DELTA DAMPERS

Bill Campbell of Delta Manufacturing, 1981 1/8th scale World Champs winning car designer, describes developments and design of shock absorbers.

BILL CAMPBELL, a graduate mechanical engineer with 20 years' experience in aerospace as a designer of small precision mechanisms and aircraft structures is now the full time designer and vice-president of *Delta Manufacturing*. Bill and brother Ken started *Delta* some 14 years ago in St. Louis, Missouri, USA. *Delta* has grown from a two man garage operation to its present status with 14 employees working in 6,400sq. ft. devoted exclusively to the manufacture of competition-quality, radio controlled racing cars in both 1/8th I.C. and 1/12th and 1/18th scale electric. *Delta*, the oldest strictly R/C car manufacturer worldwide (established 1967) has been instrumental in many of the design innovations now used worldwide in R/C racing cars. *Delta* introduced foam rubber tyres over nylon wheels to replace the popular but heavy solid rubber over aluminium wheels, thus saving ½ to ¾ lb. of weight. The *Delta* designed servo saver (copies of which are now world standard) gave the overloaded weak geared servos of the early days a chance to survive the extreme environment of the R/C racing car. *Delta*'s clamp-on flywheel (thanks to Roy Moody for this great idea) eliminated wobbly and loose fly-wheels. *Delta* also first made as standard equipment, flush chassis screws for lower chassis and CG, full ball bearings and ball joints. The first 1/8th scale ball differential appeared on *Delta* Super-J racing cars. The high point of the *Delta* company lifespan has to be the 1/8th scale World Championship win of Arturo Carbonell driving a *Delta* 'Super-J' racing car. The *Delta* company motto is to 'Take One More Step' toward reliability and performance in every part of every product.

Although our first production car 14 years ago was a full 4-wheel independent suspension chassis with many advance features, it did not have shock absorbers. It relied strictly on joint friction to dampen the suspension. While the car handled quite well (at 7lb.) it was soon shelved in favour of the lighter, simpler, less expensive design of the flat pan type chassis. That was actually some relief, as the state of the art in those days was a long way from having reliability with clutches, gears, servos and just about any other part of the car you can name. These more basic parts needed perfecting before something as sophisticated as a full suspension car with functioning shock absorbers could work. For the next 13 years we strove to improve and perfect the basic flat pan type of chassis.

In the back of our minds was the ever present knowledge that some day we would no doubt be developing once again an independent suspension R/C car. Sure enough in 1981 suspension cars were successfully introduced in Europe, thus triggering latent suspension concepts we had been accumulating for years. The result of this latest design effort is the 1982 *Delta* 'Eagle' 4-wheel independent suspension race car. The most notable prominent feature being the 'Anglewinder' direct gear drive train in contrast to the European style chain drive. But perhaps the most challenging part of the design effort was to come up with a shock absorber that would function 100% like the full sized counterpart and yet be practical and economical to produce.

Why suspension racing cars anyway?

First it is important to realise that the only time the driver has control of his car's direction, acceleration and braking is when the tyres are in contact with the ground. The flatpan chassis design relies entirely on tyre and chassis flexibility to follow the ground. The flatpan chassis does work well on smooth tracks as was proven at the 1982 World Champs where the top four cars in both qualifying and overall placing were of flatpan design, two being *Delta* 'Super-J'. Three suspension cars did qualify for the top 10, but the relatively smooth track gave them no advantage. The fact is of course that most race tracks are not of World Championship calibre, with the average track containing a fair number of bumps and dips, with some being really rough. As a rule the rougher the surface the more advantage the suspended car will have over the flatpan car.

What does a shock absorber do?

Remembering from above that the tyres must be in contact with the ground in order to have control of the racecar, it is best to think of the shock absorber as a device which helps to spring return the tyre to the ground *as quickly as possible*. Another way to state this is that they help the spring keep the tyres in contact with the ground *the greatest amount of time*.

