Dear Dorothy Fixx *Technical advice to the vehicularly distraught*

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The Committee, CCOCA.

Dear experts!

I am about to restart the restoration of my Light 15 and would like some advice on gearboxes.

I intend driving the car a fair bit and so want it to be reliable, but would prefer to retain the 3-speed gearbox for originality.

It seems to me that there are conflicting views on the old diffs:

- They gave no trouble if you have one in good condition and it is adjusted correctly.
- As above but the case should be strengthened also.
- There are some that break and some that don't, and you can tell the difference by looking at how the teeth on the crown wheel are cut.
- They are not reliable unless you fit a modern crown wheel and pinion.

Reliability is the important thing. I have a spare good box but would prefer to never go through the trouble of breaking down (always at the worst time and place, isn't it?).

Has anyone investigated upgrading the 3-speed box by say transplanting an ID diff into it? (I'm not familiar with the ID box, so don't know if that suggestion is anywhere near possible).

Do you know if the crown wheel and pinions from "Steam Car" in England are any good?

So what do you think is currently the best method of getting a reliable 3-speed box? Any help would be greatly appreciated.

Thanks for a great magazine. It alone is worth the membership fee.

Regards,

Bill Slater.

[Leigh, any chance of sending this guy a crate of Cussons goodies - with that last comment, we've obviously got to cultivate him as much as possible!]

Bill, many thanks for your fine letter. It goes right to the heart of several concerns widely shared by Traction enthusiasts. We are fortunate to have in the club several "experts" on various aspects of the cars that concern and delight us. In this case, we've passed your queries on to a couple of people, M/s Dorothy Fixx and Mr Jack Weaver, who have had much experience and opportunity over a long time to drive Light 15s under a range of sometimes gruelling conditions, to consider their performance and failings, and to restore and improve on them. In particular of course, they will address your questions about the Light 15/Legere (and Big 15/Normale) gearbox, as fitted to all these four-cylinder Traction Avants. Their considered answers to your specific concerns follow in this issue of Front Drive - Ed.

Tech Notes
THE TRACTION GEARBOX
Expert answers to reader's concerns.

Our reader, Bill Slater, asks about the varying views on the durability of the "Light 15 diff", but to answer his questions properly, we need to open the conversation up a bit and consider various other components of the Traction Avant gearbox as well.

[We'll stay with the common usage as adopted by our reader, but of course the "Light 15" gearbox is common to the corresponding French-built car (Legere = 11BL) as well as to the British-built and French-built bigger four cylinder cars (Big 15 and Normale = 11B respectively, as well as the longer-bodied Family Nine and Familiale respectively). The six cylinder Tractions used quite different gearboxes - Ed.]

Firstly, the correspondent asks about the Light 15 differential. As such, ie. the bevel gear arrangement which enables the two driven wheels to rotate at different speeds, it is very robust and gave little trouble.

Secondly, can the D Series differential can be fitted to a Light 15? Yes, with a little modification.

However, we're now being pedantic. If by "diff" you mean "crown wheel and pinion", the answer is rather different. The D crown wheel will fit, but the D pinion will not. The D pinion could be modified to accept the Light 15 gearbox components. This would be a rather expensive operation, with the results rather problematical in terms of longevity.

At this point, we need to consider some background. The Light 15 transaxle (combined gearbox and differential unit) has a number of weaknesses which have been inherent since its first appearance in the early 1930s.

The second gear assembly is included in the total gear train not only when second gear is engaged, but also when reverse and first are engaged. Obviously, it works very hard. Unfortunately, perhaps in retaliation to this extra work load, it has the habit of shedding teeth (more about the possible results of this later). This habit is exacerbated by the tendency of the two short bronze bushes inside the gear assembly to creep together. Movement of the bushes in this way has two unfortunate consequences.

Firstly, wear in the second gear bushes (and shaft) is accelerated due to impaired lubrication, since the displaced bushes block off the oil holes through which the meshing gear teeth contrive to pump oil back inside the second gear assembly.

Secondly, the effectively shortened bearing length of the bushes gives greater scope for the gear assembly to skew or rock on the main shaft. In turn, this "rocking" of the assembly allows the depth of tooth meshing to change. That is, the gear teeth no longer mesh at their designed pitch circles, but further out, thus giving rise to a dramatic increase in mechanical pitch pressure. Not surprisingly, the teeth then tend to "fall off", even when being used normally.

