the **Appendix 1** of this document.

The rebuilding process is particularly simple thanks in part to the fact that the internal replaceable parts for front and rear struts are few and identical, not the case with most other cars with CDS struts. A rebuild will cost as little as $50-$100 a unit. It will involve dismantling, cleaning, replacing 3 essential seals—improving on the design of the top mechanical seal—installing new synthetic oil, adding a Schrader valve and regassing with nitrogen*. The addition of the Schrader valve in itself represents a significant improvement, allowing monitoring of the pressurized system and periodic topping up if necessary. For a final touch it is recommended that the strut be sent to a facility that has a strut dyno (ideally the Roehrig dyno) so that the rebuild can be verified with a printout graph showing its damping curve. You will then be able to compare the results with our rebuild (see pp.17-18) and with others who will have posted (we hope) their graphs on the Alfa Bulletin Board. It must be underlined that the aim of the present rebuild is not to alter rebound or compression damping characteristics, only to “restore” the strut’s original performance specs as designed by Alfa and Boge engineers. While no single graph can represent a “base-line” of performance, several graphs will get us very close.

*note on nitrogen: Based on an undocumented report from an individual involved in the development of the BOGE CDS system, dry compressed air, was used to pressurize the original unit. However, nitrogen is superior to compressed air because it expands and contracts very little with temperature changes, It keeps the shock cooler, and its molecules, being larger, are less prone to leaking at the seals. It also prevents the oil from cavitating (forming air bubbles) as it’s forced through the valves. The original charge of compressed air was reported to be 4-5 bar (58-72 psi). It is recommended that the charge of nitrogen be kept the same.

Before commencing with the rebuild procedure it is best to summarize how the Boge CDS struts work and to address what parts wear out. The Boge CDS strut is a twin-tube design.* The inner, or working cylinder, is where the piston and shaft move up and down. The outer cylinder serves as a reservoir for the hydraulic fluid. There is one clever addition in the design of the CDS strut: an additional chamber for oil, made available by a solenoid operated by-pass valve, that gives the strut two different damping settings, a “soft” or comfort setting (affecting compression and rebound), and a “rigid” or sport one. Also called “adaptive damping”, it was the Lancia Thema 8.32 that first used this feature in 1987, followed by BMW in 1988 and Alfa shortly thereafter. Like all twin tube designs there are fluid valves in the piston and in the stationary base valve.

The base valve controls fluid flow between both cylinders and provides some of the damping force, especially on the compression stroke. The valve in the piston controls most of the damping, most of it on the rebound stroke. The term “gas shock” usually refers to the same twin-tube design, but with one improvement: low pressure nitrogen gas is added to replace any oxygen air. The effect lessens aeration and performance fade.

*see this useful website for explaining pros and cons of twin-tube design
http://www.ek9.org/forum/suspension/4741-mono-tube-twin-tube-suspension-info-tein.html

Key :

A - upper oil chamber
B - lower oil chamber
C - reserve oil chamber
1 - piston
3 - upper regulating valve
4 - lower regulating valve

RIGID (solenoid valve closed) : when piston ***extends*** oil passes from upper chamber A to the lower chamber B, and from the reserve chamber C, to the lower chamber B though the regulating valves 3 and 4 to compensate for the different quantity of oil.

When piston is ***compressed*** oil passes through the valves in the lower chamber B to the upper chamber A, and from the lower chamber B to the reserve chamber C. The function of the gas present in the air space between the external body and internal cylinder is to guarantee a constant pressure for the oil present in the reserve chamber.

SOFT (solenoid valve open) : oil passes from the solenoid channel to the reserve chamber C making the dampening acting softer. During the **extension stroke** oil is also able to pass directly from the upper chamber A to the reserve chamber C through the solenoid channel (as well as through regulating valves 3 and 4). During ***compression*** stroke the volume of oil which must pass from the lower chamber B to the reserve chamber does not find strong resistance because the solenoid valve is open.

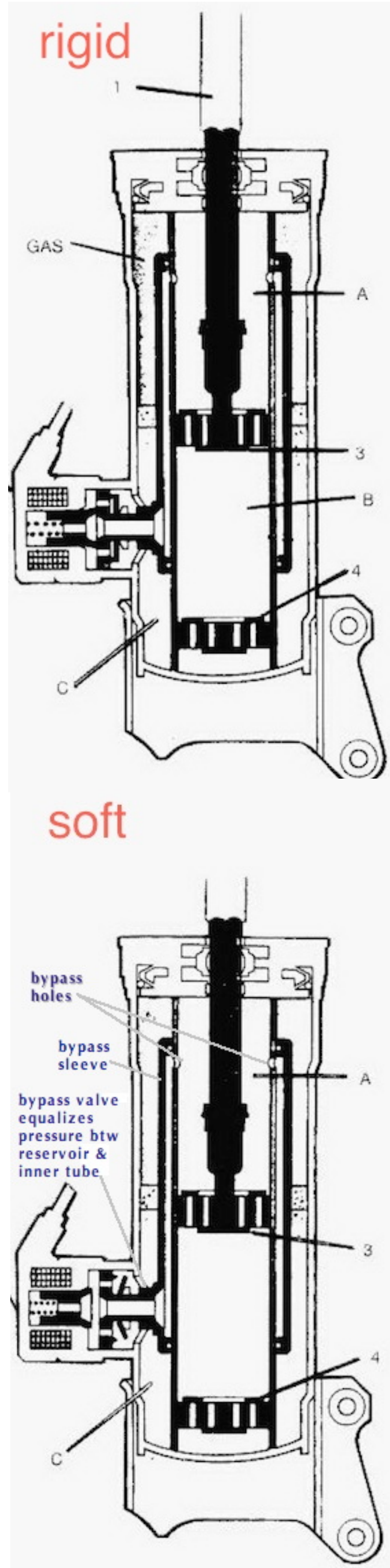


Figure 1: The Boge CDC Strut as depicted in the Alfa Workshop Manual (n.b. drawings are not to scale)

Valves seldom wear out, however, there are three important seals at the top of the Boge strut that do, and the fluid itself, over time, breaks down. Age and contamination particles in the hydraulic system are the most common reasons for the breakdown and short service life of seals. Most of the particles reach the system via the rod. ***That's why it is so important that you maintain the dust boots on your struts—it's by far the cheapest way to prolong their life.***

In the original Boge design the top wiper seal is combined in a single molding with a u-cup seal. This "double" seal rather than being housed in a seal holder is bonded to a thick metal washer (4mm thick x 4.65 mm OD) that provides the hold down thrust of the gland nut.

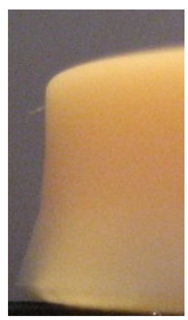
It's best to see this as an assembly: nut, washer (it sort of acts as a bearing) with integrated double seal, followed by a large o-ring (41.5 x 3mm) that is squished between the washer and the top of the rod guide/"centering bung" (the bung locks the top of the inner tube in a concentric position). While the double seal seals the rod from leakage from the *inner* tube, the o-ring seals the *outer* tube, maintaining a closed system.