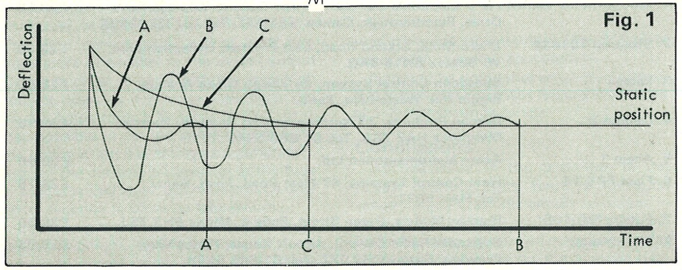


Fig. 1

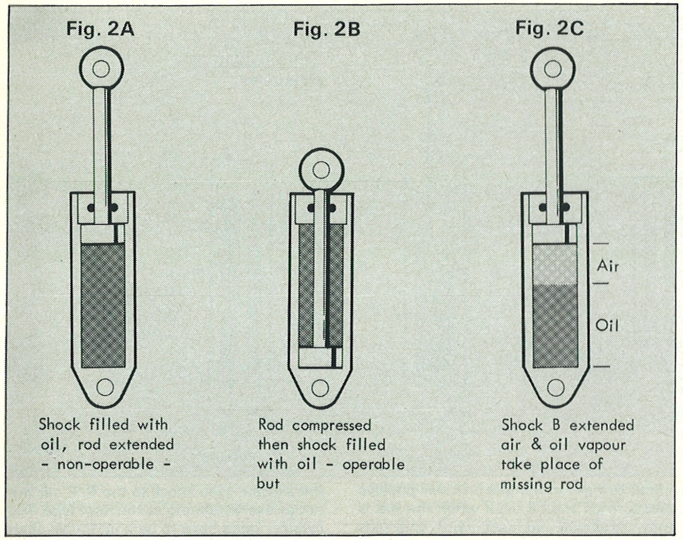


Fig. 2A: Shock filled with oil, rod extended - non-operable -

Fig. 2B: Rod compressed then shock filled with oil - operable but

Fig. 2C: Shock B extended air & oil vapour take place of missing rod

Technically speaking, we are dealing with a mass, spring and damping system. The chassis wheels, and suspension members are the mass, the springs are obviously the spring, and the 'shocks' are the damping. **Fig. 1** shows the effects of the shock absorber on this kind of system. Remember, with optimum damping, the shock absorber helps put the tyres back into contact with the ground and helps to keep them there the greatest amount of time.

Condition A. The shock has just the right amount of damping (shock oil correct). The tyre will return to normal position in the least amount of time.

Condition B. The shock has not enough damping and now the tyres will overshoot and continue to bounce for several cycles before returning to normal.

Condition C. The shock has too much damping and now the tyres will not overshoot at all but will take a long time in returning to normal.

How critical are the shock absorbers on the real world R/C race track?

If the track is really smooth you would have the best chance of getting by with no shocks. We do feel that shocks help in transitioning into and out of corners even on smooth tracks. As the track gets rougher the shock absorber becomes much more important as does the suspension itself. If you need the suspension system to provide an advantage, then you'll need good shocks to keep the suspension under control. In practice, we have found the actual stiffness of the shocks is not as sensitive as **Fig. 1** might lead you to believe.

How does a shock absorber work?

It pumps oil through a restrictor (orifice) during either compression or extension movements. Pumping oil requires energy, which comes from the motion of the suspension members. The energy thus used generates heat which heats up the oil in the shock. On R/C road racing cars the heat has not been a problem, but on rough terrain off-road racing cars it could become a factor. It is interesting to note that the faster the oil moves through the restrictor the more resistance is provided, a very good characteristic of the hydraulic shock and not like the friction shock which provides only a constant amount of resistance no matter the velocity. Friction in the suspension system is not good either as it causes what is known as hysteresis. This is the technical name for the suspension not returning to the same position when deflected up as when deflected down.

What is the biggest problem in designing an R/C car shock absorber?

After studying fullsized shock absorbers it was apparent that they could not simply be scaled down without the price escalating out of sight. To take the check valves, O-rings and orifices found in 1¼in. fullsize shocks and squeeze them into a package of 5/16in. dia. simply did not appear practical. A real breakthrough was required which would operate in this sub-miniature size. The biggest problem came from trying to solve a very basic characteristic of the hydraulic shock cylinder, oil and rod. It is necessary to understand this fact: that as a piston rod enters a hydraulic cylinder a certain volume of oil must go somewhere to make room for the rod itself. Additionally as the rod leaves the cylinder it will leave behind a volume that must now be filled with oil Refer to **Fig. 2** for illustrations of this problem.