Incidentally, there is a relatively simple modification which effectively cures the bush and oiling problems with the second gear assembly, and hence aids in "keeping the teeth on".

Teeth which may have fallen off a gear drop to the bottom of the gearbox casing and hopefully stay there. Unfortunately, they do not always do so, and may drift rearwards where they can all too readily be picked up by the crown wheel and carried up to jam between the teeth of the crown wheel and the pinion as they rotate. The ingested tooth obviously acts as a most efficient (and expensive!) wedge. The pressures developed as the vehicle moves are usually sufficient to split the gearbox casing and the bell housing which encloses the clutch and flywheel. The ominous pool of gearbox oil then deposited on the road does little for the driver's peace of mind! Few crown wheels and pinions survive such a catastrophe unmarked either.

Incidentally, it is possible in most cases to trap stray bits of metal (such as second-gear teeth) before they form a fateful liaison with the crown wheel by having a magnet (eg. from a domestic flashlight) firmly fixed into the gearbox drain plug. You may well be surprised at what is found clinging to the drain plug when it is removed for a gear oil change!

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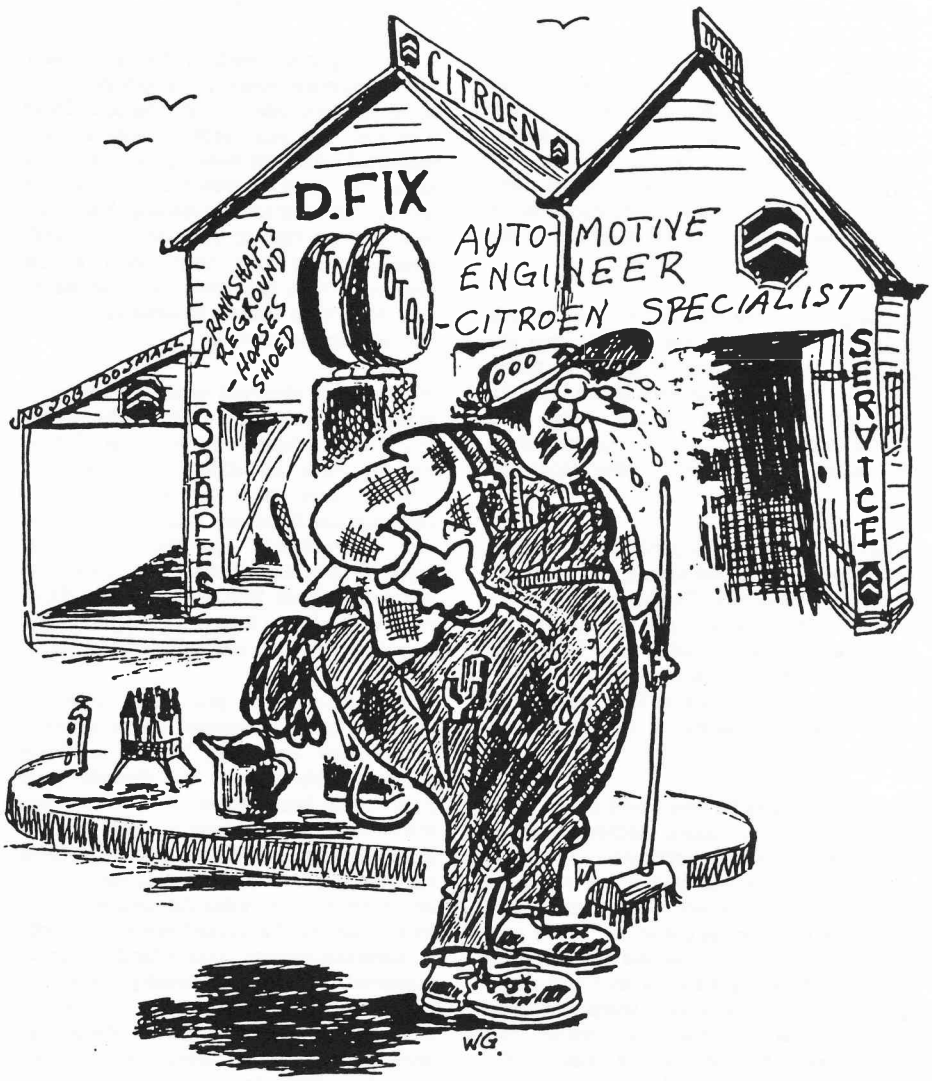
The second, and main cause of crown wheel and pinion failure is due to flexing of the gearbox casing. This flexing in turn can lead to multiple other faults which precipitate crown wheel and pinion failure.