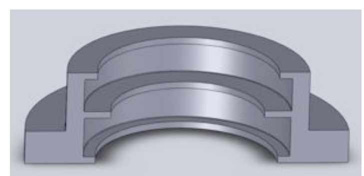
(nut side)

Since Boge does not provide any service whatsoever for these parts, and since no company makes a clone of this unique bonded double seal, our remedy—*thank you Bilstein*!—is to have a new washer/seal carrier CNC'd to "hold" two *separate* high performance 22 mm Bilstein seals from their successful 9100 offroad racing shock. Our new seal carrier will have exactly the same function: there will be a "wiper" on top (to keep dirt off the rod), and an oil seal on the bottom (keeping the strut from leaking oil and maintaining its charge of nitrogen). Everything else remains the same. These elastomeric seals are described by Bilstein as "new dual-stage" and "self lubricating"; their polyurethane construction delivers up to ten times the service life of neoprene rubber not to mention much improved sealing at low temperatures. Our carrier, machined out of 6000 series aluminum, also offers a major improvement over the "clunky" (stamped iron) washer used by Boge in that it forms a more positive seal with the top of the large o-ring (a point of leakage on an aging strut), and will not rust.

wiper seal
(top position, lips faces up)

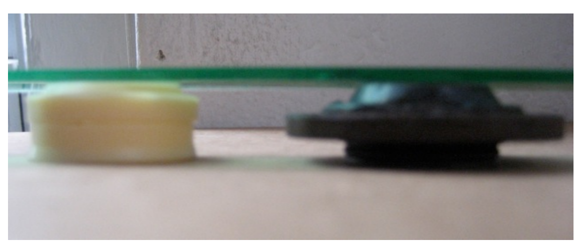
oil seal
(bottom position, lip faces down)





new seal carrier & washer (cutaway drawing)

As you can see from this photo, two stacked Bilsteins are the same height as the original Boge double seal:



Rebuild procedure

STEP 1 - get all your parts lined up

n.b. before you start buying parts be sure your strut rods are in good condition; any damage to the rod to the uppermost 5 cm will probably not be a problem as the this area is still above the seals. However if the top of the shaft is chewed up due to vise-grips being used to remove the top nut, be sure to sand down any roughness that could damage the seals during reassembly.

The list is quite simple, the quantities below will rebuild *fours* struts:

4 - Bilstein 9100 racing strut 22mm wiper seal (polyurethane 93)
part.no. 194044 $4.25 each (source: bilsteinoffroad.com)
SKF no. MPS-022-030-04,5-DT embossed on seal:
“SFK 1J72-1   22mm”

4 - Bilstein 9100 racing strut 22mm u-cup seal (polyurethane 93)
part.no. 194432 $4.15 each (source: bilsteinoffroad.com)
SKF no. UBR-125-00.875-250 embossed on seal:
“SFK 1C25-1 .875”

4 - o-rings M41.5 x 3mm Buna-N 70
$.76 each (source: theoringstore.com)

4 - Schrader valves
part.no. 191001 $3.14 each
(source: bilsteinoffroad.com)
thread size: 1/8 - 27 npt

4 - droop stop (may not need replacing!).
use standard 7/8” ID pvc vinyl tubing, cut a piece exactly 8 mm long, grind or file 6 radii on one side about 2 mm deep to match original (original: 22 mm ID, 29.3 OD, 8 mm high)

2 liters of Pentosin CHF 11S
($53)

(Pentosin is one of the recommended oils for BMW ECD struts; for 10% higher viscosity you can use LiquiMoly 1127)

Special hardware (optional, for dyno testing only)

“Stirrup” for lower strut mount so strut can be mounted in dyno “in-line” (some speedshops may charge extra for running a dyno test if they have to make this hardware). We designed this bracket to be universal for either front or rear strut; you will also need one “rod end” (14mm x 1.5mm) to screw onto the end of the rod.

Welding by Chris Bernard

female rod end 14 x 1.5mm ($14.00)
(source: midwestcontrol.com)

Optional service tools:

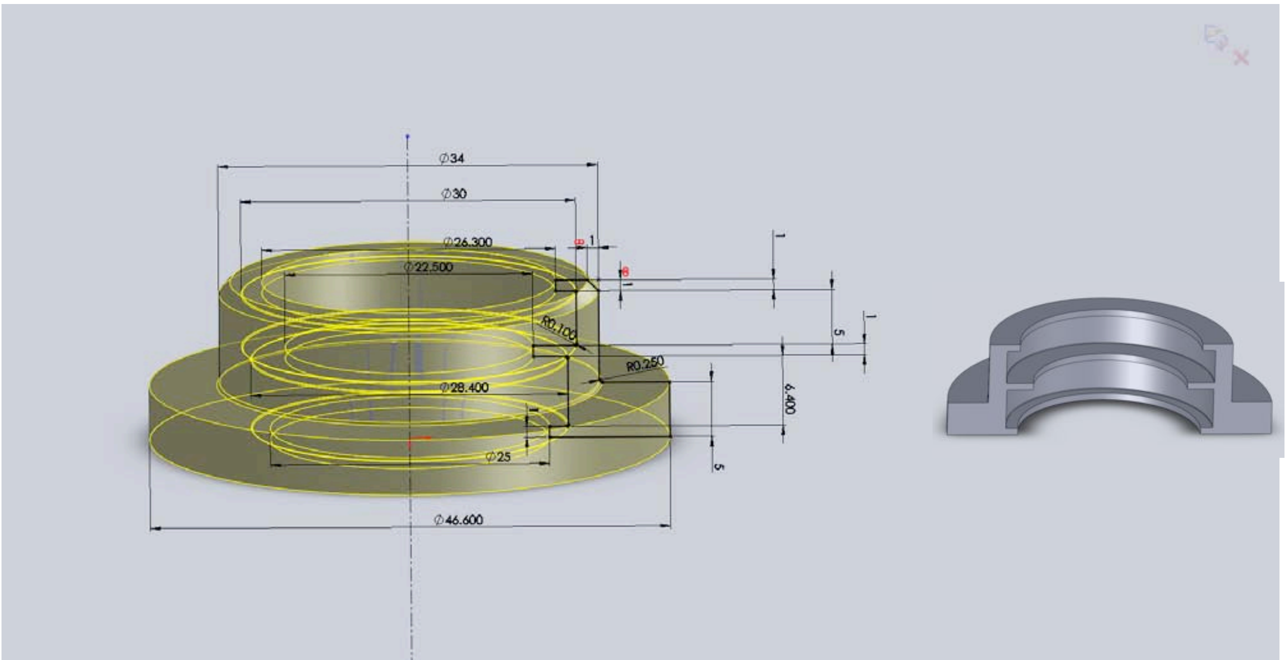
gas filling tool
Bilstein part no. 193000 ($120)
(source: teopro.com)

(far right: another fill tool, $65)
(source: trailduty.com)

beaker - *highly recommended!*
(for precisely measuring
old oil and for refilling with new)
Bilstein part no. 193020 ($15)
(source: teopro.com)

Special Machine Shop work

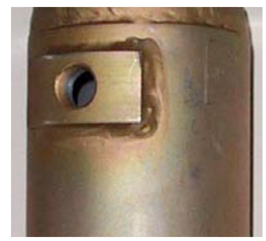
1) Have machinist CNC a seal carrier to replace the original Boge washer-seal. The material should be 6000 series aluminum and follow these specifications:



drawing and carriers by Ben Bishop

Finished carriers with the Bilstein seals installed (gland nut will slide over "top hat" of carrier)

2) Have the machinist drill and tap a hole for the Schrader valve. Best position is just below upper flange (**see arrow below**), on side that is *opposite* black cap of electronic solenoid), this way the Schrader valve will be orientated on rear side of strut tube. First have machinist drill a small pilot hole, then silver solder, braze or TIG weld a tab to the strut casing, then drill larger hole, followed by tap (1/8” - 27 NPT). *Ideally do this work with strut casing upside down so metal shavings fall downward*. **<u>Whoever does this work should pressure test the strut to be sure there are no pinhole leaks at the tabs</u>**. You should eventually wrap the threads of the Schrader valve in teflon tape before screwing it in, but for now hold off on the Schraders.



picture of “tab” to serve as base for Schrader (1/8” mild steel, ca. 1” x 5/8” bent or shaved with radius to match casing) (silver soldering by Niekamp Tool)

3) Do the same for the rear strut. Again the placement is just below the flange material, also on the *opposite* side of the black cap of the electronic solenoid.