Shock 2A: This shock was filled with oil before the rod and seal were installed. It will be impossible to compress this shock because there is no place for the incompressible oil to go. This shock is unusable.

Shock 2B: This shock was filled with oil after the rod was pushed all the way to the bottom of the cylinder. Then the seal was installed. Notice that there is less oil in Shock B than in Shock A. Can this shock be extended? See answer in Shock C.

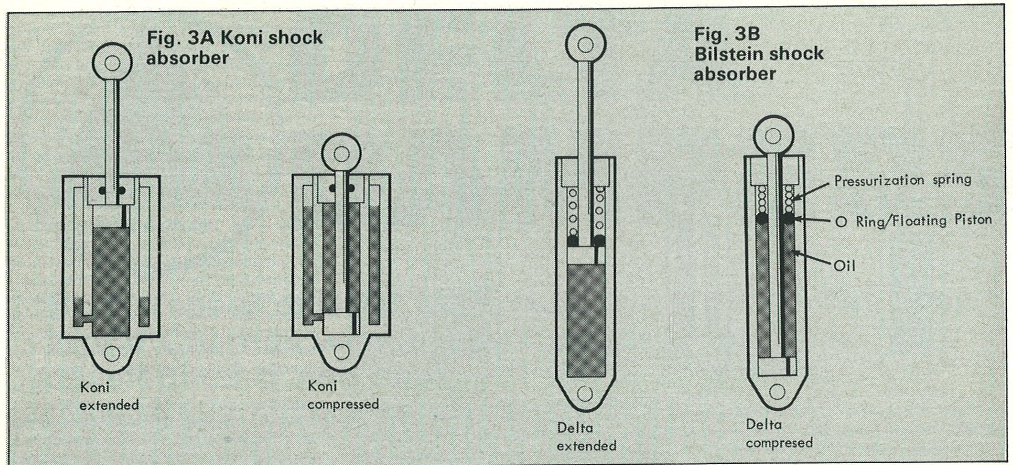
Shock C: This is what Shock B looks like after the rod has been extended. So far so good, right? Wrong; notice that no oil was available to fill the volume left behind by the rod. Where did that air come from? Well as the rod was pulled out the oil pressure was greatly reduced allowing minute air particles and oil vapour to flush out of the oil, thus allowing the rod to be fully extended. This is called cavitation, an unacceptable condition in full-sized shocks and much less than desirable in our R/C racing cars.

All R/C shock absorbers we have examined to date are of the **Fig. 2B** and **2C** type, and have the inherent weakness in that they pump not a pure stream of oil through the orifice, but a varying mixture of air and oil. This means that the shock absorber sees a varying oil viscosity through the orifice and thus for any given part of the shock absorber stroke, provides a varying and unpredictable amount of damping. I do not mean to imply that this type of shock is unusable as they are certainly better than nothing. But in line with our company policy of 'going one more step' we have developed a means of eliminating the 'air in the shock' problem.

How do full-size racing shock absorbers solve the rod/oil displacement problem?

Good question, let's take a look at the two most popular types and see how they work and why they are difficult to scale down.

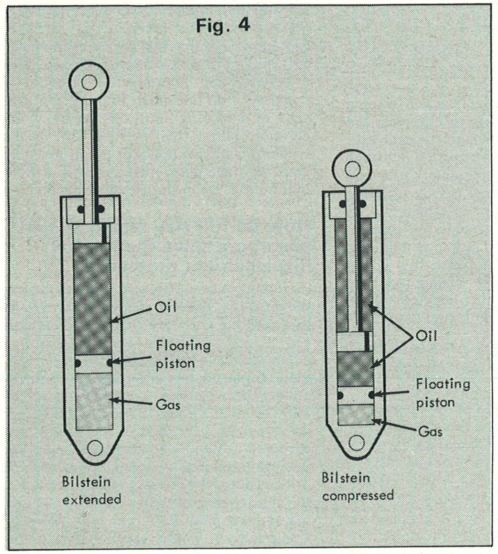
The Koni shock Fig. 3A. This is of a twin wall construction wherein an external concentric reservoir is connected to the main cylinder through a combination check valve/orifice. Oil enters or leaves the reservoir as needed to maintain the oil/rod volume relationship. The check valves and orifices act at the proper time to provide low or high resistance to the oil flow thus providing damping and yet not allowing cavitation. Problems with adapting this