Up to 1952-53 when the cap design was changed, it was not unknown for one of the alloy caps holding the differential side bearings to fracture. It is not difficult to visualise the result as the crown wheel and pinion force themselves out of mesh and skip over the tips of the teeth. Chipped teeth are then the problem.

The 12 mm diameter studs which secure the caps have only some 15 mm of thread holding them into the aluminium box casing. Hence it is not unknown for a stud to pull out or break out from the box casing, with disastrous results when the crown wheel swings out of mesh as above.

Even when new, the gearbox life was problematical, and this with only handling 54 brake horsepower. However, Coopers used the Traction box in their racing cars, and they were made surprisingly reliable, even when coping with in excess of 200 bhp. This greatly increased strength and reliability came from a few basic modifications.

Firstly, boxes employed on Coopers were fitted with longer high tensile bearing cap studs threading further into the casing, with steel strengthening straps carried over the tops of the caps themselves. Secondly, a specially fabricated "diaphragm" was added over the four lengthened side bearing studs, thereby trussing the whole structure together and stopping the casing flexing about the side bearing area.



Citroën design office must have been aware of this flexing problem. The D Series gearboxes had an altered design of the bell housing which acts as a stiffener for the box. They also overcame the problem of failing side bearing caps by incorporating them as an integral part of the bell housing. It is rare for a crown wheel and pinion to drop a tooth in a D Citroën.

Coopers Cars Ltd fitted Light 15 gearboxes, albeit with four-speed conversions, firstly to the 1100 cc FWA Coventry Climax single OHC engines, through the 1 1/2 and 2 litre series up to and including the FPF twin OHC 2 1/2 litre Formula One version. While the gear train etc was extensively modified each time power was increased, the casing and crown wheel and pinion remained Light 15. The gearbox stiffening process as described above was developed and applied as horsepower was increased, preventing gearbox flexing which caused damage to the crown wheels and pinions. These observations should remove any doubts concerning the basic robustness of the crown wheel and pinion design and manufacture. After all, are you expecting to push 200 bhp through your Traction gearbox?

Further circumstantial evidence indicating the actual robustness of the Light 15 crown wheel and pinion can be gained by considering the corresponding parts in a 19 or 20 Series Citroën gear box. The crown wheel and pinion teeth designs are virtually identical. There is no reason to suppose that there had been some major improvement in metallurgical processes incorporated in the interim. Yet failure of these components in a 19 or 20 Series box is almost unheard of, even if the car is being "caned" severely. The only known change is in the improved rigidity and strength of the gearbox casing as noted earlier.

One may question why Citroën did not apply these improvements to the Light 15 box, rather than waiting for the D to emerge. Who knows? Maybe the disruption due to wartime invasion and bombing of the plant, maybe finances, maybe the prospect of an improved replacement car in the DS. Apart from removing the spring-loaded detent ball on the gear selector shaft, thus making the change lighter, and replacing it with the clutch interlock system, it is noteworthy that the changes Citroën did make over the production life of the box from 1934 to 1957 were directed toward strengthening the box casing. Firstly, they added stiffening ribs to the outside (when they went from the A series to the B series box early in the piece), and secondly when they reduced stress concentrations in the side bearing caps by going from a "faceted" shape to a heavier form with a smoothly curved outer profile, which virtually eliminated the cap failure problem.

Another observation worth noting and considering is that at least one car, with an unmodified but seemingly "healthy" box, went through something like four crown

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wheel and pinion sets in a short time, even though it was not being driven hard. Maybe in this case, the box casing was unusually flexible, due perhaps to a casting or metallurgical problem. Another rather hypothetical possibility leading to crown wheel and pinion failure might be effects resulting from the heavy flywheel on Tractions - for example, inertial and gyroscopic forces which might cause shock loadings in the gear train or distortion of the box casing.

From the discussion and analysis above, it is our opinion that the primary cause of failure in crown wheels and pinions in the Light 15 type of box is not in the design and manufacture of these components themselves, but rather in weaknesses in other aspects of the box as described.