STEP 2 - dismantling strut, cleaning strut casing and internal parts; reassemby

You will need to buy, or better, make a special tool to remove the bronze gland nut from the top of the struts in order to pull out the piston and its seals. (Our first attempt of a tool with 1” pipe failed—it kept slipping off). The tool here consists of a piece of 1 1/2” copper tube with <u>cast</u> union on one side that has been perfectly castellated (filed) to match the pattern of the nut; another piece of tubing slipped into the union prevents the tool from slipping off nut. The total length of the tool is ca.8”. It is necessary to use the strut’s piston shaft (extended) with washers and nut to “clamp” the tool in place. Applying a 18” pipe wrench on the union just above the gland nut made for easy removal of the nut.

- tool inserted in gland nut

Warning: the gland nut may be very tight so bolting the strut casing to something heavy and stable may be necessary (we used the back blade of a tractor); a large vise might work too but be careful not to scar the casing). Using a drift punch may seem to be the “easy” way to remove the gland nut but this is not recommended as you will definitely destroy nut this way and new nuts are not easy to source.

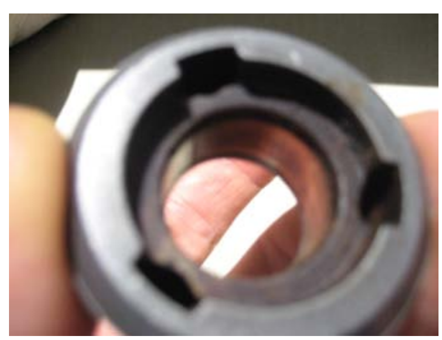
Pull out—*slowly*—the piston assembly (if it sticks you can use a slight ramming action with the piston) and lay it on a clean cloth; drain the oil from the strut casing; for documentation-sake, you should measure the exact quantity of oil that came out—the special Bilstein beaker is perfect for this task. As you proceed keep in mind that the dirtier the fluid, the more care and concern necessary in the cleaning and flushing operation of the internal parts. A low mileage strut may be relatively clean with fresh looking oil, while a high-mileage one, depending on climate and driving habits, may look like a cesspool.

Here is the whole piston assembly laid out; only the items on the lower right side of the photo need to be attended to. Also examine condition of the droop stop in the middle of the rod which protects the strut from over extension and softens the blow of (rare) offloading of the tire.

droop stop

(left to right)
- rod guide/centering bung
- o-ring
- double seal bonded to a washer

This picture shows the top of the rod guide/centering bung with cutout for the lower edge of the original Boge oil ring to fit into. The 3 slots allow oil to drain back into the reservoir tube, oil that the seal scrapes off the rod, and is a common design in twin tube struts. This area should be cleaned well since crud tends to build up around the drains.



Now carefully slip off flat rubber bushing from the outside of the rod guide/centering bung (you will reuse this bushing); the bushing is actually a check valve and under it you will find an accumulation of dirt and grim that has entered via the rod seal; thoroughly clean both inside of bushing and bung, then slip the bushing back on, dipping it first in Pentosin oil.

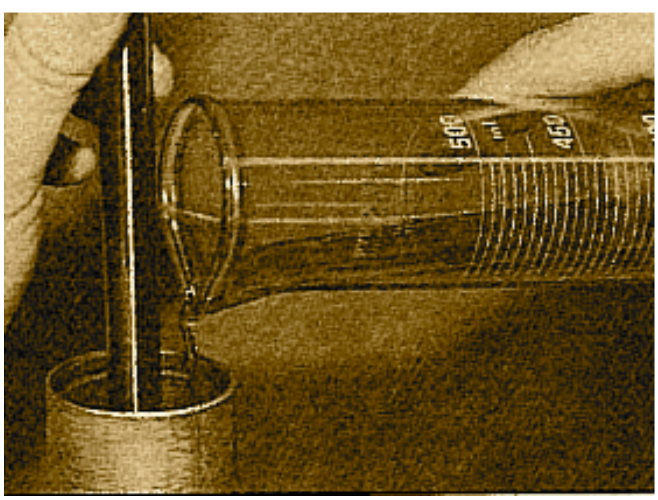
Remove the small nylon ring from the inside of the rod guide with an o-ring pick (be careful not to damage the ring!), clean the groove well and slip the ring back into place using a thin coating of Pentosin oil.

[n.b. We are investigating the possibility of finding a source for this ring. We believe its function is to capture oil for the lubrication of the bronze bushing of the rod guide and that its replacement is not necessary]

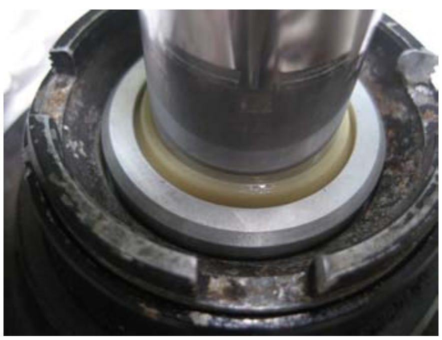
Thoroughly bathe the piston in brake cleaner and blow off with compressed air (see **Appendix 2** if you you need to disassemble the piston—this may be necessary if you notice a lot of debris, especially if the droop stop is mysteriously missing). Flush the inside of casing with brake cleaner. One method is to fill the casing with about 3-4 oz of brake cleaner, then vigorously *shake*—"bartender style"—with one hand covering the opening (you'll also need to temporarily plug the hole for the Schrader). Pour out the fluid, then repeat process, a minimum of 10 times—you will be surprised to see how much junk comes out. In order to make your brake cleaner go further you can reuse some of it if you filter it. Another method would be to fill the strut with about 250 ml of cleaner and to reassemble with piston, rod guide, <u>old</u> o-ring, and <u>old</u> double seal, screw on the gland nut finger tight, and then work the piston up and down, sometimes with solenoid powered up. Here you are forcing the cleaner through piston holes, foot valve and solenoid orifices. Tip: professional rebuilders of struts always clean the exterior of the casing first as any debris there mysteriously seems to find its way later inside the tube! Once you are finished, lay the casing upside down for 5 minutes to allow any fluid to drain out or evaporate. Then, while continuing to hold the casing upside down, give the inside a blast of compressed air. Now apply some teflon tape to the Schraders and screw them in snugly.

Now it's time to reassemble the strut. If you have not done it already install the Bilstein seals in the carrier: coat generously with Pentosin first, then pop them into the seal carrier one at a time—***wiper seal in the upper race with lip facing <u>up</u>***, ***oil seal in the lower race with lip facing <u>down</u>***. They are a tight fit so you need to deform them a bit to get them in, but they literally make a "snap" when they find their place (a seal installation tool actually exists—pictured below—but this is unnecessary, we include photos only to show you how a seal needs to be deformed). A FIRM THUMBNAIL MAY BE NECESSARY TO GET THE REMAINING EDGE IN PLACE. THEN EXAMINE THE SEALS CAREFULLY SO THAT THEY ARE PERFECTLY CONCENTRIC.