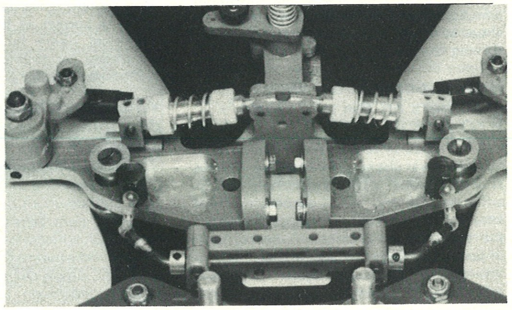
concept are not only the minute check valves and orifices but also the larger diameter required for this type reservoir forces the enlargement of the suspension springs which will be mounted on the outside of the shock absorber. Both space and weight are at a premium on the R/C competition racing car. In addition this type shock requires nearly vertical installation to keep the reservoir orifice/check valve ports covered with oil.

The Bilstein shock Fig. 3B. This type shock uses a floating piston and gas pressure to compensate for the oil volume change. An initial charge on the gas provides positive pressure on the oil even when the rod is fully extended. In fact with this gas pressure shock the piston fully extends unless restricted in some way. As the piston rod is compressed into the shock cylinder the floating piston is forced to move to make room for the rod volume. The piston moves toward the compressed gas compressing the gas even further. This is the type of shock used on many light aircraft as shock absorbing landing gear, the gas pressure providing the force to extend the gear. The problems in adapting the *Bilstein* type shock to the R/C car are not as overwhelming as the *Koni* type. The cylinder does have to be a bit longer than the **Fig. 2** type shocks, but the R/C car can adapt to length a bit better than diameter. However an O-ring sealed floating piston with its additional friction is not too attractive; and the real killer is coming up with a gas valve with which to pressurise the shock. Let's now take a look at the *Delta* pressurised shock and see how the problems above were solved.

Now that you have a basic understanding of the principles and problems of shock absorbers here is the explanation of the *Delta* pressurised shock absorber.

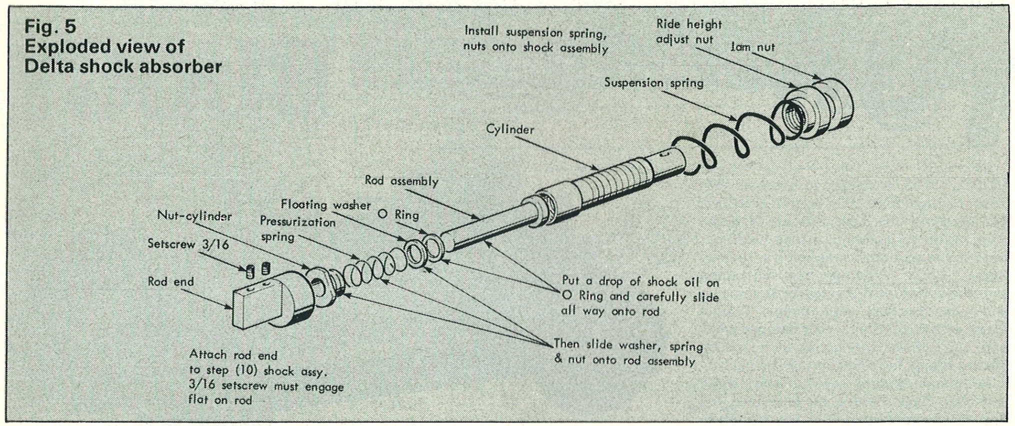


Front end of the Delta Eagle. Front suspension is of split axle type; the inboard mounted on shock absorbers can be seen clearly. Dust covers are normally fitted for racing.