None the less, there is a persistent notion that some crown wheel and pinions are inherently "better" than others. The usual explanation put forward is the way the gear teeth have been cut. We would offer as a suggestion only, why some Citroën-supplied crown wheel and pinion sets seemed to fail more readily than others, in terms of the miles they covered.

Spiral bevel gears (crown wheel and pinions) are cut on a gear cutting machine originally developed by an organisation named Gleason, the gear cutting machine being named a "Gleason Spiral Bevel Gear Generator". When the teeth on the cutter (or "hob") used on the generator are new and sharp or have just been resharpened on a tool and cutter grinder, they leave a very sharp near-right angle edge at the root of the tooth. This sharp-edged section change causes the greatest concentration of stress to occur at this point.

All gear teeth are subject to bending moment over their length, with the greatest leverage load being concentrated at the root where the teeth join the main body of the gear. A small radius at this point will serve to reduce the local stress concentration, and hence reduce the likelihood of fracture and failure. This is why, for example, crankshaft pins have radii where the pins join the webs.

As a cutting tool is used, its sharp edges wear away (becoming blunted), the tool eventually acquiring slight radii at its cutting tips. Could it be then that gear teeth cut with a newly sharpened cutter will show a greater tendency to fail than those cut with the more rounded tool tips just prior to resharpening? But please note that the radii at the base of the teeth would not be very large (only a few hundredths of a millimetre), so it would be very difficult to discern differences in these radii with the naked eye.

We have not observed gross differences in tooth form which might explain differences in gear life, and hence conclude that all sets, even if made by different suppliers for Citroën, were made to quite tight and consistent specifications. Thus we have found that "mis-matched" components will fit together quite well (unless they come from sets with different final drive ratios eg. 8x31 vs 9x31, and even then it is conceivable that they would mate up with sufficient lapping).

However, while the gear forms might be identical, there is another aspect whereby "gear quality" could vary between individual suppliers. This is in the way that the gears have been heat-treated after they were machined. Heat treatment is a complex and skilled process, and involves both initial stress relieving and later hardening. Unfortunately, any attempt to determine the adequacy of the heat treatment of a finished gear is necessarily a destructive process! Surface hardness can be measured readily, but testing teeth for resistance to side loading could well render even a good item unserviceable. Metallurgy itself is quite an exact science, but there are so many variables in heat treatment that the same cannot be said, there being a touch of magic and incantation involved!

The question is raised about the quality of crown wheel and pinion sets currently available from Steam Car Developments in the UK (ratio 10x31, 290 pounds). We have no first hand knowledge of these sets, but we have no reason to suppose that they are made to anything but the best standards. Roger Williams of Steam Car has told our Editor that two sets have been delivered to enquirers in Sydney, while South Australian CCOCA member, Jeff Harris is in regular contact with Roger. If you are seriously interested, why not ring Roger on [001144] 482 86 3344 or Jeff on 08 2513761? Also you might like to talk to Keith James on 049 30 1729 (CCOCA member in NSW). Keith brought a couple of UK sets in two and a half years back at an all-up cost of about $700 each. He hasn't put them into use yet.

Now, how do you go about setting up a really reliable gearbox? Well, the answer depends on how good you want it to be, how "painful" it is to you should it fail (money and convenience), and how much money you are prepared to spend. Of course, you could carry a spare gearbox on the front floor, as Lance Collins does in Queensland.

Ideally, it would be best to fit a new crown wheel and pinion. All the gears in the train should be magnafluxxed. This process is non-destructive and detects even minute cracks. The gears finally selected could all then be "stress-relieved" and heat treated again. We would not recommend having any crown wheel and pinion sets stress relieved and heat treated again as distortion and warpage would be an ever present threat. We would strongly recommend magnafluxxing only. This way, you would know something about the health of the teeth.

Carrying out the modifications as indicated (including new crown wheel and pinion), competently and professionally, may set you back the better part of a couple of grand. For maximum reliability, it is an all or nothing situation. Anything else would be a compromise. Life wasn't meant to be easy, we've been told.

We have not gone into minute detail of the box improvements mentioned above. However, it is intended to cover these more fully in an illustrated technical article to follow.

Dorothy Fixx and Jack Weaver.