Add the right quantity of hydraulic fluid to your beaker (the front struts take exactly 360 ml; the rear need 490 ml). The Bilstein beaker makes filling very easy. Pour oil into the inner tube until its about 3/4 full, insert piston (without rod guide), and press down slowly to get piston below the oil level; finish pouring the remaining oil into inner tube; after it is full let the remaining oil run over into the outer reservoir tube.



Slip on rod guide/centering bung, o-ring, and seal carrier, *all liberally coated with Pentosin*. **Be careful not to injure the seals as you maneuver them over the sharp edge of the 22mm shaft** and be especially mindful if the shaft has any rough spots which should have been sanded with emory paper beforehand. Press the carrier down into the casing. You might want to polish the bottom surface of the gland nut with 800-grit sandpaper so that is glides nicely on the aluminum carrier. Screw on gland nut and torque to about 60 foot pounds.



Before regassing follow this simple procedure to be sure there are no air cavities in the system: hold the strut upright and cycle the rod in and out a number of times to bleed it. Now it’s ready for regassing. Although pulling a full vacuum via the Schrader valve to vacate the “air” compartment would be ideal before pressurizing with nitrogen, this is not necessary; at say 75 psi, we're applying 5 atmospheres which means that the air that's already in there only represents 1/6th of the volume of gas (at 60 psi, in the middle of the range, it's 1/5th). By all means pull a vacuum if you have a vacuum pump at your disposal—that’s the beauty of the Schrader valve.

STEP 3 - take strut to a shop to have it charged with nitrogen via Schrader valve

Sources of nitrogen will vary where you live. A good bet would be a tire shop (that offers nitrogen inflation), welding shop, speed shop, or bicycle shop. A shop that can dyno test struts will also have nitrogen on hand. Get them to inflate it to 58-72 psi following the original specs. If you have invested in the special Bilstein nitrogen filling tool (although it is completely unnecessary) you screw it onto the outside of the Schrader fitting, and then wind in the screw to depress the core - fill with gas, unwind screw to close core without losing pressure, and then remove from the Schrader.

n.b. Gas pressure cannot be used as a “tuning” device (getting the strut to act stiffer or softer based on the amount of pressure). We tested this proposition in the dyno test, testing the same strut with 58 psi, and then again with 72 psi. The damping results were the same.

STEP 4 - get the strut tested to get performance graphs (optional)

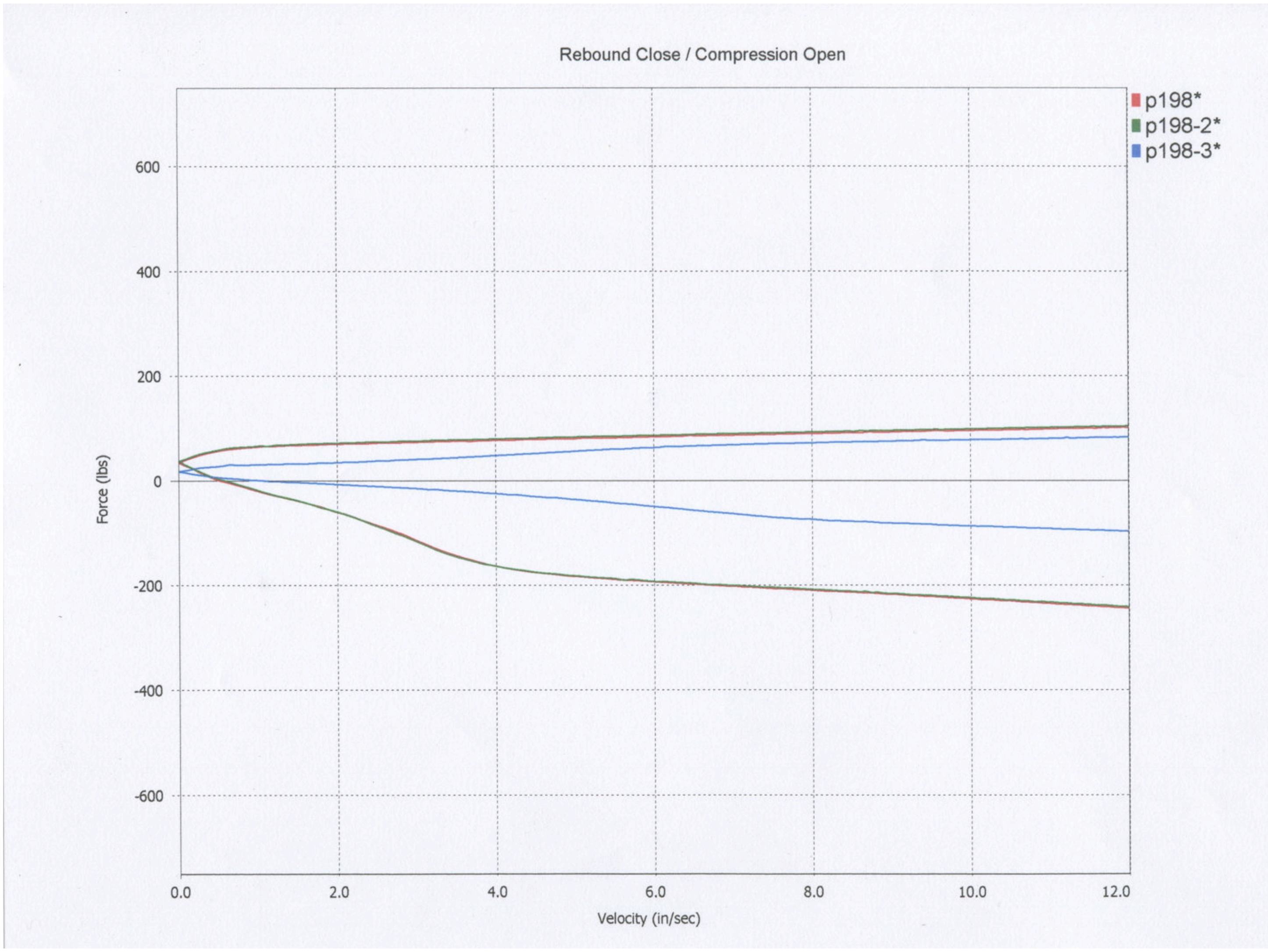
The **Roehrig Dyno**

The graphs on the following pages were produced by Bruce Kindberg of Bruce's Speedshop in Rockaway Boro, New Jersey. By providing Bruce with a 12v charger with plug-in connector and on-off switch it was possible to test both "sport" (off) and "auto" (on). In the PVC graphs on pages 17-18 the compression damping curve is shown on the top and the rebound on the bottom (n.b. the rebound curve reaches higher forces because rebound has to work *against* the springs, while compression works *with* the springs). The dyno test is preceded by a vigorous "warmup" of the strut (to 100° F); the test itself actually takes less than a minute. Here is a link to Roehrig's explanation of the CVP and PVC tests and how to interpret them:

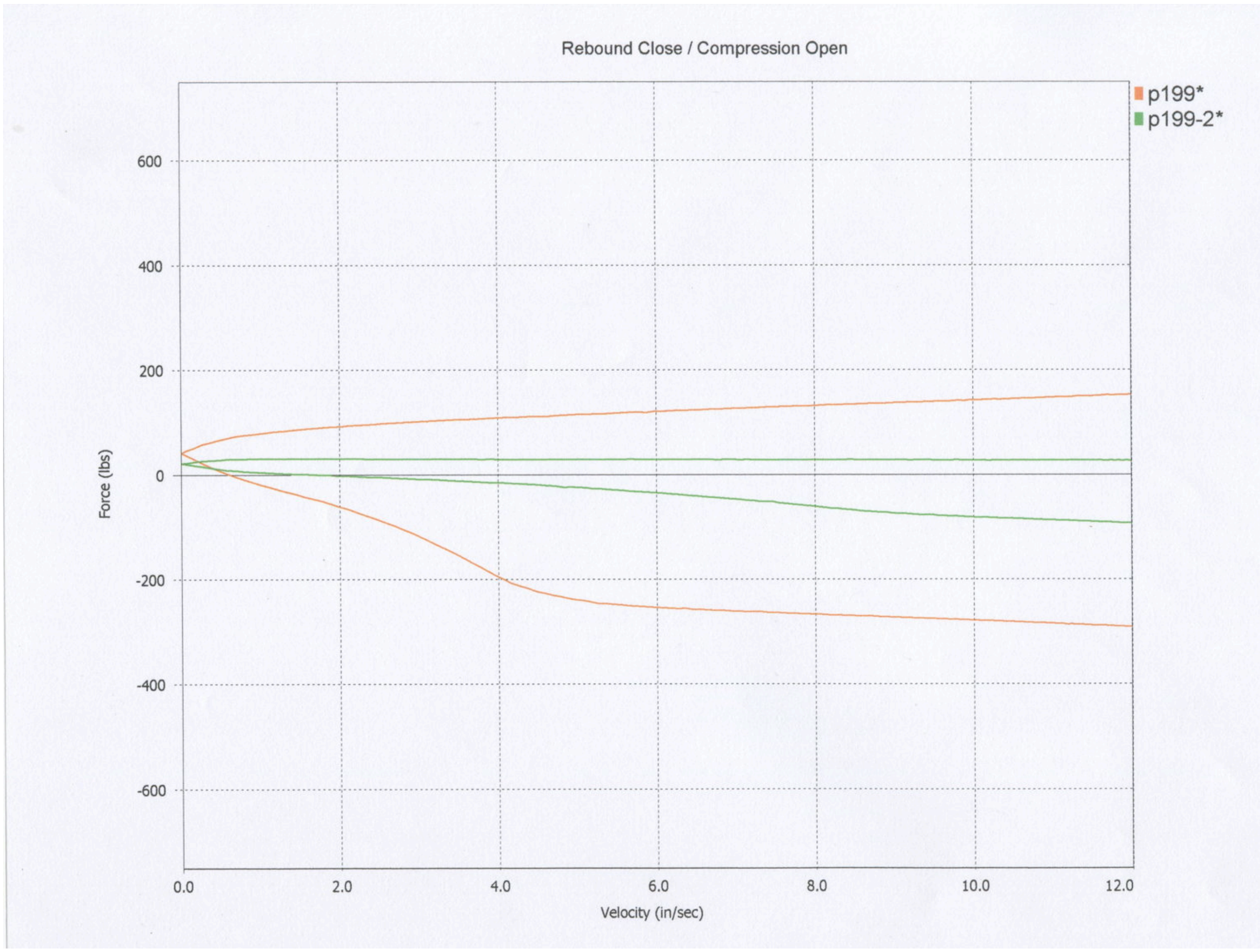
http://www.roehrigengineering.com/Technical%20Information/UNDERSTANDING%20PVP%20AND%20CVP.pdf

http://www.roehrigengineering.com/Technical%20Information/Where%20the%20graphs%20come%20from.pdf

REBUILT BOGE CDS, ALFA 164S FRONT, *PASSENGER SIDE*, pentosin syn. oil
P198 = "SPORT" SETTING with 58 psi nitrogen
P198-2 = "SPORT" SETTING with 72 psi nitrogen
P198-3 = "AUTO" SETTING with 72 psi nitrogen
(n.b. there is no performance difference between 58 psi and 72 psi)
tested Nov. 2, 2011: (compression on top, rebound on bottom)
mileage on struts before rebuild: c.105K; replaced parts: none except for o-ring and top seals



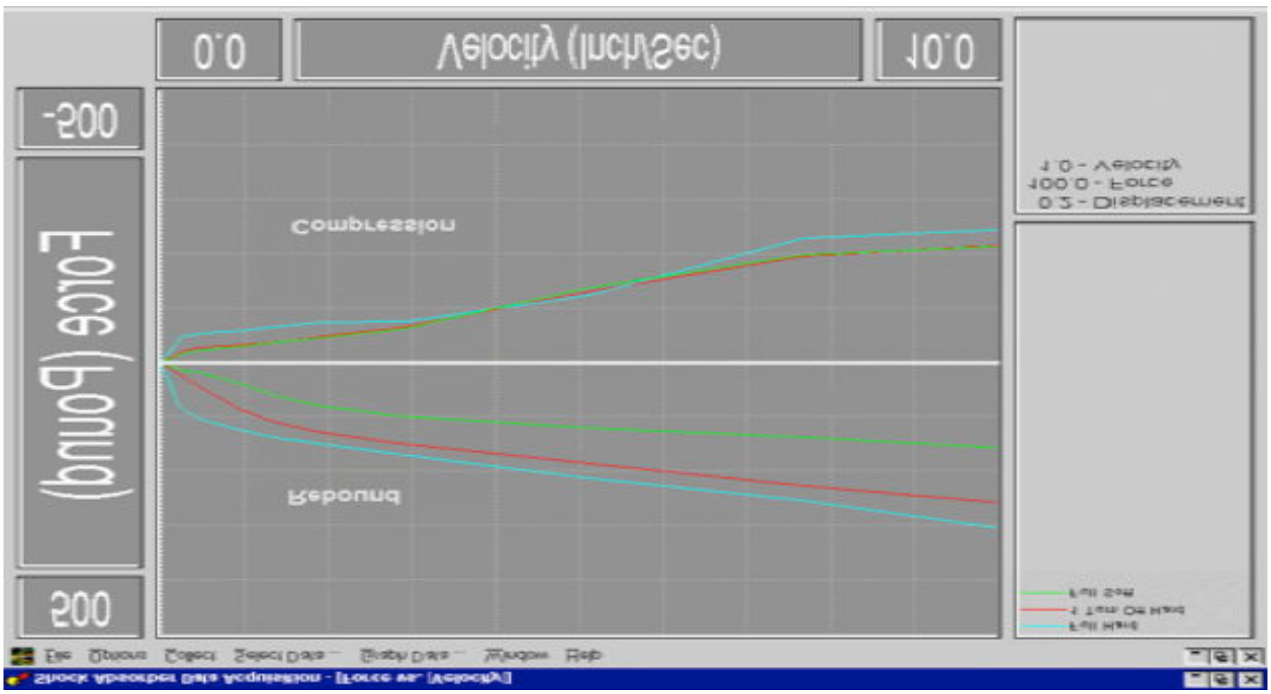
REBUILT BOGE CDS, ALFA 164S FRONT, *DRIVERS SIDE*, pentosin synthetic oil
"SPORT" SETTING with 72 psi nitrogen
"AUTO" SETTING with 72 psi nitrogen
tested Nov. 2, 2011: (compression on top, rebound on bottom)
mileage on struts before rebuild: c.105K; replaced parts: none except for o-ring and top seals



(FOR ROUGH COMPARISON PURPOSES)

KONI SPORT, BMW E30 M3 FRONT

n.b. Koni struts are rebound adjustable only;
graph has been flipped and adjusted to allow better comparison with the Boge CDS strut performance; blue = full hard, red = 1 turn off hard, light green = full soft



Keep in mind that the Koni sport is for a BMW (a rear-wheel drive car with totally different "knee" value to offset its particular spring force). What's notable to conclude is that the Boge acts at lower velocity as soft as the Koni on "full soft" and as the velocity approaches 4.0 as hard as the Koni "1 turn off full hard", but never as hard as the Koni on "full hard".