Operating principles

This shock is more of the *Bilstein* type but with many simplifications to make practical for the R/C racing cars. Instead of gas, a spring is used to provide the pressure. The spring is very simple, light and eliminates the need for a pressurisation valve. Secondly, we found that a single O-ring could be used as not only the floating piston but would also act to seal the oil into the cylinder at both the rod and the cylinder.



This was the big breakthrough we had been looking for. With the single O-ring, overall shock friction is very low and parts count and construction techniques very simple.

As the piston rod moves in and out of the cylinder the floating O-ring moves up and down inside the cylinder to keep the oil under continuous pressure and thus compensates for the change in volume discussed previously. This *Delta* pressurised design then provides for a pure oil (no air) moving through the orifice and thus fully predictable and controlled damping characteristics throughout its full stroke.

We predict that this simple *Delta pressurised shock absorber* design will become the standard for R/C car racers worldwide as have many of other *Delta* innovations discussed elsewhere. We are publicly disclosing this design here so as to establish the origin of this simple but truly effective shock absorber. If you have an application for this shock design please contact Bill Campbell at Delta Manufacturing, 27 Racecar Court, Lorimor, Iowa, 50149 USA. (515)-763-2220. We have several configurations of this shock absorber and would be willing to help match or design one for special applications. One configuration in particular will replace the long shock presently used in the *Tamiya* manufactured Off-Road Buggies.

CONTINUED FROM PAGE 57

7. Futaba

As to be expected from such a leading maker, the unit comes complete (as did the *Simprop*) fitted with on/off switch, fuse and holder 7.2 V type plus plug and spare socket.

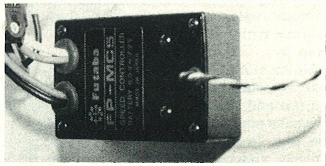
The instructions were straightforward with pictorial connecting-up diagram, all in reasonable English.,

Electronically the unit is more "mechanical" than most. There is only one transistor in the system power line, a massive NEC double, top-mounted job. In addition there is a relay of double pole changeover type to achieve the forward reverse function plus a bypass relay to short out the transistor in the full power setting.

We felt the relay contact areas were a bit on the small size for the types of load mainly associated with this type of unit.

Again, it would appear the dynamic braking is achieved by a large size diode plus a set of four diodes connected from the input leads to the motor output leads. A regulated output for the receiver + steering servo is fitted.

The two pots for adjustment of the neutral and cut-in point of the stick at which the full power relay cut-ins are of micro miniature size without any slot to insert a screwdriver. We found them quite vulnerable to damage and would expect at least a skeleton type pot in a unit where these adjustments would have to be made quite often.



On test naturally with a bypass relay the volt drop was insignificant and it is possible to adjust the point where the relay came in.

A maximum current of 25A is claimed. With the size of transistor fitted. It is felt that 10Amps on a semi-continuous basis would be realistic.

8. Skyleader Track Master

The unit submitted was a forward only type. It is necessary to use an additional unit to obtain the reversing function. The unit is fitted with four hefty transistors on a substantial heat sink which also forms the base plate of the box. We were pleased to see load sharing resistors on the bases of the output transistors of substantial size of ceramic construction, which suggests the current drive to the output transistor is adequate to fully turn on the transistors for minimum volt drop.

As with the other units, 4.8 V stabilised output is available for operating the receiver and a servo and a switch lead are also incorporated.

We did find the wording of the setting-up instructions a little confusing as it would appear they are used for both the forward and the reversing unit and the potentiometer operation is reversed, but we got there in the end.

An LED is fitted to enable the unit to be set up whilst the motor is being connected. This LED is used to set up both the neutral position and the full power position. Again a third potentiometer utilises the LED to set up the maximum braking position. As we said before, a better worded set of instructions would, we feel, be helpful for the not too technical operator.

On our fixed 5A load test, we found the unit got warm but not hot. No claims are made as to the maximum running or peak power rating of the unit, but 10A continuous and 20A peak would not seem too unrealistic. We found the volt drop at 5A to be 0.38 Volts. Sizes of the unit 65 × 43 × 41 mm, weight 3.5oz.