Conclusion:

As far as we know these are very first damping curves for a Alfa 164S strut. It would be preferable if we had a set of brand new struts to test so that we could have a baseline. In lieu of that we have to work with what we have, hopefully if enough owners perform this test and share them we will eventually be able to calculate a baseline as a mean.

All the plots show a digressive curve, that is, as speed increases, damping forces increase at a decreasing rate. Digressive shocks provide low-speed damping control without being overly harsh. The advantage of a digressively valved shock is vehicle control, offering more stability because mitigates a lot of the body roll of the car which in turn enhances the corning ability. Although the tests above show a plot going from 0 to 12 ips (inches per second), most normal street driving falls in the realm of 0” to 2” (a strut will actually spend most of its time in the 0” and 1” per second range in both compression and rebound, the tire continually fluttering); highly aggressive driving falls in the range of 0 to 4. So this is the range that is the most important to focus on.

Importantly there are no signs of a bad strut, for example, a sudden drop-off in the damping rate might signal a bent or binding shaft; a significant downgrade in performance across the whole spectrum signals a worn out strut. The “knee” in the rebound line is there to accommodate the preload of the big spring. Both struts have a certain amount of hysteresis (lag time where the strut is preventing the tire from being planted on the ground), shown by plots that are not centered on 0, theoretically ideal. Partly to blame here may be the scraper ring on the pistons which were not replaced. On “sport” setting both passenger and driver’s-side struts perform quite well although the driver’s side is stronger (especially if you look past 4 ips).

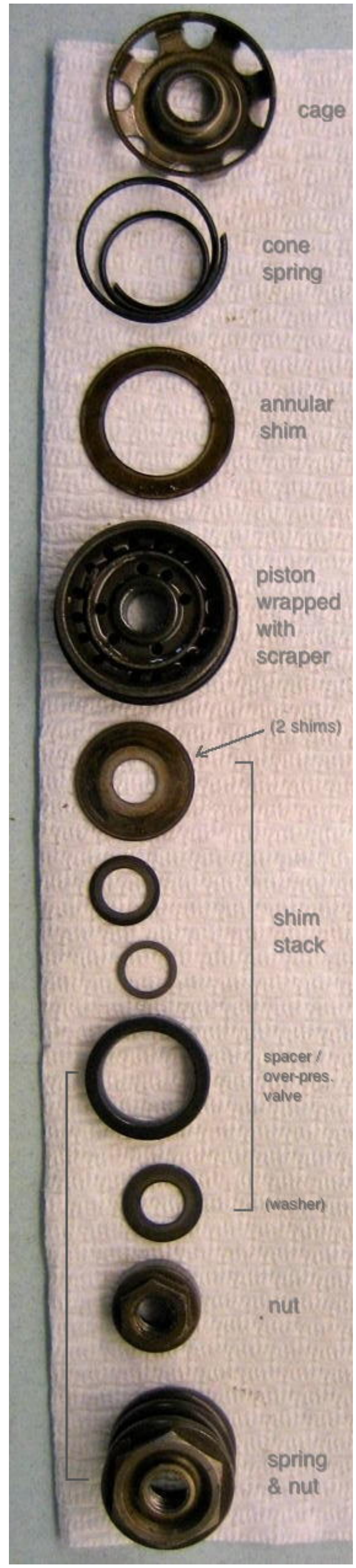
The “soft” setting, however, tells a different story. Here the driver’s side strut is significantly weaker and we believe this imbalance could cause “wiggle” sensation on an unlevel road. Although no two struts, even with the identical part number, will be identical in performance this discrepancy should be looked at. It will require a break down of the strut and examination of the piston to see if the scraper ring needs additional tensioning or replaced altogether. High quality struts are said to be carefully manufactured so that damping force has been matched with spring rates and vehicle weight, but the claim of “calibrated piston and foot valves” and “flow-rated valves” (suggesting that all struts of the same model perform identically), may be somewhat a dream, as it is unlikely that each individual strut (back in the early 90s) was dyno tested and verified, indeed, the only way to verify these claims.

Thus in our present case further “tuning” the two CDS Boge struts to perform more closely, although doable, would be messy, as it would entail removing the piston, fiddling with the adjusting nut or possibly the shimming of the ports. As any shock rebuilder can attest (especially those who prepare competition shocks), the process can be tedious and may require more than one breakdown, reassembly and dyno test to get it right.

Given the fact that most of us are not racing our cars, a slight imbalance in strut performance might have to be tolerated. Before we break apart this particular pair of struts to attempt to do some “tuning” (to bring the two struts closer in performance) it would be best to compare our dyno tests with other owners who hopefully will share their tests. Until that happens we thought it would be a good exercise to hypothesize what tuning methods might be at our disposal.

Here follows a short Q & A, or more accurately, Steven’s questions and Ben’s answers.

Does the annular shim on the top side of the piston affect compression, and if so, can the compression be adjusted by altering its height?
The single shim on the top of the piston is a "pop off" shim—it's only retained by that light spring—it acts as a one-way valve forcing the oil through the rebound stack on rebound, and effectively acting as a kind of fixed orifice on the compression stroke—the compression damping is mainly looked after by the foot valve. No real way to adjust it.



Does the shim stack on the bottom side of the piston affect rebound, and if so, can rebound be adjusted by altering the combined height of the shims?
The 2 shims and the heavy spring on the bottom side of the piston affect rebound—the spring preload affects the position of the "knee" in the damping curve—the difference in the two rebound plots in sport on your dampers comes down to spring preload differences. The thickness and diameters of the shim stacks affects the shape of the curves—not a lot of point messing with them I feel.

Would you recommend cleaning the shims themselves with something slightly abrasive, for example, a rubbing compound? (my thought here is that this might improve the "sealing" capacity of the shims)
I'd only clean the shims with rubbing compound if they were scratched—the sealing is not hugely critical on them once you pass a certain point in leak path size, and the thickness of the shims is fairly critical—they're precision ground, and if you look closely, they're clean where they actually contact the piston. They should come mostly clean with a soak in brake cleaner/carburetor cleaner-degreaser.

What does the large cone-shaped spring on top of the piston do? Is this adjustable?
Not really adjustable—allows the single annular shim to act as a one way valve—ditto in the foot valve with the single shim on the tube side of the footvalve unit.

What exactly does the stiff spring on the bottom do? Obviously this one is adjusted with the bottom nut.
see above—sets the point of the knee in the rebound curve—more preload = knee further from the origin. I think the spring is used instead of a larger stack of shims that other dampers use.

What is the function of the large spacer ring (4th item from the bottom)—is it a check valve whose tension is determined by the

heavy spring on the bottom?
It's kind of a check valve—more of a over-pressure valve, hence the spring preload controlling the knee point in the curve. If it was purely a check valve it would have a light spring like the cone spring or the conical spring in the foot valve.

Is there a way to "crank up" (increase) the force that the piston wear ring (scraper) exerts on the cylinder?
I found that when i disassembled and then re-assembled the piston the wear ring re-seated slightly larger (was harder to re-insert into the tube)—it appear that the way it is designed and installed the wear ring is forced outwards by hydraulic pressure during operation, and the clamping force between the cage and the piston prior to installation.

Replacing the 2 o-rings that are on each side of the solenoid valve assembly obviously might improve general performance in both sport and auto, no?
The small o-ring is the critical one—the large o-ring just stops the oil and gas pressure disappearing out the solenoid valve threads.

Cleaning the solenoid plunger (a no brainer) could improve the sport performance, no?
Should do. Main effect that it would have is improving the speed at which it switches modes.

Reseating the surface of the plunger (the surface that presses against the valve), for example with 800 grit sandpaper, could also improve sport performance?
I'd only do this in a lathe, and only if the seating lip is damaged.

Might stretching or replacing the plunger spring improve sport performance?
May have the effect of reducing the effectiveness of the solenoid valve - may not retract properly. Giving it a good clean is the big thing - mine were almost completely full of goop when I pulled them out.

If sport performance is adequate, but auto is low, what issues might be the cause of this?
Loose shim stack nut on the 3 hole plate? It may be that the auto is fine and the other damper has too much damping on auto. Would be interesting to see what new old stock dampers plot on the dyno.

Appendix 1 - Salvaging CDS struts with non-CDS parts

Rod / Inner Tube Replacement - FRONT STRUT

If the rod of your CDS strut is bent or scored beyond an acceptable condition you can source one from either a new Boge **non-CDS** strut or used one in good condition. Our experience here is limited to only two examples so you should proceed here with some caution. Keep in mind that the non-CDS strut is a “factory-sealed” unit (with crimped end securing the washer-seal), so in order to remove the shaft you need to hack saw off the top part of the outer cylinder to remove it (be careful doing this on a new strut as it is under pressure, also cut exactly below the crimp, ca. 1/8” from top, to avoid injuring the rod guide/centering bung, which, depending on age, may be worth reusing). One of our examples is from a strut removed from a 1991 164B with 5 speed transmission. Although the rod assembly is identical—22 mm shaft diameter, with a total length of 37.6 cm (measuring only the 22 mm portion)—there is one difference worth pointing out: the position of the internal droop stop is 8 mm higher on the non-CDS strut, in other words, its rod extends from the casing 8 **mm less** than the CDS shaft. Although there may be some rationale in the design, it is not likely that this 8 mm difference will cause any problems so long as you replace the rods in pairs, i.e., never mixing the two type of rods. In using the donor rods, be sure to swap over the CDS pistons—and all the relevant shims and springs (CDS pistons have different porting!). We believe the rod guides are identical, so simply pick the guide that shows the least wear on the bronze insert.

If you have a damaged inner tube, for example, one that has internal scraping or scoring, you can use a non-CDS tube from a <u>rear</u> strut; since the rear tube is longer than the front it will have to be machined down (shortened) and holes drilled sideways for the bypass sleeve); slip the special CDS bypass sleeve over your donor tube, voilà, you’re finished; be sure to use the CDS footvalve as they are different from the non-CDS footvalves (as explained elsewhere the foovalve can be tapped out with a thin wooden dowel).

Rod / Inner Tube Replacement - REAR STRUT

A set of CDS struts dampers can be salvaged with careful use of non-CDS parts with a little machining. We have successfully taken a non-CDS rear rod to restore a bent CDS rear rod. The droop stop of the non-CDS rod is lower than the CDS rod so you will have to add a spacer so that the stop height is the same as the CDS rod.

If the inner tube of the CDS strut is damaged, the non-CDS tube will work as a replacement however you have to make a spacer (46.60 mm OD) to go between the centering bung (rod guide) and seal carrier to make it captive; you also have to use non-CDS shafts without a spacer under the droop stops, otherwise the open length will be too short. As in the case of the front strut be sure to use the CDS footvalve. Do not disassemble the footvalves.

Appendix 2 - Disassembly and Cleaning of Piston Assembly, Shim Stacks & Foot valve

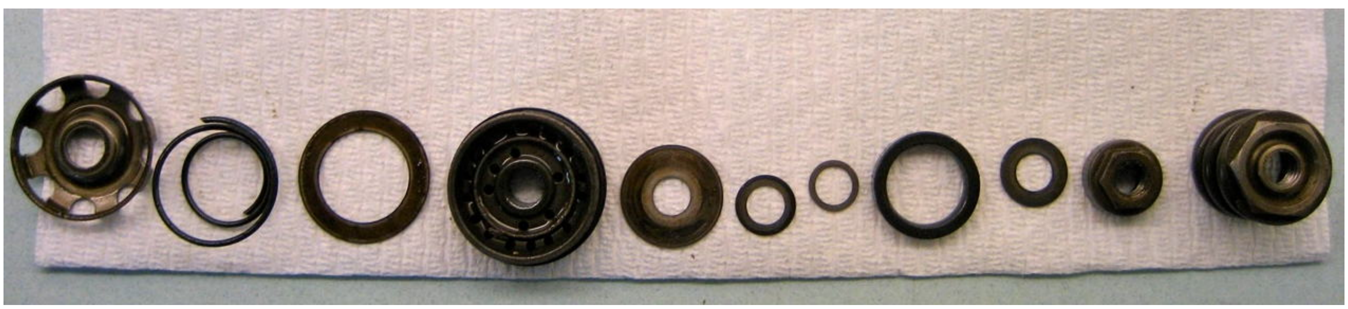
If you take apart your strut and find, for example, a missing droop stop, you can be sure that it probably broke up into small bits, some of which may now be lodged in the holes of the piston. Simply dismantle the piston assembly and clean in brake cleaner. The nuts seem to be loctited from factory, so our recommended procedure is to:

- remove the spring retaining nut and spring (far right) (note as you do this the number of turns so you can reinstall nut with the same tension)

- run an M8x1.0 die nut down the thread to clean off remains of the loctite

- remove the shim stack nut (second from the right) either in a vise or with a hexagonal wrench or socket, being careful not to slip off the nut, rounding it (you can hold the shaft, protected with some rubber tube, in the vise

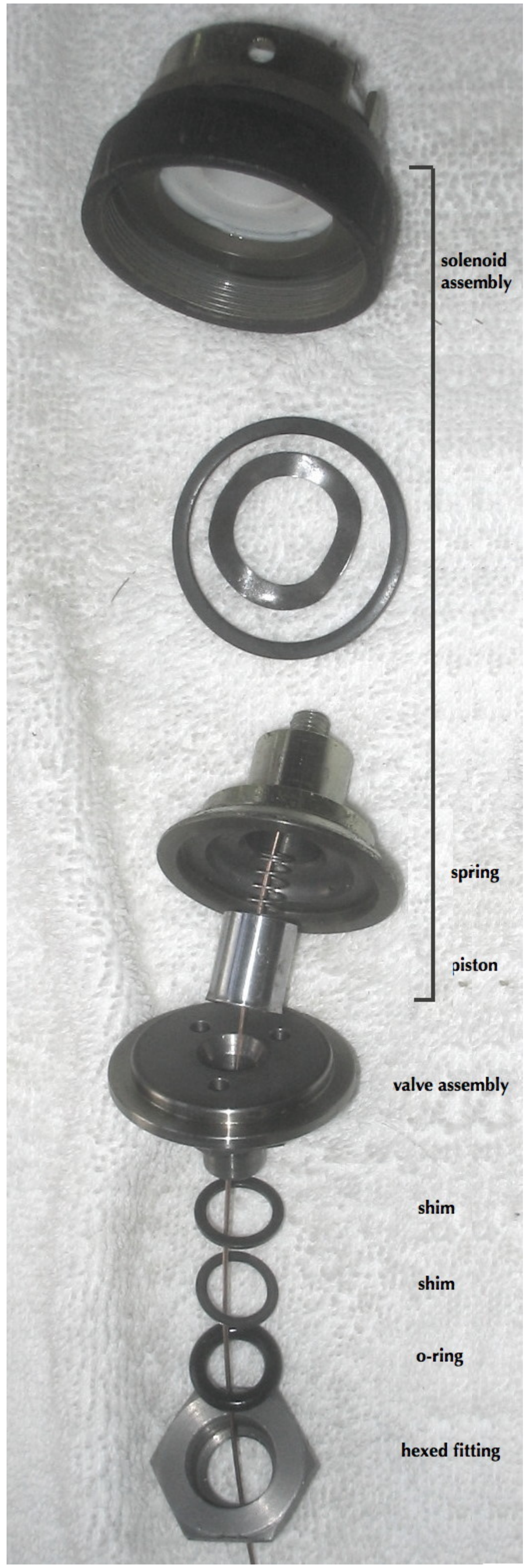
Photo below: piston assembly disassembled (left= top, right = bottom)
(n.b. shim to the right of the piston is actually two shims)



The foot valve located at the base of the inner tube can be removed by inserting a wooden stick in tube and gently tapping on the outer edge edge of the valve; <u>do not try to turn hex head from the outside, you can damage the valve</u>. To reinstall, use a wooden or plastic mallet to tap into place.

Appendix 3 - Solenoid Assembly, Valve & Inner Tube Removal

The solenoid assembly can be removed from the the outer strut casing by unscrewing it counter–clockwise. For front struts the solenoid can be removed wires and all (use a a special collar wrench not to scar the collar, or pipe wrench with caution); for rear struts the wires first need to be unsoldered in order for the cover to clear the mounting brackets on the casing. Once this is done an o-ring (M2.5 mm x 31 mm ID) and valve assembly is visible; pulling out the valve exposes a 22 mm hexed fitting that is screwed into the inner tube. Note that the nib of the valve assembly is a friction fit in the hexed fitting sealed by 2 small shims and an o-ring (M3 mm x 8 mm ID) (see bottom of photo on right).



Appendix 3, cont. - Solenoid Assembly, Valve & Inner Tube Removal

Removing this fitting allows the inner tube to be pulled out of the casing. Now you will understand why CDS struts are so expensive: the inner tube is quite an engineering marvel

with its extra sleeve (with machined ends and internal o-ring grooves, held in place by o-ring "stiction"), creating an passageway that allows oil to be diverted to the solenoid valve. Here's how it works: when the solenoid is powered up (="soft") a little plunger—normally pressed against the oil passage like a closed door—pulls back, allowing oil to enter the valve via 3 small orifices; the pressure forces the oil through the shim stack of the valve, releasing the oil into the reservoir area; this bypass action softens damping. Struts where the oil has really deteriorated badly and taken on moisture may have muck stuck inside of this bypass sleeve. The only way to clean it is to slide the bypass sleeve off the inner tube. Be sure to check the condition of the 2 o-rings (M2.5 x 33 mm Buna-N 70) on each side of sleeve (not shown) and replace if necessary.

Online Resources

LAD strut rebuild http://bmwe32.masscom.net/gavin/LAD_strut_rebuild.htm

Lancia/Koni rebuild http://www.lancisti.net/forum/showthread.php?135-Rebuilding-Koni-struts

Mercedes strut rebuild http://www.benzworld.org/forums/w124-e-ce-d-td-class/1375224-hydraulic-strut-rebuild.html

BMW EDC rebuild http://www.bimmerboard.com/forums/posts/614960

strut re-valving
http://www.stockcarracing.com/techarticles/scrp_0606_qa1_shocks_revalve_and_repair/index.html

Soarers strut recharge http://planetsoarer.com/nitrogen/nitrogen.htm

Scoarer strut rebuild http://planetsoarer.com/UZZ32/uzz32struts.htm

strut rebuild http://www.shocksetup.com/pdfs/ReadMore_RebuildManual.pdf

oil fill/Ni charge (monotube) http://www.bilsteinus.com/fileadmin/user_upload/user_upload_us/pdfs/motorsport/en/valvingmanual_21to30.pdf

strut regassing Honda http://honda-tech.com/showthread.php?t=2437593

dyno graphs http://farnorthracing.com/autocross_secrets18.html

ShockTek to Bilstein http://farnorthracing.com/shocks_2.html

Notes on Boge EDC-System for front BMW M5 strut
source: http://www.e34m5.de/board/showpost.php?p=68851&postcount=17

According to a Boge engineer who worked on the development of the EDC System for the BMW E34 M5 struts

--front strut is the so-called twin-tube type

--filled with gas pressure of 4-5 bar (58 - 72.50 lbs)

--gas is normal ambient air from a compressor

--air inserted at the top scraper with the aid of a needle after oil is already in place

--thought that working cylinder was filled full with hydraulic oil with no air space

--the reserve area between the inner and outer cylinder should only be 2/3 full, the remaining 1/3 is for air (4-5 bar)

Original German text:

Ich habe tatsächlich mit einem der Mitentwickler der Firma BOGE (jetzt ZF-Sachs) gesprochen, der u.a. an dem EDC-System für den E34 M5 (S38B38) beteiligt war.

Die vorderen EDC-Dämpfer sind sog. Zweirohrdämpfer und bilden ein geschlossenes System.

Seinen Angaben zu Folge waren die vorderen EDC-Dämpfer mit einem Gasdruck von ca. 4 -5 bar Überdruck befüllt.

Die Befüllung mit Gas - "normale" Umluft aus einem Kompressor - erfolgte über den obersten Abstreifer an der Kolbenstange. Der EDC-Stoßdämpfer wurde fertig montiert und verschlossen, d.h. die Ölfüllung war bereits erfolgt und der Stoßdämpfer verschraubt. Nun wurde entweder der Abstreifer an der Kolbenstange gespreizt und dort dann der entsprechende Luftüberdruck im Dämpfer erzeugt, oder aber die Dichtung mittels einer Nadel durchstoßen, so daß eine "Gasbefüllung" durch die Nadel erfolgte. Die Dichtung verschloss sich nach dem Durchstoß wieder und der Dämpfer war dicht.

Angaben zu den Spezifikationen der Ölfüllung der Dämpfer konnte er keine Anagben mehr machen, das Öl kam über Zulieferer. Er meint nur, was für die hinteren EDC-Niveau-Dämpfer gut sei, kann für vorne nicht falsch sein. Der Arbeitszylinder muß komplett mit Hydrauliköl gefüllt sein, es darf keine Lufteinschlüsse geben, die Ölreserve zwischen dem Innenzylinder und dem Außenzylinder darf 2/3 nicht überschreiten. Die dort verbleibenden 1/3 Füllmenge wird für die Gasfüllung (4- 5 bar Überdruck) benötigt.

Nun genug der Technik! Ich habe Kontakt zu einem Dichtungshersteller in Deutschland aufgenommen, der sich um die Herstellung des Dichtungssatzes für die vorderen EDC-Dämpfer (Kombidichtung aus Simmering und Abstreifer, etc.) kömmern will. Ein Vertreter der Firma hat alle Teile mitgenommen und Mitte September werde ich eine Antwort bekommen, ob es klappt oder nicht und werde dann auch einen Preis erfahren.

Darüber hinaus werde ich mich dann mal in einem ruhigen Nachtdienst an eine "Reparaturanleitung" für die vorderen und hinteren EDC-Dämpfer begeben - ein Dichtungssatz ohne Einbauanleitung macht ja wohl wenig Sinn - oder?

Für weitere Fragen und Anregungen stehe ich natürlich weiter zur Verfügung.